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The Next Normal

The future of self-driving cars: Safer, smarter, and everywhere

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The age of autonomous vehicles (AVs) is no longer a distant promise—it's here. Today's early fleets of AVs point to a future in which harried commutes turn into productive hours, jammed intersections into orchestrated traffic flows, and all roads into safer corridors. But realizing that vision will require breakthroughs in technology, infrastructure, and public trust. In this edition of *The Next Normal*, we explore the possibilities, challenges, and choices that will shape the driverless future.

In this edition

Ali Rizvi

Emily Shao

Kersten Heineke

Mingyu Guan

Philipp Kampshoff

Timo Möller

Beyond the wheel: Perspectives on autonomous vehicles

The rise of self-driving cars is about more than technology—it's about reshaping trust, infrastructure, and everyday life.

The shift to self-driving technology could transform both daily routines and city landscapes. In five videos, McKinsey experts explore what autonomous mobility could mean for daily routines, urban infrastructure, and consumer trust. Ultimately, the story of autonomous vehicles (AVs) will be less about the cars and more about the new patterns of life and work that they enable. An edited transcript of the conversations follows.

2040: A day in the autonomous life

Ali Rizvi: 2040 may seem far away, but it's not. When I think about 2040, what really excites me about AVs is the way that they will have affected urban planning. If you think about the way that AVs are starting to operate within our urban cities already—take San Francisco as an example—what you're starting to see is how efficiently they communicate with each other and the way they follow the rules of the road.

Philipp Kampshoff: I think if you go as far as 2040 or '50, AV technology will be a commodity. I think everybody will expect that the new cars that you buy have level-four autonomous capability. AV technology is going to be like the shower in your hotel room: You just expect it.

Emily Shao: By 2040, my kids will be in their late teens, early 20s. They probably won't have driver's licenses, because they just want to use AVs to get back and forth.

My hope is that even in the near future, maybe before they're even able to drive, I could put them in an AV and ship them to their activities so that my husband and I could just keep on working, doing what we need to do. And my parents would get to use an AV, as well, to get around and have more mobility.

Mingyu Guan: Ten years, 15 years down the road, I imagine there's no more need for driver licenses. All the vehicles on the road will be autonomous driving equipped.

This will free up our time to do something else. The vehicles will make sure that we are safely moving from point A to point B without worrying about anything on the road, so we can focus on more productive stuff that, as human beings, we can uniquely contribute.

Philipp Kampshoff: You could get very creative with what the future of AVs could look like. I could take you even further in the future. It's not going to happen tomorrow—and probably not in the next five years—but why not imagine, instead of robo-taxis, robo–hotel rooms?

A hotel room comes to your house, you get into it with your family, you have a beautiful bed, you have a beautiful TV, you watch a movie, and everybody falls asleep, and when you wake up, you are in Miami.

The AI revolution

Kersten Heineke: The biggest tech change we're seeing in autonomous driving is the discussion between end-to-end AI systems and rule-based systems. For the user, that doesn't really make a huge difference. The difference is the system quality and the faster development speed if you switch to include more AI. We'll get to see these systems on the road with high quality, high performance, and ultimately high safety levels much quicker.

Ali Rizvi: With the advent of gen AI and AI models, you're no longer thinking about a car that needs to read the sensors to understand the situation of what's on the road and use predetermined rules to take the next step.

Imagine you're sitting in a car. When you drive, you are using all the visual cues that are available, whether a red light or the pedestrians around you. You take the context of that image, and you make a decision. Similarly, companies are starting to think beyond rule-based engineering: "The light turns red; the sign says *X, Y, Z*; and then I can do this." Cars are instead taking the full image, passing it through AI and machine learning models, and saying, "It's safe for me to take the next step"—just like the way that humans drive.

Mingyu Guan: Recently I tested some vehicles in Shanghai in city traffic. I was in the vehicle, and—still several hundred meters out—the vehicle decided to merge lanes. I wondered why; I thought it could have done that at a later time. And then, ten seconds later, I figured out that the lanes had actually already merged. That means the car saw the road that I couldn't see. I think you can really see that what the technology can do is guarantee more safety.

Changing cities and infrastructure

Kersten Heineke: In my view, by 2035 or 2040, all of the major cities in major countries will be AV friendly, and we will see a tremendous amount of AVs deployed in these cities.

Emily Shao: This isn't an iPhone or a software thing where you can just deploy it and everyone accepts it. You actually have to crack it city by city. You need to work with the local regulators. You need to set up local infrastructure for charging, for the depots. You need to set up maintenance and all the infrastructure around it. It really is a city-by-city incremental play.

Philipp Kampshoff: Rush hour won't exist anymore. That's the nice thing. All of these vehicles are now communicating with each other, so you can go much faster everywhere. Right now you have parking spaces all over the city, which probably you won't need as much anymore, especially when you think about robo-taxis that are moving around all the time. What you will need is more places where the cars can maybe park for a little bit to let people in or out. So I would say the size of the roads will need to change.

Timo Möller: We'll need a lot of new form factors on the road for AVs without a steering wheel. Autonomous shuttles—to carry eight, ten people—will look completely different from vehicles on the road today.

Mingyu Guan: Some Chinese players are paying a lot of attention to low-altitude-aerospace-mobility solutions. A city will not just have two dimensions—with highways, et cetera. Another

dimension is being added where you can hop on a bigger drone that people can sit in and be transported to a different spot in the city without worrying about road traffic.

