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The Reimagined Car

Shared, Autonomous, and Electric

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The Reimagined Car

Shared, Autonomous, and Electric

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AT A GLANCE

By 2030, a substantial proportion of people in the largest US cities will have exchanged their private cars for shared autonomous electric vehicles (SAEVs). This move will usher in the greatest change in mobility the US has experienced in well over a hundred years. Ultimately, we believe, it will change the world.

All Signs Point to SAEVs

A convergence of technologies—allowing for ride sharing, autonomous vehicles, and electric powertrains—enables the move to SAEVs. These technologies are progressing rapidly, and multiple pilots are underway. And consumers in cities are ready for a transportation alternative that will improve safety, access, and reliability.

Start Your Strategy Engines

Reinventing mobility will upend the status quo. Cities face challenges in urban planning and more, but those that move forward proactively stand to reap benefits. Automakers and suppliers' long-held business models will be shaken and in some cases toppled. These companies need to take a long hard look at their position and capabilities and figure out how to succeed in a new mobility paradigm. Some companies will reinvent themselves as providers or suppliers of mobility as a service; others will become obsolete. Disruption is here, and decisive action is needed now.

This report is part of BCG's ongoing research on the reinvention of automotive, a series of publications focusing on new technologies that are transforming the automotive industry. Here, we examine the ways in which shared autonomous electric vehicles will change mobility in the US. Upcoming publications will focus on the evolution of powertrain technologies and the impact of technological change on the profit pools of the automotive-based mobility industry.

WHAT IF WE TOLD you that we researched and wrote this entire report while each of us was driving to appointments in different cities, completely alone in separate cars but still videoconferencing, referencing our latest financial models, and researching last-minute details—all the while comfortable that we were driving in a way that was both safe and environmentally conscious. What if you could read this report during your commute, focusing on it all alone in a car moving safely through the city at rush hour, pausing your read—but not your ride—to make notes or pick up your phone to call or email or text us with questions or comments. We'd be able to answer—even if absorbed in the latest issue of *Automotive News* while on the way to our children's soccer games or a dinner date with friends.

Today, that seems like a science fiction dream. In the near future, though, it will be reality.

You've heard about autonomous vehicles. You've seen electric cars. You've probably used a ride-sharing service like Uber or Lyft. There's a lot of buzz about each of those innovations. Imagine the level of buzz when they are combined, in the form of shared autonomous electric vehicles (SAEVs). That's more than a buzz—it's a breakthrough. And it's on the verge of happening. In fact, you might never buy another car again.

There's a lot of buzz about the technologies that underlie SAEVs. Combining those technologies makes for more than buzz—it's a breakthrough, and it's on the verge of happening. In fact, you might never buy another car again.

We estimate that by 2030, a substantial share of the 175 million Americans who live in the nation's largest cities will turn to SAEVs, cutting transportation costs by nearly 50%, reclaiming time instead of losing hours a day to traffic and putting up with all the expense and hassle of urban automobile ownership. SAEV fleets will account for nearly 25% of all auto passenger miles traveled in the US by 2030. Such a change will have an enormous impact on health, safety, and quality of life in cities: Traffic accidents and fatalities will be reduced by nearly two-thirds. Pollution will be drastically curtailed. Cities can repurpose millions of square feet once used for parking to new green spaces or commercial uses while securing more affordable mobility and accessibility for elderly, disabled, and low-income people. (See the sidebar, "About Our Research.")

In short, the advent of SAEVs will usher in the most sweeping change in American urban life since the invention of the automobile itself. Numerous factors indicate that this change is imminent. Our outlook is for 2030, and that's really right around the corner. Stakeholders—cities, automakers, suppliers, fleet owners, and more—will see profound benefits, opportunities, and challenges. They should take bold steps now to prepare. Think about it in terms that are both automotive and appropriately anticipatory: Don't just fasten your seatbelt. Turn on your headlights, see what's in view, map your journey, and hit the gas. If you plan to succeed in the new mobility world, you can't afford to wait.

ABOUT OUR RESEARCH

We began our research into the economics of and consumer attitudes toward SAEVs in October 2016; we shared our preliminary findings with the media and select clients in April 2017.

Building a Cost Comparison

For our analysis, we built a side-by-side comparison of the total cost of ownership for today's vehicles versus tomorrow's SAEVs. We used a midsize sedan (specifically, a 2017 Ford Fusion) as the basis of comparison.

First, we put together the total retail cost to purchase a SAEV by creating an inventory of hardware, software, and other features.

Then, we forecasted and aggregated the individual costs of traditional vehicles for the 2030 timeframe (accounting for overhead, R&D, OEM markup, and other incremental costs). We also estimated operational costs, some on an annual basis (parking, for instance) and some on a per-mile basis (such as maintenance and electricity).

To ensure accuracy and a high level of rigor, we shared our assumptions with clients and crosschecked our data against industry reports and other publicly available data.

We then combined these inputs to create a cost curve that showed the estimated cost per mile for traditional vehicles at a variety of miles; this allowed us to compare the economics of SAEVs with the economics of today's conventional manual vehicles.

Our analysis found that in 2030, a fleet-operated SAEV would cost a consumer 55 cents to 70 cents per mile in very large cities, depending on the regulatory climate and the level of competition. We used the top end of this range for the subsequent calculations of adoption and economic impact.

Compared with today's conventional vehicles, which cost consumers in very large cities about $1.22 per mile at 10,000 miles per year, this represents savings that could drive significant adoption of SAEVs in the coming years.

Building a SAEV Adoption Model

Our core adoption model was built on granular, time-series traffic data from 100 US cities combined with the results of our survey of more than

All Signs Point to SAEVs

This is, in many ways, a story about convergence: A convergence of technologies that makes SAEVs not just economically feasible but economically enticing. And a convergence of demands from consumers and cities for a more accessible, reliable, environmentally responsible, and safe form of transportation that will ultimately make the world a better place. When these powerful forces come together, we will see the greatest change in mobility the US has experienced in more than a hundred years. In fact, we believe these convergences will ultimately change the world.

6,000 US consumers; the purpose of that survey was to better understand consumers' driving habits and gauge their attitudes toward SAEVs.

Our model also included detailed, forward-looking cost curves that represented relevant technologies. We augmented all of this underlying data with assumptions on pricing, average wait times for pickup by ride-sharing vehicles, and more, all based on benchmarks from ride-sharing companies and verified through discussions with industry experts.

The resulting analysis projected SAEV adoption and fleet operator economics in a variety of geographic markets, categorized as follows:

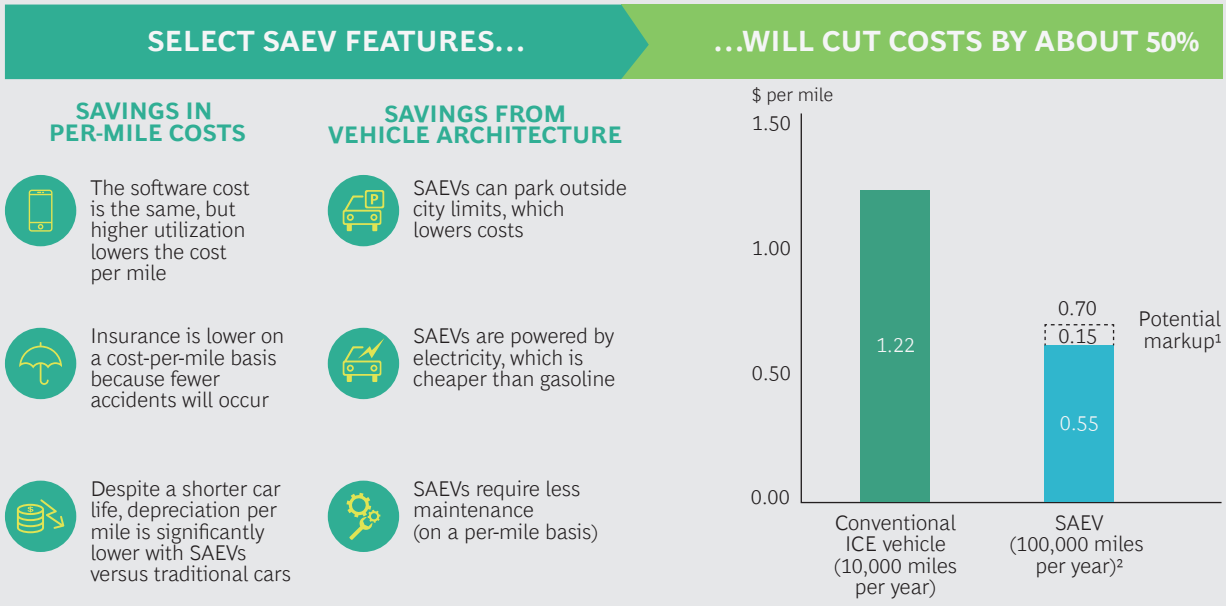
- **Very large cities,** which have populations that exceed 3 million (such as New York City and Chicago)
- **Large cities,** which have populations between 1 million and 3 million (such as Denver and Portland, Oregon)
- **Midsize cities,** which have populations between 500,000 and 1 million (such as El Paso and Tulsa)
- **Small cities,** which have populations between 100,000 and 500,000 (such as Jackson, Mississippi, and Salem, Oregon)
- **Rural areas,** which have populations of less than 100,000

For each geographic market, our adoption model projected the share of total miles that the SAEV fleet operator would choose to serve in order to maximize profits, and what those profits could be.

We calculated nationwide adoption based on average adoption for each US market type as determined by the total number of miles driven in each market type.

Finally, we translated that adoption rate into total vehicle impact by taking into account average annual miles driven and the average lifetime of both conventional vehicles and SAEVs.

EXHIBIT 1 | How SAEVs Will Cut Costs for Consumers in Very Large Cities



Source: BCG analysis.
Note: ICE = internal combustion engine; SAEV = shared autonomous electric vehicle.
[1]The potential markup reflects the opportunity for SAEV fleets to charge more than the baseline of 55 cents per mile, depending on regulations and competition.
[2]Based on our forecast for SAEV features and component costs in 2030.

FOR CONSUMERS, SAEVS WILL BRING BENEFITS TOO COMPELLING TO IGNORE

It's becoming less and less appealing to own and operate a car, particularly in a city. Long commutes, traffic jams, and the quest for a parking space eat up time. Congestion feeds air pollution. Your safety's at risk—for the first time in decades, the number of auto fatalities is increasing across the US. And owning a car is expensive, especially in urban areas.

We've found, through extensive research and economic analysis, that an individual who owns and operates a car 10,000 miles a year in a very large city such as Chicago or New York pays, on average, $1.22 per mile (versus an average of about 79 cents outside of very large cities). Parking is expensive (when you can find it); operating costs for items such as gasoline, insurance, and maintenance tend to be well above national averages; taxes and fees quickly pile up; and tolls, tickets, and fines take a $500 bite out of urban car owners' pockets annually.

But when the three technologies underlying SAEVs—ride sharing, autonomy, and electric powertrain—are combined, the cost of personal mobility drops drastically, by approximately 50% in very large cities. (See Exhibit 1.) For consumers who switch to SAEVs, that represents a near doubling of the average American's discretionary income. Imagine the economic impact of that vast new spending power.

To determine the possible level of savings, we modeled a variety of scenarios. (See Exhibit 2.) Let's look at one in more detail: a consumer in a very large city.

"Jane" drives approximately 7,500 miles per year, within the city, primarily back and forth to work and to run errands. Traffic is heavy, so these trips take longer than they should. Still, more than 95% of the time, Jane's car sits idle while she's at home or at work. Given all the expenses of ownership and maintenance, it costs $1.53 per mile to operate this vehicle. (In this scenario, the cost per mile is higher than the $1.22 cited previously because Jane drives her car 7,500, rather than 10,000, miles per year.) Annually, Jane spends $11,475 for her car. But if she switches to SAEV use exclusively, she'll spend just $5,250 on her city travel and keep more than $6,000 in her pocket each year. And she won't waste time looking for parking, sitting in traffic, or getting the car fixed.

What makes SAEVs so much less expensive?

Primarily, it's the much higher utilization, which is made possible by the combination of autonomy and sharing—and which magnifies the benefits of electric power. We estimate that each SAEV will operate approximately 15 hours a day, with the potential to operate closer to 20 hours a day if needed, and will travel up to 100,000 miles per year, approximately 80,000 of them while carrying passengers. That allows fixed costs to be spread across a far greater number of miles, which, in turn, reduces the cost per mile. At this level of utilization, the powertrain economics quickly swing away from gas-powered engines in favor of battery electric vehicles, which are far cheaper to operate on an ongoing basis. Another benefit: the move to autonomy allows ride-sharing fleets, which will own and operate SAEVs, to avoid the cost of the driver (currently the largest single cost in ride sharing and the main reason why ride sharing today typically costs $1.50 to $2.50 per mile). (We'll talk more

EXHIBIT 2 | Who Will—and Who Won't—Adopt SAEVs?