Timo Möller: I believe that AVs are the missing puzzle piece of the new mobility ecosystem. Imagine a world where we have, on the one hand, scaled micromobility, which doesn't need a lot of space. On the other hand, we have public transport. But we need something in between—for individual mobility for elderly people, for example—that's relatively speedy.

That's where autonomous shuttles can come in. The new shuttles are running fully autonomous in a very affordable way, which will enable us to build an ecosystem that is on a completely different level when it comes to sustainability, affordability, productivity, speed, quality—all dimensions that we're looking for. It will be really, really great.

Trust, safety, and consumer adoption

Timo Möller: Everybody who hasn't done it and has the opportunity should try it out. It's a crazy experience.

Philipp Kampshoff: I have yet to meet a person who has said, "I felt unsafe in a robo-taxi." But you're going to meet a lot of people who say, "I don't trust the technology." What's the difference? The former have experienced it firsthand.

I'll tell you from my personal experience: you get into a robo-taxi today, you check, "Does it really stop at the red traffic light? Does it get into any dangerous situations?" And then 30 seconds or a minute into it, you realize, "Oh, this is perfectly safe," and you're back to doing emails or other things because you trust the car so much.

Kersten Heineke: The ideal feedback from somebody riding in an AV is that it's interesting for a few minutes but then gets boring very quickly. As a passenger, you do not want to be worrying about what is happening around you or whether the vehicle is safe.

Philipp Kampshoff: You can get an AV to behave correctly 95 percent of the time relatively quickly. But that's not good enough. The AV has to be much better than a human driver. And a human driver behaves correctly in 99.999 percent of the cases. So the AV has to be better than that. And that means you have to conquer pretty much every edge case out there.

Emily Shao: I've been talking to my parents for years about what an amazing technology and product it is. And I had the luxury of being able to show them that experience last year. I took them to San Francisco and ordered an AV for them. At first, they didn't even want to do it. But they came out completely transformed. They said it was an amazing experience, such a safe ride. The cool thing was, as soon as they got out of the car, they wanted to take a picture with the car. And the vehicle stopped before it left so that my dad could take a picture with it. And then their next question was, "When do we get to own a vehicle like this?"

Mingyu Guan: On the difference among consumers across regions and countries, I think at the end of the day, consumers are actually very similar. They want to see good value for money. In China, because autonomous driving and all the other innovations are in a reasonable price range, consumers are very much in the mode of, "Let me embrace innovation."

Once innovation is put in front of them at a reasonable price, I'm actually pretty confident that European and American consumers will end up also embracing a lot of these innovations. When it becomes affordable, it's going to change their life experience in a very interesting and potentially substantial way.

The next generation of talent

Emily Shao: This is not an industry that exists fully at scale yet. There's no playbook you can follow, so you need to develop first-principles problem-solving in order to make this technology easily accessible and one that actually will scale.

So if I were talking to a young person, my biggest advice would be to build your problem-solving skills. Be able to crack tough problems that don't have a playbook. Personally, I highly recommend consulting. Ultimately, there are so many new problems to solve that core problem-solving is going to be key.

Mingyu Guan: I think hardware and software will both be essential components in the future of AVs. So for anyone who is interested in this domain, I think they can probably start with whatever area excites them the most.

They should just keep in mind that whether they choose hardware or software, in the end, the knowledge and understanding of how the overall tech stack works and how the hardware and software are integrated will be utterly important. You've got to know the overall landscape. And then, obviously, you can go deep into one particular area.

Timo Möller: There might be people who are completely in that software development space. For those people, I would say, "OK, you definitely need to get familiar with—or not just familiar with— you need to become a pro in using gen AI" because you are not coding anymore. Gen AI is coding the whole thing for you. And so you need to train yourself in how to best get it done.

Kersten Heineke: There are two types of skill profiles that I find very interesting. One is the computer science space: AI, the ability to develop AI models, understand them, and take them to market.

The other one, which is much less of a tech capability, is how to manage a city with a certain mobility offering, including maybe eventually tens of thousands of AVs. If you think about a bus fleet today—hundreds of buses in a city—it's already pretty complicated to manage. If you add 10,000 AVs, complexity goes up quite sizably.

Timo Möller: Having started my career in automotive with internal combustion engines, without a lot of driver assistance systems in those vehicles back in my early days, seeing how smoothly these devices are operating today, I'm still surprised and energized by what seems to have become possible in a relatively short period of time.

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'The real promise of shared autonomy lies in reshaping urban mobility—not necessarily replacing the private car.'

— Ani Kelkar
Partner, Boston

→ *Read the article*

'By embedding generative AI directly into autonomous vehicles, automakers can deliver safer driving, smarter in-cabin experiences, and real-time personalization.'

— Martin Kellner
Partner, Munich

→ *Read the article*

'The inflection point has arrived': Waymo's vision for the future of mobility

As Waymo's autonomous vehicles gain traction, the company's chief product officer considers the next phase of autonomy: international rollouts, safer streets, and growing consumer trust.

Saswat Panigrahi

If you've been to a big city in Asia, Europe, or North America over the past few years, you may have seen them: the whirring, sensor-studded electric autonomous vehicles (AVs) that navigate city traffic on their own, signaling, merging, braking—all without a driver. Once a futuristic novelty, AVs are now quietly becoming part of daily life in urban areas worldwide.