JANE

- A 24-year-old who lives in downtown Chicago
- Bought her compact car for convenience when she got a job at a tech firm in the city but is frustrated by the high cost of parking and does not enjoy driving given the traffic congestion
- Drives about 7,500 miles per year, mostly within the city to get to and from work and to run errands

Substitute: Will switch to SAEVs

BRUCE

- Forty years old and lives in Naperville, a distant suburb of Chicago
- Drives his SUV about 20,000 miles per year, mostly between suburbs for work or for weekend leisure; he enjoys driving, especially on weekends
- Travels to Chicago, and within the city, several times per year for meetings and tradeshows

Complement: Will use SAEVs sometimes

JOHN

- A 57-year-old resident of Wheaton, a small town in Illinois
- Grew up in Detroit, got his driver's license the day he turned 16, and is passionate about driving—and skeptical of technology
- No amount of savings will persuade John to give up his Mustang

Pass: Will not switch to SAEVs

Source: BCG analysis.

about fleet-related issues in the upcoming section "Tracking SAEVs' Trajectory Via Fleet Economics.")

With the convergence of all of these forces, we project that the cost per mile for consumers traveling via SAEVs in a very large city will range from 55 cents to 70 cents—offering a clear economic advantage over private-vehicle ownership, current ride-sharing offerings, and, in some cases, public transit.

The economic benefits for SAEV owners are not the only upside. Especially for city dwellers, SAEVs promise a significant lifestyle improvement. Americans can take back a total of 30 billion hours per year that they now spend driving, sitting in traffic, or looking for a parking space, for example. SAEVs will make life easier and better for city commuters. In fact, they'll make cities better overall. We'd go so far as to say this: SAEVs are essential to ensuring that sizable cities can thrive and offer their residents a good quality of life in the future.

The influence that SAEVs will have on quality of life will secure their place at the heart of cities.

For Cities, SAEVs Promise Remedies and Reinvigoration

It's clear that SAEVs promise consumer economic benefits that will ensure their adoption: a 50% savings is a strong backbone. But the influence that SAEVs will have on quality of life will secure their place at the heart of cities. City officials face some hard challenges. SAEVs can help solve them.

For one thing, SAEVs offer respite for cities with aging or strained infrastructure or public-transit systems. Thoughtfully planned models in which SAEVs coexist with public transportation can improve mobility and save money in the long term.

This need will be exacerbated as city populations climb—and climbing they are. From July 2011 through July 2016, the overall US population grew by 3.7% even as the population of the 20 fastest-growing metropolitan areas increased by more than 11.5%. That's according to US Census Bureau data, which also shows that the primary cause of growth is migration to those cities.

Cities need to better serve their residents' mobility needs.

Bear in mind that populations are aging. SAEVs will be life changing for the growing number of elderly people and for handicapped citizens, vastly expanding mobility for people who cannot drive themselves, have difficulty using public transit, and cannot afford other forms of private transportation. The fastest-growing city from 2011 through 2016? The Villages, Florida, a retirement destination whose population leapt by 25.8%. And it's not the only such destination on the list of fastest-growing cities. This growth trend suggests that similar cities, though small right now by our definition, will have developing needs that SAEVs might eventually address.

SAEVs also offer a new mobility option to people who live in metropolitan areas built on the hub-and-spoke premise that has dominated urban development for a century—but that has left many areas along those spokes underserved and economically disadvantaged. For commuters in spoke areas, SAEVs will help make fixed public-transit lines more accessible and offer a better option than long, unproductive commutes.

SAEVs will not only be life changing—they will be lifesaving. They will make cities healthier. The move from gas-powered to battery electric vehicles will dramatically curtail emissions: 100 million fewer tons of CO_2 will enter the atmosphere. The effects will be concentrated in the largest cities, where up to half of the surface miles traveled will shift to SAEVs, making an enormous difference in air quality and health. And they will make car travel far safer. For the first time in decades, auto accident fatalities are on the rise. The sad tally of car accident deaths rose from a little more than 30,000 in 2014 to over 40,000 in 2016; that two-year increase was the biggest in half a century. Distracted drivers are a very real problem, and new distractions come along all the time. Collision statistics will undoubtedly get worse before they get better.

We understand that new technologies, like SAEVs, can be unsettling and that people wonder if traveling in SAEVs will be safe. But given that the majority of accidents are caused by human error, introducing autonomy will clearly save lives. We estimate that autonomous cars will cut the number of accidents by 3 million and the number of accident fatalities by 25,000 nationwide annually—with the potential for even more positive impact as the adoption of SAEVs increases over time.

In a city of SAEVs, planners and developers will have less need to consider parking as a prime concern for any new project. Self-driving cars will have a significant impact on parking demand because the vehicles can take themselves to parking spaces outside of congested areas. We estimate that in some of our largest cities, SAEVs will free up about 150,000 parking spaces. Including on-street parking and parking structures, that means about 25 million square feet of newly available space, which can be used for parks, housing, or other purposes.

The potential benefits are many; the planning processes that cities will need to undertake to tap those benefits will be multifaceted and extensive. Cities must ensure that SAEVs complement public-transit systems, that sufficient solutions are developed for pickup and drop-off, and that needed infrastructure and data investments are made so that traffic flows can be proactively managed and congestion avoided. (Read more in the upcoming section “Stakeholder Implications.”)

For consumers and for cities, SAEVs make very good sense. For the fleets that will own and operate SAEVs, what’s required is very good dollars.

Cities that manage this well will be safer, healthier, better places to live and work. Cities that do this not only well but also proactively and promptly, in the next decade, will distinguish themselves as forward-looking urban-technology pioneers—and that’s where tech talent and innovative companies will want to be. Ka-ching. The benefits will just keep on coming.

How big of an impact can SAEVs have, and how soon? Read on.

Gauging SAEVs’ Trajectory Via Fleet Economics

For consumers and for cities, SAEVs make very good sense. For the fleets that will own and operate SAEVs, what’s required is very good dollars. The economics have to work for ride-sharing fleets if this entire concept is to become reality.

It’s a complex equation, a seesaw of supply and demand. Fleets need to know that

their SAEVs will get enough use to justify the investment. So, they must be confident of their potential ridership, market by market. Otherwise, they won't invest in SAEVs. And riders in each market, for their part, need to know that enough SAEVs will be available to meet their travel requirements promptly. Otherwise, they won't give up their private vehicles and adopt SAEVs.

Equilibrium exists. We've figured out where, and where not, by methodically researching the answers to several questions:

- How big is the market opportunity for SAEVs?
- Is there a compelling investment case for fleets?
- Where does density equal demand?
- How quickly will SAEVs be in business?

Barriers to SAEV adoption will fall over time, as people gain a better understanding of SAEVs and as entrepreneurs step in with niche offerings to address unmet needs.

That analysis reveals the formula for a favorable SAEV return on investment (ROI).

How Big Is the Market Opportunity for SAEVs?

SAEVs, for all their benefits, will not work for everyone. We surveyed 6,000 consumers from across the US to assess their openness to new transportation offerings. Only 14% had no interest in SAEVs. But it's clear that barriers exist.

Some people think they will never be comfortable getting into a driverless car. Others have true functional constraints: they might use a vehicle to transport work equipment, for example, or travel with kids in child seats, or they might like to bring their dog along for rides. Many others just like to drive; they take great pleasure from having their hands on the wheel of a luxury auto, vintage muscle car, sporty convertible, or any vehicle at all. After all, some people still practice horsemanship in their free time.

We modeled the results of our survey and eliminated from the addressable market all participants with any constraint. This step was in keeping with our use of the most conservative measures. Thus, our outlook might well underestimate the demand for SAEVs.

So, conservatively, we estimate potential SAEV ridership at 45% of the US population. Rates of SAEV uptake are lowest in rural areas (where 67% of people have significant barriers to SAEV adoption) and highest in very large cities (49% with significant barriers), where people are more familiar with alternative forms of transportation—and more fed up with the difficulties of owning and operating a vehicle.

Younger people are more likely to be willing to use SAEVs than older people: our survey found that 56% of people aged 18 through 24 had no significant barriers to SAEV use; only 37% of those aged 45 through 64 had no such barriers. This age-related trend bodes well for the future of SAEVs. Kids who are growing up in today's digital world are likely to embrace them without hesitation, thus driving up our projected adoption rate.

Other barriers will fall over time, too, as people become more educated about SAEVs and as entrepreneurs step in with niche offerings to address underserved needs. In the not-too-distant future, SAEVs will be available to meet the overwhelming majority of niche needs, whether it be providing child seats (something that companies, including Uber, have already begun doing in select markets), accommodating pets, or allowing smoking. A rider seeking these niches might have to wait longer and pay more, but if the need exists and can be met profitably, it will be.

Is There a Compelling Investment Case for Fleets?

One signal of the ubiquity of search engine use and Google in particular was the "verbification" of that company's name; we all google information when we need it. The same thing is happening with ride sharing; we "ubered" to the airport just the other day. True, neither ride sharing nor Uber has achieved Google-level success, but Uber alone has accounted for more than 5 billion trips since its inception.

Despite the rapid rise of ride sharing, the business model is flawed and the true economics are masked. Drivers and customers are heavily subsidized, with fleets offering incentives to attract both drivers and passengers. As a result, these companies are struggling to earn a profit.

These businesses recognize that they, like consumers and cities, need SAEVs. Travis Kalanick, then CEO of Uber, spoke of the "existential risk" of not moving fast enough on autonomous vehicles in a 2016 interview with *Business Insider:* "The world is going to go self-driving and autonomous. So if that's happening, what would happen if we weren't a part of that future? If we weren't part of the autonomy thing? Then the future passes us by, basically, in a very expeditious and efficient way." Already, Uber has autonomous vehicle pilots underway; indeed, nearly every one of the major automotive mobility players does.

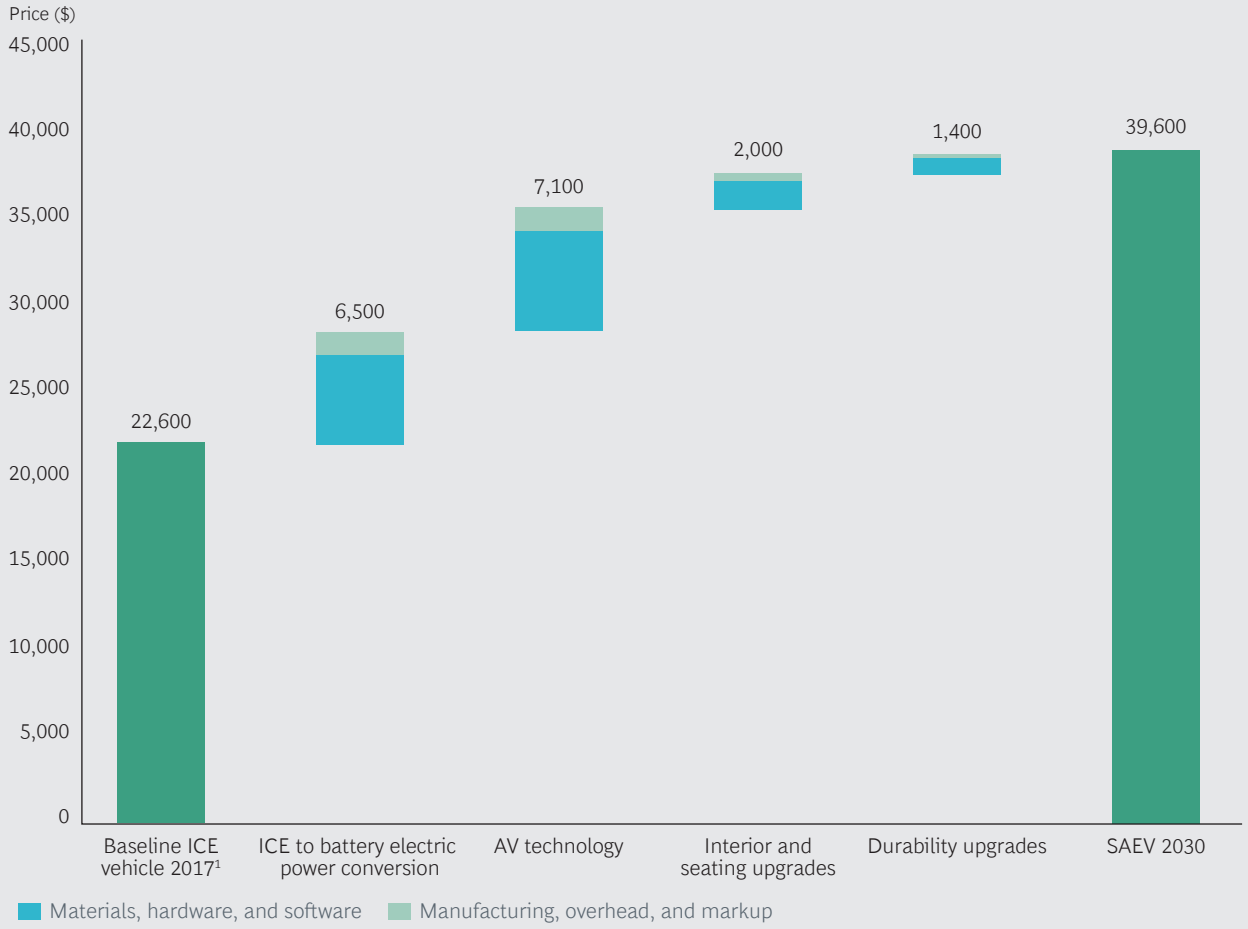
Despite Uber's willingness to embrace autonomous vehicles, a large-scale move to SAEVs is no simple thing. To move away from the current asset-light model, in which fleets leverage drivers who are monetizing their own private vehicles, ride-sharing fleets will require a compelling return on what will be a big investment.