Waymo, Alphabet's self-driving-car unit, is a leader in the AV industry. The company now completes more than 250,000 paid rides a week across markets, including Austin, Los Angeles, San Francisco, Phoenix, and recent addition Atlanta; Dallas, Miami, and Washington, DC, are on deck, and international testing is underway in Tokyo.

At a recent McKinsey conference in California's Carmel Valley, Waymo's chief product officer Saswat Panigrahi, and McKinsey Partner Emily Shao discussed how AVs have transformed from a niche experiment to a mainstream transportation option. Their conversation has been edited for length and clarity.

Reaching beyond early adopters

Emily Shao: Let me start with an anecdote: I took my parents, who are in their 70s, on a Waymo ride last year in San Francisco. They are not your typical tech first adopters, but they loved it. The first question they asked me when they got out of the vehicle was, "When can we buy one of these?" How have you seen ridership diversify in recent years?

Saswat Panigrahi: I believe we are in a unique moment where the inflection point has arrived. It has been amazing to see all the love from diverse users. My in-laws, who are in their 80s, have also taken a ride.

We see that trust builds quickly based on the smoothness of the drive and how consistent the experience is. When you think about how many folks over 70 depend on others to get around, this is a huge enabler of their personal autonomy. That's also true for visually impaired people.

AVs are great for parents just taking their kids around. When parents pick the kids up from soccer practice, they can look in their kids' eyes and ask them, "How was your game?" as opposed to being focused on the road, stressed about driving, and only half-listening. Giving people this time back, this freedom—making our autonomous vehicles not just a privilege for a few but generally safe and accessible for all—is really enriching to watch.

I've personally experienced the benefits of all the time you get back when using an AV. When I'm in San Francisco and I have to shuttle between meetings in different parts of the city, in the past, that would have involved some parking-related stress, at the very least. Now I don't have that. And I have my own space for sensitive work calls. I can use the Waymo as a mobile office. If it's a late night, I can doze off in the car if I need a nap.

Or think about date night, riding in a taxi or rideshare. Sometimes, you can be in the awkward position of, "The date can begin when we get to the restaurant, but before that, we have to watch our conversation." Now, you have not only privacy but also the freedom to have a couple of drinks and not worry about getting home.

Emily Shao: If someone says, "I'm nervous about getting into a self-driving car," how would you win them over?

Saswat Panigrahi: In 2019, I spoke to the first ten riders to try a fully autonomous ride in Phoenix. What was surprising was that it didn't take a lot of convincing. Folks were willing to give it a try. Then we interviewed them when they got out and saw how sold they were after just one ride. That was powerful.

In 2025, people have heard about Waymo's safety record, or they'll be influenced by a friend, colleague, or acquaintance who has tried riding in a Waymo. I've found that once they enter the car, everyone becomes a convert. Within a few minutes, they notice the car's capabilities. Of course, we don't rest on that. We continue to test ourselves at the scale of billions of miles of simulation.

Emily Shao: How will the driverless experience change the design of the cabin interior? Is there a path toward a custom-built vehicle where there is, for example, no steering wheel?

Saswat Panigrahi: There's a lot of room for innovation in the interior of the cabin now that it's being designed for a rider instead of a driver. For decades, cars have largely been designed around the driver. Sure, there are vents and speakers in the back for passengers, but the positioning of the instrument panel is a clear indication that the driver has been the focus.

The steering wheel gets a lot of attention, but there are a lot of other features for which we're listening to our audience and thinking about their needs, such as the location of the screen and the type of information riders can access. Waymo not only has the most on-road experience, we also have the most experience with customers. We have their survey feedback, which gives us a good amount of intel as we innovate. For example, we were hearing repeatedly from our riders that they want more variety in music options, so in addition to our iHeartRadio partnership, we recently integrated Spotify into our product to help meet that need.

The safety case for AVs

Emily Shao: You've said that the safety case alone is sufficient for pursuing autonomous vehicles. What's a specific incident or data point that reinforced this belief for you?

Saswat Panigrahi: In the United States, more than 40,000 people die on the roads per year. That's hundreds every single day. If you look at the number globally, it's more than a million. What's causing these fatalities is largely preventable human error, which none of us should be comfortable accepting. Since the pandemic, fatalities have been increasing.

Now juxtapose that with the reality that Waymo's AVs have 80 percent fewer injury-causing crashes compared with an average human driver—this is based on empirical data, not forecasts or simulations. Clearly, scaling our service with this level of safety would be great. In my experience, both as a rider and as a designer, Waymo has prevented many collisions that I, as a driver, simply could not have.

Emily Shao: Are the safety numbers in line with what you expected from your simulations?

Saswat Panigrahi: For years, our safety simulation has indicated that Waymo would be a lot safer than human drivers. But now we can see that in our empirical data because we have published our results for 70-million-plus miles. Overall, no matter which metric you look at—from injury-causing collisions, pedestrian injuries, airbag deployments—we are 70 percent, 80 percent, or even 90 percent safer than cars with human drivers.

The tech-strategy nexus

Emily Shao: Waymo has driven over 100 million miles fully autonomously and billions more miles in simulation. How has simulation data directly influenced a change in strategy?

Saswat Panigrahi: The majority of our discoveries and improvements have come directly from simulation experiences. Let me give you an example. Let's say that in the real world, you saw a car speeding—not by ten miles per hour above the speed limit but by 60 to 70. I didn't know this kind of thing happened, but in Phoenix, we observed a case where somebody was driving about 90 miles per hour in a 25-mile-per-hour zone.