Nearly every one of the major automotive mobility players has autonomous vehicle pilots underway.

We worked with leading automotive suppliers and vehicle manufacturers to estimate the cost of a SAEV in 2030 versus that of a typical midsize vehicle today. We factored in the costs of conversion from an internal combustion engine (ICE) to battery electric power, autonomous technology, changes to the interior, and durability upgrades. Using a 2017 Ford Fusion as the basis for our modeling, we determined that a SAEV will cost roughly $39,600—75% more than the Fusion's approximately $22,600 retail price today. (See Exhibit 3.)

It's important to note that our cost assumptions are predicated on a continued substantial reduction in the cost of key components—we estimated the cost of a battery pack at $97 per kilowatt-hour in 2030 versus $203 today, for example, and the cost of light detection and ranging (LIDAR) technology at $200 per vehicle rather than the current $8,000. Our conversations with many key suppliers indicate that these cost levels are clearly attainable.

EXHIBIT 3 | SAEVs Represent a Big Investment



Source: BCG analysis.
[1]The vehicle used as the baseline was a 2017 Ford Fusion.

WHERE DOES DENSITY EQUAL DEMAND?

With an understanding of the required per-vehicle investment, we next modeled a variety of demand scenarios based on geographic market (from rural areas to very large cities). This let us see where, and to what extent, a fleet's investment in SAEVs would make sense. We looked at both revenue- and profit-maximizing curves, recognizing the tricky balance that fleets will face in ensuring that there is enough supply to meet peak demand (an excessive wait time in this scenario is three minutes, illustrating the challenge of satisfying this marketplace) but not so much supply that the number of unused assets during nonpeak periods renders the business unsustainable.

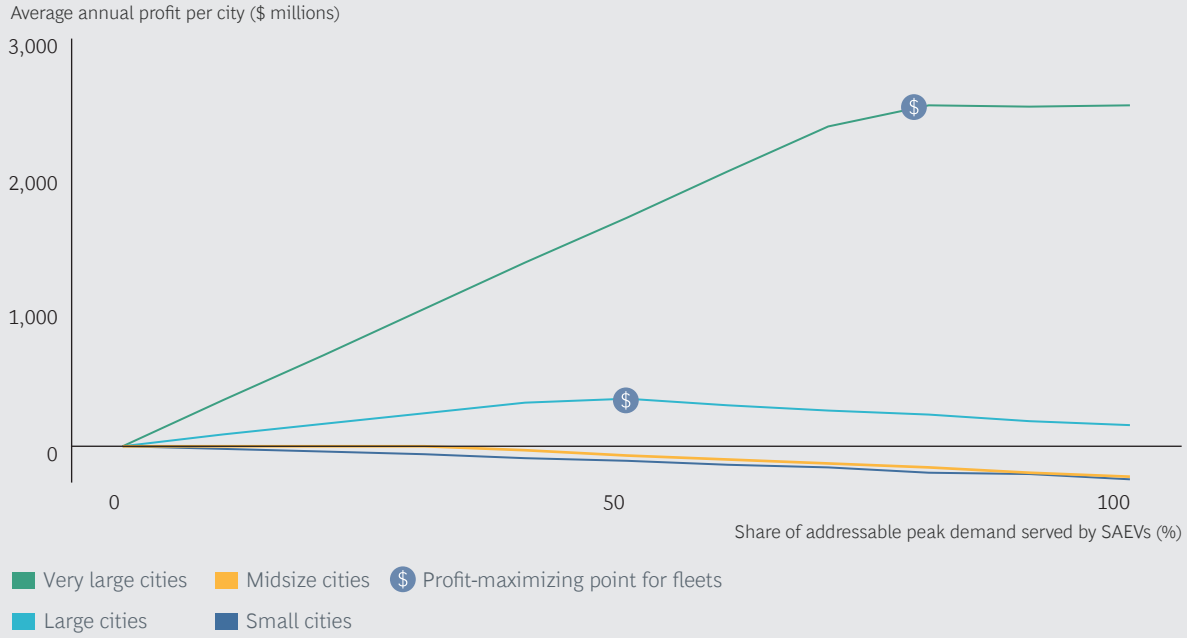
All in all, our analysis considered the size of the population in specific locales, the percentage likely to switch to SAEVs exclusively or occasionally, demand for travel at certain times of day as reflected by current traffic patterns, consumer willingness to pay, the number of vehicles required to serve that locale's ridership, the number of miles those vehicles would travel, and the cost of each vehicle.

For large and very large cities, the numbers work. SAEV fleet owners would see a significant return on investment. At the profit-maximizing point, they would serve approximately 80% of all addressable peak demand in very large cities and about 50% of that demand in large cities. (See Exhibit 4.)

For small cities and for rural areas, the economics don't justify the investment. Fleet owners would not find enough ridership to generate the needed ROI. They could downsize the fleet in these locales to compensate for the lower demand, but that would leave potential customers dissatisfied with the availability of cars and therefore unlikely to give up their private vehicles for SAEVs. Alternatively, fleet owners could raise prices—but in so doing they would price away the advantage that is core to SAEV adoption. For these areas, then, we see the ride-sharing model of the future remaining much as it is today, with fleets leveraging the current asset-light model in which vehicles are owned and operated by individuals.

For midsize cities, though, the case for SAEVs is nuanced. Our analysis suggests that, right now, SAEV fleets would struggle to break even on any SAEV investment in a midsize city. But different trends are possible: the technology could evolve more quickly than anticipated, projected costs could end up being far lower than what we have modeled, and opportunities to generate more revenue (through consumer pricing as well as through ancillary sources such as advertising and monetizing data) could increase. Thus, a market for SAEVs in midsize cities could well emerge. If 30% of the addressable peak demand in midsize cities is served, the share of miles that SAEVs account for nationally would increase by about 5 percentage points.

EXHIBIT 4 | Fleets' SAEV Investments Will Pay Off in Large and Very Large Cities



Source: BCG analysis.

Competition is also a consideration. Determining ROI depends not just on demand and expected utilization. The level of competition will influence the price that SAEV fleet owners can charge over our baseline cost of 55 cents per mile. In a city with only one or two players, there's a bigger markup potential—but not so big that it dissuades users. (At the high end, at 70 cents per mile, fleets would achieve a margin of approximately 25%.) And as other players enter, competitive intensity will climb and prices for consumers will fall. This will be a dynamic to watch.

Large and very large cities need SAEVs, to enable them to address pressing mobility concerns. We expect that cities will vie to attract the best and most capable fleets for testing and, later, commercialization.

How Quickly Will SAEVs Be in Business?

The theme of convergence reemerges when it comes to the timetable for SAEVs: The technology is rapidly advancing; already, more than 100 autonomous vehicle pilots are underway globally. Consumer demand is increasing. And cities and ride-sharing companies are looking for more cost-effective ways to meet demand.

All of this constitutes an urgent call for SAEVs.

In 2016, BCG, in support of the World Economic Forum's Future of Urban and Autonomous Mobility initiative, interviewed transportation officials from leading cities. One question we asked: What are the top impediments to implementing SAEVs in your city? We anticipated that cities would indicate that they would present barriers in the form of regulatory requirements, but few did; only 20% of participants cited regulatory issues as a top impediment. The barriers most commonly cited involved consumer acceptance (56%) and technology issues (44%). In fact, 90% of city governments said they expect to see commercialization of the SAEV model by 2025. (See *Self-Driving Vehicles, Robo-Taxis, and the Urban Mobility Revolution,* BCG report, July 2016.)

The reality is that large and very large cities need SAEVs; SAEVs will enable them to address pressing mobility concerns. As the technology and its benefits become better understood, we expect that cities will vie to attract the best and most capable fleets for testing and, later, commercialization.

SAEV fleets, for their part, will fuel the urgency as they seek to establish a beachhead in large and very large cities. The sooner they are ensconced, the greater the competitive advantage they will accrue. So, they have a big interest in a fast move to SAEVs. Latecomers will struggle to compete.

In sum, we anticipate widespread commercialization in well-defined areas—large and very large cities—beginning with small pilots in the next year, followed by meaningful citywide pilots during the early part of the next decade. Thereafter, wide-scale deployment will happen in the biggest cities by 2025, followed by rapid scaling through 2030 and beyond.

What Do SAEVs Mean for Stakeholders?

A century after the automobile changed how the world moves, mobility is about to be reinvented. And, again, the world will never be the same. A change of this magnitude is a shock wave that will ripple through nearly every aspect of society. Here, we focus on the implications for cities and the automotive industry—two groups

that will grapple with profound challenges in order to grab the significant benefits of the move to SAEVs.

Cities Must Keep an Eye on the Prize

It's worth reiterating some of the benefits that will accrue when SAEVs come to cities, because keeping an eye on that prize will help cities persevere through the enormous decision-making, investment, and implementation efforts that will be required in order to realize the full potential of SAEVs. To recap, then: Auto accident fatalities will fall by 60%. The typical US city will free up 25 million square feet now dedicated to parking. Motorists across the US will begin to take back 30 billion hours per year lost to traffic. Cities will find a more cost-effective way to provide accessibility and mobility for the disabled and growing elderly population.

Those benefits are something to strive for. But you don't get something for nothing. Cities face a massive planning process. They must ensure that SAEVs run smoothly. Some cities—very large ones with well-established public-transit systems—must also make sure that SAEVs don't simply create a new kind of congestion as consumers opt to use SAEVs rather than public transportation for short trips. Combating congestion will require close integration with fleet providers and the implementation of data platforms to create traffic transparency and institute economic "brakes" (such as dynamic pricing and tolling) to control traffic at peak times. The introduction of SAEVs will also give cities the impetus to enhance the value proposition of their local public-transit options. Cities could, for example, turn to autonomous mini-buses, likely in partnership with a SAEV fleet, to provide greater route flexibility and convenience at a more competitive cost relative to individual SAEVs.

A host of other infrastructure investments will be required. Most will be relatively minor: investments to ensure that there is adequate space for pickups and drop-offs, for example, and that lines separating lanes are painted and clearly visible. Some stakeholders believe that other, more significant infrastructure investments—such as expenditures for making cities "smart" and supporting V2X (vehicle-to-x; x represents any other entity, such as infrastructure or another vehicle) communication—will be required. In our view, though, these investments will not be necessary: vehicle manufacturers are developing SAEVs to be completely self-reliant so that the SAEVs can operate among other vehicles that may or may not be autonomous. Another reason for the approach is to ensure that adoption won't be delayed by, for example, regulations mandating expensive infrastructure that most cities cannot afford.

Automakers are developing SAEVs to be completely self-reliant. One reason: so that SAEVs can operate among other vehicles that may or may not also be autonomous.

Even as they take steps to enable SAEVs, cities will have to reconcile a loss in the revenue that currently comes from fees and fines associated with private-car ownership and public-transit-system ridership. (We anticipate a drop of up to 20% in public-transit use, driven primarily by a decline in short trips, particularly during periods of inclement weather or late hours, when riders will be tempted to use SAEVs instead.) One way cities can compensate for the loss is to place a tax on SAEVs; indeed, in our SAEV economic modeling, we included a 7-cent-per-mile tax, which we project will be sufficient for cities to offset their losses. Dynamic tolling and pricing, paying for access to dedicated SAEV lanes, and fees for SAEV permits are other avenues that cities will no doubt explore to keep the books balanced.

Cities will also have to direct new services to their residents. They will have to educate people about SAEVs. (One approach to education is an autonomous vehicle "petting zoo." The City of Boston, in conjunction with MassRobotics, hosted one of these events in October 2017 to help people gain a better understanding of autonomous technology by showcasing autonomous vehicles and having experts on site to answer questions; nearly 1,500 people attended. See *Making Autonomous Vehicles a Reality: Lessons from Boston and Beyond,* BCG report, October 2017.) And they will have to contend with a loss of employment. More than 7.5 million people in the US are engaged in driving-based professions; we estimate that a significant portion of them will be at risk of losing their jobs over time and would need retraining and placement services. (Fortunately, the move to SAEVs will create new job categories with openings for tens of thousands of workers in areas including SAEV fleet upkeep and support as well as dynamic traffic management.) Another task: promoting the benefits of being a city of SAEVs so as to attract new residents and new businesses and the income and vitality they will bring with them.