We wouldn't often encounter a situation like this in real life, but with simulation, you can vary the speeds of all agents. This gives you far greater predictive power of how your car and its software will perform in these situations. Once you have built your system to be resilient in these situations, you can inject other elements, such as rain, or test how the vehicle performs at night.

We have the scale to continually simulate thousands of cars, which is a huge advantage. We invest heavily in AI and machine learning to make these scenes realistic while preserving the difficulty. It's often an overlooked part of building an autonomous driver.

Emily Shao: What's an undercover hero feature in a Waymo vehicle, something people don't even notice, but it makes a big difference in their experience?

Saswat Panigrahi: Many collisions happen not while the car is driving but when riders are about to exit. People instinctively open the door without checking for bicyclists on the left or right of the car. The cyclist, who wasn't anticipating the door opening, smashes into the door. This is called "dooring" risk.

We're uniquely positioned to know exactly when we have reached our destination. We know the door is about to open. And we have a 360-degree view of where the cyclists are, even when the car isn't driving. So we're able to warn the rider that a cyclist is approaching and make sure that everyone is safe.

Emily Shao: Which cutting-edge technologies will have the biggest impact on AVs in the next ten years? How will they change the user experience?

Saswat Panigrahi: AI has already played an incredible part in solving core safety issues. It still has an important role to play in terms of understanding user intent and preferences. Say you're getting picked up on the side of a 45-mile-per-hour road. You really care about being picked up on the right side of the road, but if you are on a narrow residential street, you may not want the car to go all the way to the end of the cul-de-sac, turn around, and come back and pick you up. We've been working on these kinds of nuances with the help of AI.

The second area where AI plays a big role is in simulation. There's a tremendous amount of opportunity for creating virtual worlds that increasingly get harder to navigate so that we can learn how to deal with difficulties in the simulated world before they happen in the real world. Simulations also help us recreate real events where the Waymo vehicle needed help, so we can generate better solutions than if we were just looking at data logs.

Adapting to new markets

Emily Shao: Waymo is now operating in several cities: Phoenix, San Francisco, LA, Austin, Atlanta, and more to come. How does each city's distinct urban personality shape how you design and deploy the technology?

Saswat Panigrahi: Our first cities were Phoenix and San Francisco, which we see as two extremes of urban driving experiences. We went fully autonomous with external riders in 2019 in Phoenix, which has some dense areas like school zones, but largely, it's a high-speed environment, with a lot of 45-mile-per-hour thoroughfares.

The streets in San Francisco are much narrower, especially when cars are parked on both sides. Lots more cyclists, lots more pedestrians. What we had hoped, which thankfully turned out to be true, is that once you can handle the high-speed maneuvers needed in Phoenix as well as the dense urban environment of San Francisco, you'll be able to handle a lot more scenarios.

Many other cities will fall somewhere in the middle. Take Los Angeles as an example. Parts of Hollywood are dense like San Francisco, but other areas have high-speed traffic like Phoenix. We were hoping that solving these two markets would allow us to move a lot faster, and that's exactly what happened. Los Angeles is rolling out really well, and we have seen the same bear out both in Austin and Atlanta, where we have also launched.

Emily Shao: Waymo started test operations in Tokyo in January 2025. How are you thinking about international expansion?

Saswat Panigrahi: We have started testing in Japan and will evaluate multiple additional international cities. Think about when you go to a new city or country. You don't need to relearn the entire task of driving; you just need a little bit of reorientation. That's also true of our technology. Domestic launches—from Los Angeles to Austin and Atlanta—are getting faster, and we're generalizing well. That gives us confidence that when we go international, we'll have an autonomous driver that's fundamentally safe. And the fact that we have been investing in artificial intelligence for more than a decade gives us a foundationally capable driving technology that can generalize.

The collaborative AV ecosystem

Emily Shao: Let's talk about the ecosystem. Waymo has the vehicles, but so many other factors come into play to deliver the service. How do they all work together?

Saswat Panigrahi: Our goal is to make trillions of miles safer. We can only accomplish that if there's an entire AV ecosystem. We rely on the expertise of many, many players in pursuit of our goal. There are infrastructure providers, folks who understand charging really well or who can do maintenance on tires and vehicles better than anyone else. We're already working with many of them in our current deployments. Now that people can experience Waymo themselves, we're seeing a lot of attention from players who, only a couple of years ago, may not have seen autonomy as a priority.

Emily Shao: You've spoken before about collaborating with regulators. What's a successful partnership or a dialogue with the regulator that has helped advance Waymo's deployment?

Saswat Panigrahi: Waymo has collaborated with regulators as well as key stakeholders from the federal, state, and city levels from the beginning. Even before we were fully autonomous and we were just testing, we have always had a very transparent and direct engagement approach.

At the federal level, this has involved collaborating with NHTSA [National Highway Traffic Safety Administration] and being more transparent than they require. So far, we are the only company that has released detailed information about all our collisions, no matter the cause. At a state level, we have collaborated with the DMV [Department of Motor Vehicles] in California to get permits for San Francisco and Los Angeles. In every city where we've deployed, we've worked not only with political offices but also law enforcement officers and first responders, undertaking direct testing with their vehicles to make sure Waymo responds properly to them. This transparent, open engagement has helped usher in a market transition in attitudes toward AVs.

Emily Shao: Looking ahead five or ten years, how is autonomy present in the world around us? What do our streets look like?

Saswat Panigrahi: As more and more people choose these options, more of the city will become available. Today, we subsidize more of our parking than our housing in some of our markets. This option will also result in many second-order benefits, such as freeing up the city from more parking structures. And most important, in addition to safety, we'll be able to provide accessible transport options to people who may not have them today.

Saswat Panigrahi is the chief product officer at Waymo. **Emily Shao** is a partner in McKinsey's Detroit office.

For more from Saswat Panigrahi, see the videos accompanying this article on McKinsey.com.

Mobility and beyond: How autonomous technologies could transform lives

Tech investor Laurie Yoler shares her thoughts on the evolution of autonomous vehicles, changing mobility patterns, and the long reach of autonomous technologies.

Laurie Yoler

Laurie Yoler has witnessed the transformation of autonomous vehicles (AVs) from sci-fi concept to on-the-road reality. Now a venture partner at Playground Global and a board member at multiple companies, Yoler has decades of industry experience, including early stints at Tesla and Zoox (the Amazon-owned robo-taxi start-up). These experiences have given her a front-row seat to the commercialization of self-driving technology.

Today, the AV sector is in a transitional phase. Companies such as Waymo operate commercial services with self-driving vehicles in a few cities, and driver-assistance systems have become more common. Fully autonomous vehicles remain far from mainstream, however, because technical and regulatory hurdles persist. Public trust is also still evolving. Even more change is coming as automakers, tech firms, and start-ups continue to make investments and create different visions for autonomy's future.

At a recent McKinsey conference in California's Carmel Valley, Yoler spoke with McKinsey Partner Emily Shao about the evolution of AVs, the challenges of deployment at scale, and how changing attitudes toward mobility may shape the future of transportation. An edited excerpt of their conversation follows.

A vision becomes reality

Emily Shao: What was the moment that made you believe AVs could become mainstream?

Laurie Yoler: AI has been around for a long time. I was playing with robots as a kid, thinking about how incredible actuation was—you give commands and suddenly you have this robot doing things autonomously, without remote control. Applying AI to vehicles is exciting but scary to some because it involves large vehicles moving around in cities and neighborhoods.

I started believing in AVs when I saw how software could transform vehicle architectures. I then looked at sensors deployed in phones and other technologies and learned how they allowed autonomous vehicles to "see" the world more broadly than humans can. And I saw how AI could be integrated into those vehicles to make magic happen.

I remember riding in one of the first Waymo prototypes with [Waymo cofounder] Sebastian Thrun. It was going through a very fast obstacle course, and I was screaming, thinking it was so exciting. When Zoox was starting up, it was clear that the technology worked and that there would be a number of phenomenal players. I also loved that both Waymo and Zoox were very focused on safety.

Emily Shao: What are some of the biggest challenges you've observed in AV development?

Laurie Yoler: Two things primarily. First, it's large companies trying to grapple with this huge disruption. Second, it's consumer confidence. I travel around the world and talk to consumers in different markets who say, "This will never make sense in my city for the following reasons."

Regulators, too, think about safety and what this could do to their city. City, state, and federal legislators are trying to do the right thing, but fear this huge change, even though AVs are way safer—in the US, we still have 40,000 deaths a year that could be avoided by using AVs. That education takes a long time.

'A huge generational shift'

Emily Shao: I've heard you talk about the changing attitudes toward driving among young people. Can you elaborate?

Laurie Yoler: There's been a huge generational shift in interest in getting a driver's license and driving. Young people today spend their time differently—many are on mobile phones or listening to music with headphones. It's not this rite of passage of "I got my driver's license and now I'm independent. Hallelujah, I can get out of the house." Young people now have many other options for getting out of the house. I think the car as a symbol of freedom has waned a bit.

I had to beg my children to get their driver's licenses because they felt it was taking on a lot of responsibility; they could get in an accident and hurt someone or themselves. In the 1980s, between 80 and 90 percent of 18-year-olds had driver's licenses. Today, it's closer to 50 percent. That's a huge change.

The other 50 percent of 18-year-olds may be taking public transit, using ride-share services, riding bikes, or walking. And I see a lot of scooters and e-bikes, certainly in San Francisco and in cities throughout Europe. I see a lot of new vehicles that are not cars and that are not being driven. Many of them are electric, which is great for the environment. I'm not seeing as much interest in owning cars, especially in crowded cities where finding a parking place is very difficult.

Emily Shao: Today, AVs still look like regular cars. Thinking ahead to 2030 or 2035, what does the autonomous experience look and feel like for a rider?

Laurie Yoler: Since I've been working in this field, I've been called by many movie studios and game developers saying, "This is going to be great when we all have AVs. Everyone's going to want to play games and watch movies." I don't know about that.

On an airplane, when there's no turbulence, everyone is watching a movie or looking at a device. I love listening to music and podcasts in vehicles, so a voice interface and audio experiences absolutely make sense. How much we want visual experiences will depend on how rough the road is. There's a lot of experimentation happening right now. I've seen so many concept cars that try to integrate full-length films so that people can start seeing an AV as a space to relax.

Maybe there are opportunities for new experiences in the AVs of the future. But being able to make a great phone call, not worry about the safety of the vehicle, and have personal time or time with friends is going to be excellent.

Business models and market transformation

Emily Shao: Are you seeing any indicators that mobility business models will need to change in the next decade?

Laurie Yoler: The whole industry has tried to move from just hardware and manufacturing—which requires a lot of scale to get costs down—to adding more software and services. Will we get to the software-defined vehicle? We've certainly seen that happen in China and with a lot of the new innovators.