Take a good look at today's automotive industry. It's going to be very different by 2030.

Cities that do all of this well will be held up as exemplars of project planning, infrastructure transformation, and technology entrepreneurship, and they will reap the rewards.

The Automotive Industry Must Prepare for a Brand-New World

For cities, incorporating SAEVs means massive work. But the automotive industry's effort to adapt and thrive will require so much more. Hundreds of billions of dollars in assets will be made obsolete. Long-held business models will suddenly become irrelevant. Long-established parts of the value chain—such as dealers, especially in urban areas—will find it challenging to justify their continued existence as SAEVs are sold to fleets via direct sales. Capabilities currently unforeseen will quickly become essential. Veterans and upstarts will vie for position; winners will step up and losers will slip away. Take a good look at today's automotive industry. It's going to be very different by 2030.

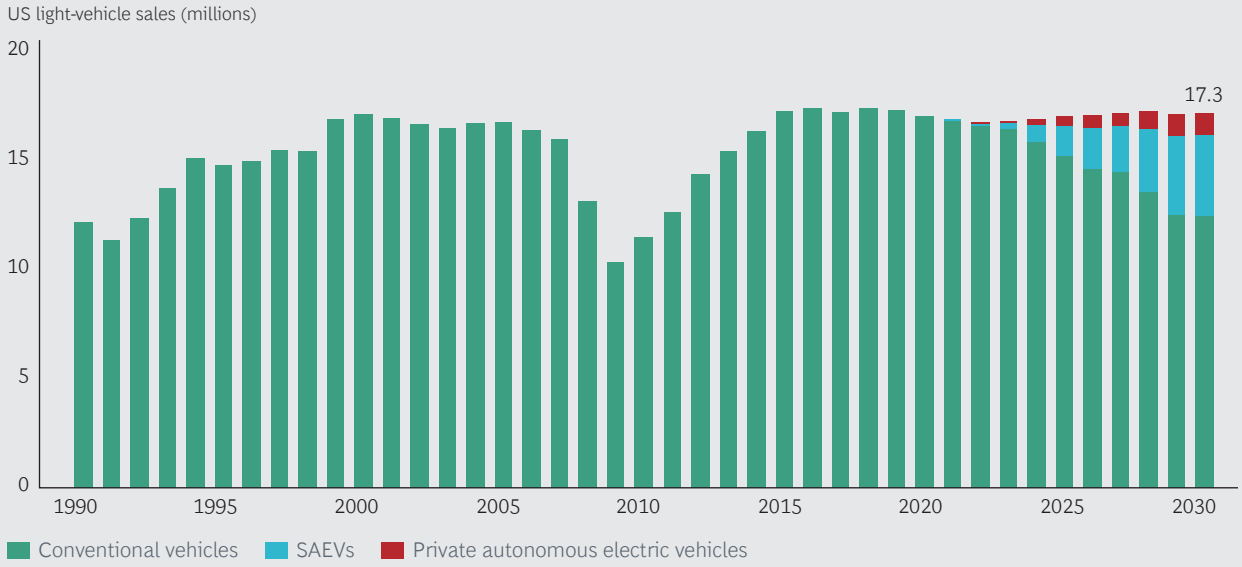
That's a daunting prospect. But here's a detail the industry will want to heed: We foresee not a dramatic decline in sales but a shift. (See Exhibit 5.)

There are solid reasons for this outlook: We expect SAEVs to be replaced on a 3-year cycle, which is much faster than the 11.5-year rate that we generally see today, because of their higher utilization. And autonomous electric vehicles will exist not only within the ride-sharing domain. Rather, we expect that about 8% of all new autonomous electric vehicles will be sold not to fleets but to private owners. Some of these will be high-income individuals who are willing and able to pay the premium for these advanced technologies. And some will be budding entrepreneurs willing to pay more than they are truly able because they intend to monetize their vehicle when they are not using it by participating in one of the many car-sharing concepts likely to emerge.

In sum, there's still plenty of money to be made, but auto industry players will need new ways to operate if they are to tap those opportunities.

The outlook and the challenges differ for various players along the value chain.

EXHIBIT 5 | Vehicle Sales Will Shift, Not Shrink



Source: BCG analysis.

Following, we offer an overview of the emerging landscape for auto manufacturers and suppliers and insights into the winning characteristics of some forward-looking industry players.

What's on the horizon? A whole new competitive landscape for the automotive industry.

Now is the time for automakers and suppliers to reflect and critically assess their very reason for being: What needs does the business exist to meet? How will the emergence of SAEVs affect the role that your company plays? What opportunities and risks do you see? What's your company's strong suit—does the company possess unique characteristics that you can capitalize on in the transition to a new world of mobility?

Answering these questions will not be easy. You must be ruthlessly honest about your prospects, good and bad. Look at your company through the eyes of a competitor—what would that foe do to disrupt and overtake your business? Make that move yourself, before a real rival does it for you.

You'll have to make some hard choices. You can't make a transition like this and be everything to everyone. Instead, you'll need to focus your efforts. Determine where and how to play and hone the capabilities you'll need to get there. Be prepared to leave behind lesser lines of business that are not among your core competencies and even traditional moneymakers whose star is destined to fade.

For some companies, this self-assessment will lead to a complete reinvention in which they abandon the traditional automaker model (design, manufacture, mar-

ket, and sell a vehicle) in favor of a new paradigm: providing mobility as a service. The automakers most likely to succeed on this path are the ones making meaningful investments in autonomy, electrification, and fleet management today, through car-sharing models, subscription models, or partnerships with ride-sharing companies.

This is a tricky balancing act: move to the new mobility too soon, and you jeopardize the near-term margin that the core business makes possible; move too late, and the opportunity will pass you by. Also, it is no easy task for a public company to reinvent itself while investors are constantly looking for near-term results and prefer to leave the future of the new mobility to tech giants such as Apple, Waymo (formerly Google's self-driving-car project), and Tesla.

It's a tricky balancing act: move to the new mobility too soon, and you jeopardize the near-term margin that the core business makes possible; move too late, and the opportunity will pass you by.