Automakers are thinking about the question of new business models, especially with regard to AI. They're asking, "Is my data valuable? Can I monetize that data? What will AI allow me to do? What are the new business models in and around the vehicle that are going to be exciting?"

Tesla, for example, looked at, "What else do consumers want?" Well, they want easy and fast charging. They want to be able to charge at home. They care about energy storage and clean energy for their vehicle. So, there are a number of different opportunities. In China, you see battery-swapping technologies.

Emily Shao: Speaking of China, what's your perspective on how autonomy in China compares with the US, and how is the global landscape evolving?

Laurie Yoler: In China, there were many new entrants and a very supportive government encouraging innovation in the automotive sector. It had deep manufacturing expertise because the mobile phone industry was dominant there. But China had not traditionally been a huge automotive powerhouse, so Chinese AV companies were able to start with a blank sheet of paper, much like Tesla, Lucid, and Rivian were able to do with electric vehicles in the US.

Will we see vehicles going back and forth between the US and China as imports and exports? That will have a lot to do with geopolitics and what both governments allow.

Predictions about autonomy

Emily Shao: Do you see a future in which individuals own L4 autonomous vehicles?

Laurie Yoler: L4 doesn't make as much sense in a passenger-owned vehicle. If you want to drive on weekends but want autonomy during the week, I think the L2++ safety features, such as lane keeping and accident avoidance, make sense.

True AVs are expensive. If you really want a safe AV, you're getting into expensive sensors and lidar. The bill of materials makes it difficult to justify costs for vehicles sold to individual drivers. It's great when they're used all day long, and the robo-taxi use case ensures higher utilization. Individuals use their vehicles to get to work, get home, maybe drive on weekends, but the vehicles are just sitting there for much of the day.

Emily Shao: Your firm, Playground Global, focuses on deep-tech investments. Beyond self-driving cars, what emerging technologies in the mobility space excite you—and how do you think they might reshape the mobility landscape?

Laurie Yoler: We are interested in mobility at large. We've made investments in automotive technologies, such as driver-monitoring systems. Then we looked more broadly at applying sensors, actuation, and software to other exciting areas, including robotics and drones.

The mobility industry's manufacturing and design talents can be applied to many different mobility modes. You've got ground, air, sea, and space—many different places to apply autonomous technologies.

Emily Shao: What's your boldest prediction about how autonomy will impact our lives in the next 20 years?

Laurie Yoler: To me, the big questions are about robots: Are we just going to have robots in factories, or will we have personal helpers at home and work? Can we take all those technologies used in robo-taxis and phones and create personalized robots to help us throughout our lives?

Today, AI is enabling a lot. The speed of AI adoption and integration is amazing. With autonomy, you need the sensors, perception, and AI to push it forward rapidly. The software has to be fantastic for safety and other use cases. I think we still have a long way to go with autonomy more broadly—not just in vehicles, but in how autonomous technologies can transform our lives.

Laurie Yoler is a venture partner at Playground Global and serves on the board of multiple technology companies. **Emily Shao** is a partner in McKinsey's Detroit office.

This article was edited by Stephanie d'Arc Taylor, an editor in the New York office.

For more from Laurie Yoler, see the videos accompanying this article on McKinsey.com.

Sascha Meyer

Europe's next mobility leap may be driverless

Moia, a Volkswagen subsidiary, is preparing for an autonomous transition. CEO Sascha Meyer explains the real work: changing minds, not just tech.

After years of hype and setbacks, autonomous vehicles (AVs) may finally be on the verge of entering everyday urban life in Europe—not as personal pods but as part of public transportation systems. They may soon become just another way to get to work, meet friends, or run errands in the city.

That's the vision behind Moia, a ride-pooling service owned by Volkswagen. Since 2019, Moia (named after the Sanskrit word for "magic") has operated a fleet of several hundred battery electric shuttles in the German cities of Hamburg and Hanover. Now, Moia is preparing to take the next step: launching an autonomous service in Hamburg starting in 2027. In pursuit of its longer-term goals, Moia is working with partners to create a multicity accessible-mobility fleet comprising newly developed Level-4 autonomous ID. Buzz AD vehicles.

At a recent conference just outside Munich, Moia CEO Sascha Meyer discussed his vision for the autonomous future with McKinsey Partner Kersten Heineke. "There is a need," he says, "for more comfortable, more flexible solutions. With autonomous vehicles, we will be able to bridge the gap between large-scale transport systems and the individual-owned car."

The following conversation has been edited for clarity and length.

Collaborating on the ID. Buzz AD

Kersten Heineke: Tell us about how one of these autonomous vehicles gets built. What does Moia do? What does Volkswagen do? Who are your other partners, and what do they do?

Sascha Meyer: The car is built in Germany by Volkswagen Commercial Vehicles, so we collaborate closely in engineering. There's a company called ADMT, more or less our sister company, which integrates the virtual driver into the car and builds the systems—including software and hardware components—necessary for autonomous driving. We also collaborate with Mobileye from Israel; we use its self-driving stack for sensing and for the drive function.

Moia then builds software for passenger management, ensuring passengers are safe on board and orchestrating the fleets in the cities where the cars will drive. We make sure that if there's any problem, we're able to respond. We also offer a white-labeling solution to help providers create mobility services.

Kersten Heineke: The ecosystem that the car operates in seems critically important to making the vehicle work, which is probably at least as important as the vehicle itself.

Sascha Meyer: Absolutely. Building a self-driving vehicle is a very, very complicated task. And on top of that, if you want to bring those vehicles into cities, you need to be able to control the fleets. That means knowing where those vehicles can and should drive. It means being able to respond to road blockages and increases in demand. We've built the fleet control systems that are necessary to pick up passengers and carry them safely to their destinations.

On convincing the skeptics and overcoming challenges

Kersten Heineke: What would you say to someone who says, "I'm never getting in an AV"?

Sascha Meyer: I'd say, "Wait for it." A lot of people said the same thing when, for example, mobile phones first came out. They said, "I have a phone at home; why do I need a mobile phone?" Same thing when smartphones became a thing: "Why would I need to send pictures in a message?" Now, of course, smartphones are ubiquitous.

I think we'll see the same adoption with AVs. Once people get on board, they realize it works and it's safe. At first, it's very exciting. But after people have been on board for ten minutes, they pick up their phones, check their emails, and start thinking this is normal.

We think people will start seeing the advantages; they'll see the benefits of a reliable, comfortable transport option, and that will create customer acceptance.

Kersten Heineke: What's the hardest problem Moia has solved so far? And what's the hardest problem you still need to solve?

Sascha Meyer: When it comes to the pure transport mode, the hardest problem we've solved is convincing passengers that sharing is a good thing. People who are accustomed to using taxis were a bit confused at first when other people started getting in the car with them. But with customer communication and education, we convinced them that shared mobility is just another option in their mix of transport solutions. It's not replacing anything; it's an addition. That's the challenge I anticipate with AVs as well. We need to help people answer questions like, "How should I use AVs? What are they intended for?" It's about creating awareness that these vehicles are not there to become the dominant mode of transportation; they are there to support you in your daily life.

I think a lot of people in the industry forget about consumers. OEMs don't deal directly with the consumer, and many tech companies are focused on building the best tech possible. Sometimes the consumer is an afterthought. But the cities we operate in are full of people, and those people have emotions, and we need to take them along for the ride. That's why I emphasize this so much: to make sure we in the industry understand that it's not only about the tech but also about who it's good for.

AI and AVs

Kersten Heineke: What cutting-edge technologies do you think will have the biggest impact on AVs in the next couple of years?

Sascha Meyer: AI has been integral to the success of AVs so far, and AI will take us one step further. Today, it's a rule-based system, where the car is given a set of rules and then decides what it should and shouldn't do based on what it perceives. End-to-end AI will help us create more capable systems that can deal with edge cases that might be a struggle for cars operating under today's rule-based systems.

We also use AI to help us understand how passengers are doing in the car. In the future, AI should help us provide a better experience for people with disabilities, for example. We think it's possible to be a concierge service—like a private chauffeur—but at the price of a bus ride.

The private-car paradigm

Kersten Heineke: What will happen to private cars when AVs hit the road?

Sascha Meyer: Private cars will still have their place in the future. They offer great mobility for families in a city or anyone who wants to travel to rural areas. But at the same time, with AVs and public transport, we can create systems in areas of high traffic that can decrease congestion. It's really about having flexible, comfortable, broad offerings for customers.

Kersten Heineke: Will there be a use case for a privately owned AV?

Sascha Meyer: I expect we'll see private AVs in the decades to come, but for now, centrally operated fleets are the best way to bring AVs safely into operation. You need professionals to keep the car clean and the sensors calibrated to run a safe driving system. There still needs to be a huge amount of operational control in the background and support for the vehicles in situations where the system is uncertain of the right thing to do. In the five- to ten-year timeline, I don't think that the systems will have evolved to the point where customers will be able to take over service and management.

Kersten Heineke: What would you say to one of your kids if they said, "I want to own an AV"?

Sascha Meyer: I think my response would be, "Why would you? Why would you want to spend money on something you can use as a service?" I think the curiosity of driving a car and all the emotions associated with driving will become less and less important for future generations. We already see that some people care more about what's on the screen than what's in the engine. I think the next step will be that they care less about driving the car and less about the screen experience. They will just want to get from A to B conveniently. And if we can offer autonomous mobility at a price point of an individual car today, I think that will be a game changer. A lot of people will struggle to find a good reason to own a car. And I hope that includes my kids.

Predictions for the next five years

Kersten Heineke: In five years' time, how much of the mobility journey will be autonomous? What will people use these vehicles for in their day-to-day lives?

Sascha Meyer: In five years, we will see the beginning of the transformation. By then, Moia and other companies will have introduced AVs in selected cities. In the beginning, as we've seen with Moia, they will be more like an addition that you use out of curiosity. And then, when people see that we provide a reliable service, they will start using AVs for some appointments or other travel needs. Then, adoption will start to increase. Slow and steady adoption is great for us; it's better than dropping huge numbers of vehicles in cities and scaring everyone off.

Kersten Heineke: In which cities will AVs gain traction? Are they in Europe, the US, everywhere? Are they big cities, small cities?

Sascha Meyer: In five to seven years, we think AVs will not only be in the US and China but also in Europe. It's more complex in Europe because there are lots of regulatory requirements for safety, such as redundant brakes and redundant energy supply in the system. I think this was the right

thing to do because now we have absolute certainty in the investments we make. We know our vehicle is built to pass the high regulatory bar. Once we pass this bar, we know we are ready from an operational and commercial standpoint. I think this will create an environment where lots of players will want to come to Europe.