For other automakers, this self-assessment will reveal a renewed commitment to the core. For example, manufacturers of cars that have a strong brand, consumer appeal, or functional niche will likely retain a steady clientele—albeit in a diminished market. Still, companies like this should work to reinforce their brand differentiation, leverage aspects of autonomy to make their vehicles better and safer, and incorporate new sales models such as subscription-based offerings that allow customers to access the full breadth of the product offering. Some may even go so far as to equip their vehicles with peer-to-peer (P2P) car-sharing functionality, which will allow the vehicles to be monetized during times when the owners are not using them.

The outlook is very different—downright bleak—for those automakers that focus primarily on the small to midsize cars now popular in cities and that are failing to make the significant investments needed to reposition themselves. Some of today's automakers will go away. Some will try to reconfigure themselves, leveraging their manufacturing and assembly know-how so that they can make SAEV fleets for newer entrants that lack traditional automotive-manufacturing capabilities, for example.

The same applies to suppliers as the mix of required components shifts. Some component sectors, such as gasoline and diesel powertrain, will see a dramatic decline in volumes. Consolidation will occur as a result; the remaining suppliers will have to be more lean and nimble to compete and survive. For suppliers in sectors that are integral to making SAEVs work (battery management, sensors, cybersecurity, and more), though, ample opportunity awaits. But they too will not be immune to competition—growth attracts rivals, and competition could lead to excess capacity and pricing pressure, which would ultimately eat away at margins.

Another challenge for auto industry stakeholders transitioning to the new world of mobility: in the near term, they'll be traveling a road that's still being built. Common standards and platforms are not yet available. Suppliers, for example, will have to manage a plethora of component types as they seek to serve an industry still finding its way.

Looking ahead, automakers will still be making cars, suppliers will still be selling components, and there will still be plenty of money to be made in the automotive industry. Regardless of how they choose to compete in the new mobility world,

automakers and suppliers alike must, in the meantime, continue to strive to be the best at the game as it is played today.

Companies should accelerate their efforts to tackle costs and hone the capabilities they need to compete in the future. They should leverage Industry 4.0 and big data to achieve a step change in their manufacturing and supply chain performance, embrace more agile forms of innovation and product development to hasten their time to market, and find new ways to connect with customers and build intimacy so that they can identify and meet customers' needs far better than any competitor.

These traits matter now, and they'll matter all the more as competition ratchets up and volumes shift. Manufacturers and suppliers must be prepared for rapid product development cycles and refresh rates unlike anything they've faced, given that SAEVs will require replacement more often than current privately owned vehicles do. And these companies must be able to continually evolve to meet customer demand and incorporate a steady stream of new and/or improved technologies.

What will it take to be a king of the road? Be bold and proactive. Disrupt from within rather than wait to be disrupted. Place big bets now. Consider not just the future opportunity but the current impact on your existing operations. Carve out a space that you can own, and make yourself essential.

Plenty of companies are tiptoeing into the new mobility. These companies are not likely to secure a place in history. Baby steps won't cut it.

Plenty of companies are tiptoeing into the new mobility. Only a select few have made moves that are big enough to matter.

But a select few automakers and suppliers have already made moves that are big enough to matter as they transition to the new world of mobility. These companies, guided by strong leaders, recognized early on that new technologies and business models posed a threat and correctly concluded that continuing to just sell cars or the same old components would not be a viable way forward. So they began developing a thorough strategy for transforming themselves, making investments and acquiring and nurturing new businesses in order to gain access to the technologies that make SAEVs, as well as broader ventures into mobility as a service, possible. This strategy isn't right for every automotive player, but the conviction with which these leaders are reforming their businesses can be a lesson for everyone in the ecosystem. (See Exhibit 6.)

Delphi, a tier 1 auto supplier, has been one of the boldest players. Over the past several years, this traditional supplier has taken heed of the changes in the industry and carefully considered its options. The company decided to capitalize on its distinctive strengths in software and electronics in order to become the leader in autonomous technologies, separating unrelated businesses such as powertrain and thermal in order to narrow its focus and sharpen its expertise. With smart investments and numerous acquisitions (most recently, of nuTonomy, BCG's partner with the World Economic Forum in supporting the Go Boston 2030 future transportation initiative), the effort is paying off: Delphi, now known as Aptiv, is the new mobility darling of the automotive technology supply base.

EXHIBIT 6 | Executive Checklist: Six Steps to Prep for SAEVs

Source: BCG analysis.

A number of automakers are also making big bets:

- GM's CEO, Mary Barra, announced in early 2017 that the company is now capable of mass-producing self-driving vehicles. "No other company today has the unique and necessary combination of technology, engineering and manufacturing ability to build autonomous vehicles at scale," she said. Already, GM has produced 130 self-driving Chevrolet Bolts for testing, and in October 2017, the company announced its commitment to "zero crashes, zero emissions, and zero congestion."

- Ford has invested more than $1 billion in a collaboration with Argo AI to develop autonomous-driving software; it's also running pilots with Uber, Lyft, and others.

- Daimler recently founded Moovel, which offers a set of customer-facing apps that allow users to seamlessly book and pay for a variety of transportation options; this move positions Daimler as a key player in urban mobility.

These steps are encouraging, but they are no guarantee of long-term success. No automaker, so far, has committed to the kind of major portfolio shift that Delphi tackled in making the tough choice to spin off powertrain manufacturing and focus on the future. For automakers, product development timelines remain measured in years rather than months. That will not suffice going forward. So, what will they do to fix that? And what will be the dealer's role in a more fleet-centric world? These are among the many questions that cut to the core of automakers' identity.

These questions need to be answered soon. Doing so will require strong leadership, a truly customer-centric mindset, a commitment to act rather than react, and a willingness to place bold bets. None of this is easy, but it is essential. Companies that

start following in the front-runners' footsteps stand to reap great rewards. Those that choose to stand on the sidelines now may never get to play.

Start Your Strategy Engines

Right now, there is perhaps something otherworldly about the image of millions of driverless vehicles maneuvering through our cities, pulling up outside of homes and offices to pick up riders, navigating traffic, compensating for weather-related and other issues, and delivering passengers who might not have glanced outside once during their trip, instead focusing on conversations or work or just resting. Once, though, planes, trains, and automobiles were all disruptive technologies. Like SAEVs, they were sparked by imagination and technological possibility. They initially inspired both awe and trepidation, but ultimately they became commonplace tools for everyday commerce and convenience. So too will SAEVs emerge as integral components of the nation's mobility.

The sooner we start working together to plan this business and social transformation, the smoother the ride will be.

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