No one silver bullet will dominate all transport within cities. It will be a combination of various options. For peak times, like during commuting hours, we need high-speed rail and very capable bus systems. At the same time, we need the flexibility of shared AVs in cities where demand is increasing. We will need to use our existing infrastructure wisely and help our cities' street networks grow as needed.

The people who build driverless cars

Kersten Heineke: Let's talk about talent. I'm sure you face intense competition for talent. What types of roles are hardest to fill?

Sascha Meyer: It's all about data. We need data engineers, algorithm engineers, and machine learning engineers who can make sense of the data. But equally, we need to tackle complex engineering challenges in the vehicle, so we need people who know how to build safe and reliable cars. Finally, we need great software engineers who take it to the next level in integration and ensure that these complex systems work brilliantly together to create an ecosystem within the vehicle, so that we can make AVs that are ready to be shipped.

Kersten Heineke: If I'm a young person who wants to work in the AV industry in ten years, what would you tell me? What should I study?

Sascha Meyer: Based on what's happening at the moment, AI is key. Today, AI is vastly dominated by generative models, but there's more to it. Having the fundamentals of AI and the awareness of how to create the complex systems that bring AI into reality will be a key competency for the years to come.

Sascha Meyer is the CEO of Moia. **Kersten Heineke** is a partner in McKinsey's Frankfurt office.

This article was edited by Stephanie d'Arc Taylor, an editor in the New York office.

For more from Sascha Meyer, see the videos accompanying this article on McKinsey.com.

# AV costs are likely to decline sharply

Operating costs for AV fleets may soon drop dramatically. The biggest savings are expected to come from longer lifespans for autonomous-driving systems, improved operations, and less need for R&D. Together, these advances could reduce the cost per mile for AVs from more than $8 today to just over $1.

That steep decline in costs could accelerate real-world adoption. Better per-mile economics could make AVs more attractive in commercial fleets, ridesharing services, and logistics networks. As the economics improve, AVs may more quickly move from pilot programs to scalable offerings, changing how people and goods get around.

Read more about the economics of autonomous mobility

Costs related to autonomous vehicles are expected to go down by more than 80 percent by 2035.

Autonomous vehicle cost per vehicle-mile traveled, by cost component, $
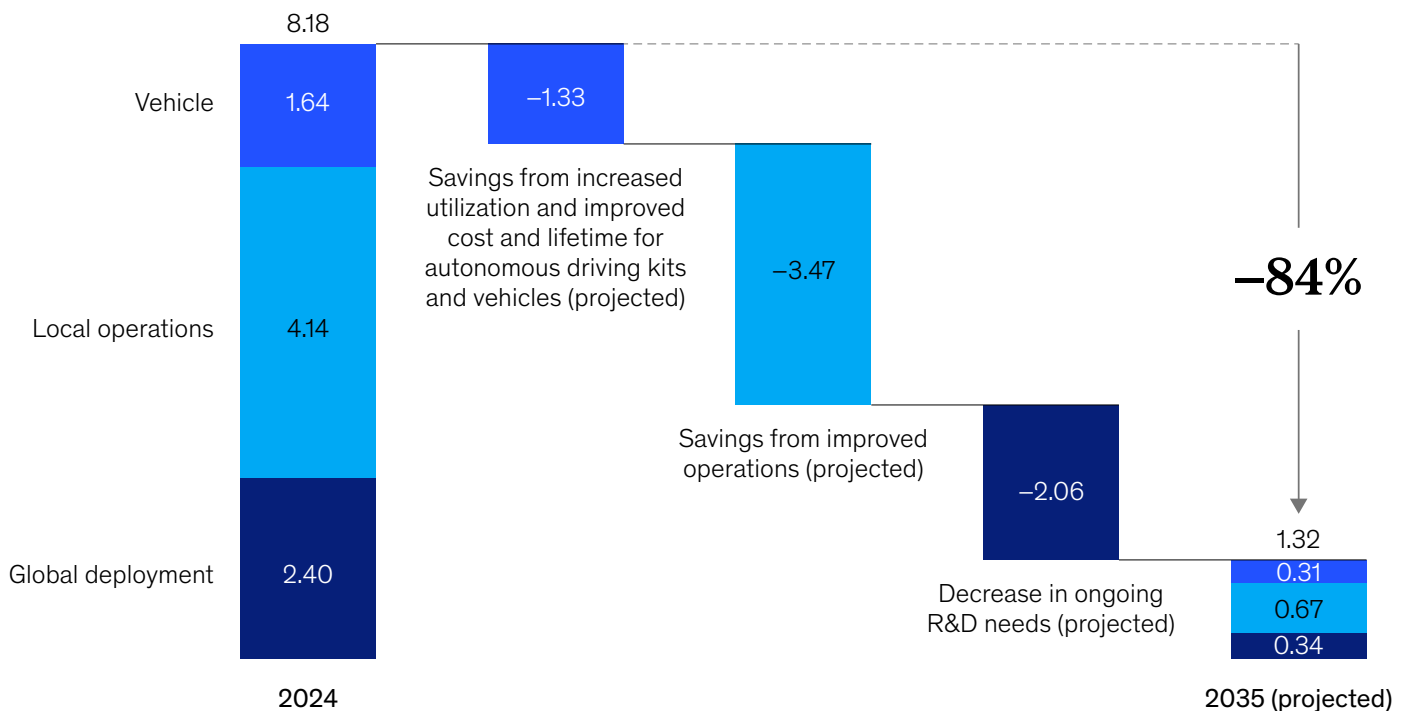
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