PERSPECTIVES

Self-Driving Vehicles: Evaluating the Possible Impacts

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admin

The race to develop truly autonomous vehicles continues to pick up speed. Not only are passenger cars in the race, but also trucks and buses. Autonomous vehicle technology truly holds the potential to reshape many industries, in ways we probably haven't even thought of yet. Recently, Franklin Templeton Investments assembled a panel of industry experts to talk about where they see the future of self-driving technology, and how long they think it will take to get to the finish line.

Listen to our full "Talking Markets" podcast and learn more about this subject.

Here are some highlights of the views of speakers represented in the podcast:

- The automotive industry in general has been traditionally a mechanical-engineering type industry; there's a digital gap. It progressed slowly through the adoption of electronics and embedded software. Then, suddenly, auto tech became a thing.
- There have been so many false starts in industrial technology. On the transit side, municipalities have tried methanol, ethanol, bio diesel, LNG, CNG, parallel hybrid, serial hybrid, and the one thing all those technologies had in common for them was that they didn't quite save as much money or improve their environmental footprint as much as promised. So, there's a bit of skepticism right now with anything new.
- Trucking operations are limited by human drivers—not only the hours an individual driver can work but also a labor shortage in the industry limiting growth. With the addition of platooning, truck utilization can be increased even when the entire journey isn't automated.
- It's important to understand the various subtleties in the intersection between technology and society and financials. What's the best way to make money with a fleet of autonomous vehicles?

The full transcript of the podcast follows.

Host/Richard Banks: Hello and welcome to Talking Markets with Franklin Templeton Investments: exclusive and unique insights from Franklin Templeton.

I'm your host, Richard Banks.

Ahead on this episode, an expert panel takes us to a future with self-driving vehicles.

Host/Richard Banks: Leading the discussion with our panel of experts is Robert Stevenson, a research analyst and portfolio manager with Franklin Equity Group who specializes in analyzing automotive, transportation and technology research.

Here's Robert and the panel.

Robert: I'll start with brief introductions. Ryan Popple: He's the CEO of Proterra. They're the leading manufacturer of zero-emission buses in North America. Dragos Maciuca: He's the technical director of the Ford Innovation Center in Palo Alto [California]. Chad Partridge: He's the CEO of Metamoto. They've created software to train, test and validate autonomous vehicle software. Josh Switkes: CEO of Peloton Technology. He's created a method for trucks to platoon on highways, reducing incidents of crashes and improving fuel efficiency.

So I'd like to let each of them expand just a little bit on what they do, what their company does and why they think it's important. So Ryan maybe you could start?

Ryan: So where we're currently building against probably a year/year-and-a-half backlog now and we're shipping heavy-duty, all- electric, long-range, mass-transit buses to places like Seattle and San Jose [California] and city of L.A. [Los Angeles], but also places that you wouldn't necessarily expect to be early adopters of this technology, like Louisville, Kentucky, Nashville [Tennessee]. We just shipped to Shreveport, Louisiana. So as we get into it, I think one of the themes that's worth exploring in industrial tech is that the early adopters may not actually be confined to the innovation hubs; that there's an intense hunger for better productivity out there, kind of throughout the industrial market.

Robert: Dragos, can you talk to us about why Ford thinks it's important to have a presence here in Silicon Valley.

Dragos: The main reason we're here is there is this digital gap. The automotive industry in general, and Ford being part of that, has been traditionally a mechanical-engineering type industry, and we've progressed slowly through the adoption of electronics and embedded software. And a lot of these technologies were not even meant for the automotive industry.

All of the sudden, auto tech became a thing. The VC [venture capital] community understood us because we're starting to speak the same language. We're starting to speak software, we're starting to speak sensors, we're starting to speak compute platforms. The language gap between Silicon Valley and the automotive industry has shrank.

I have a portfolio of people, so about 80% are engineers, the other 20% are ethnographers and industrial designers to make sure that things actually get designed properly for human beings, not for other engineers. We have about 80% that are brand new to the automotive industry, and I don't even want to ask them how many of them cannot drive a manual-transmission car because that number is huge, I'm sure. And 20%—they come from the automotive industry—to make sure that we actually design things meant for a car and not for a phone.

Robert: Chad, maybe you can tell us what it means to create software to train software.

Chad: You know, I'll start by pointing out you've probably seen in the news lately, you know, lots of validation of the principle of simulation being extremely important for autonomous systems that is an enabler for safety. You know, you're seeing what was once in the automotive world, a hardware world, moving into a software-focused world, and, you know, with that, is coming a lot of software best practices. The concept here is, especially with these neural-network-based approaches for driving, that you can just no longer drive your way to safety; that you need billions of miles of testing to be able to adequately you know test you know verify that safety, and that is not just for the testing aspect—that's also for the training aspect too.

So being able to, within a virtual safe virtual environment, to be able to capture training data sets to be able to train your vehicles; furthermore, to be able to test the data sets even more so and typically on completely different data sets; you wouldn't want to test and train with the same types of data sets to get into the over-fitting types of problems. But then, you know, wisely coupling those practices with physical-testing practices, which aren't going away, and being able to validate that the levels of scalable simulation that you are doing has correlation with the physical world. And to do this on a very highly scalable enterprise fashion; doing this when there's changes to your training data sets. When you train something new, there's not really a great intuitive understanding of how your black-box controller changed.

So you have to take a very, very exhaustive approach to testing your system every time that you've made changes. And that results in millions of tests in a cycle and adopting best practices of regression testing and unit testing, and now, simulation sits alongside that just as much as your standard functional testing would in the software world.

Robert: Josh, there's a lot of talk about autonomous lately, obviously. Peloton is a little bit different. So can you talk to us about how you came up with the idea of sort of focusing on platooning and what the technology does, and sort of why you think it's the right approach for right now?

Josh: So I think there's sort of two distinctions between Peloton and most of the other autonomous-vehicle companies you'll see. One is that we're in the trucking world, so I'll talk a little bit on why we focused on trucks. The other is that our initial goal is not a self-driving truck. So, we've taken the approach of how can we apply automation to trucks to bring real value to freight customers today. We focused on trucking and freight because trucks spend a lot more per year on fuel and on labor and on everything than cars do just because instead of driving 2,500 miles a year, they'll drive, you know, 130,000 miles a year. So a lot more is spent on all those expenses which means the hardware cost for whatever level of autonomy is less important on the truck side than it is for a passenger car.

So we focused on trucks. And we said, "Okay, let's develop a system that can provide value today." And so what we've developed is platooning. Platooning is where you electronically couple a pair of trucks together. So we combine vehicle-to-vehicle communication with vehicle-to-cloud communication to basically form a virtual coupling between those two trucks. So if you're in that rear truck, there's still a driver, that driver's steering, but your feet are off the pedals. So you are controlling the gas and the brake similar to cruise control or something you may have used radar, adaptive cruise control, but we are able to basically synchronize the actions of those two trucks.

So immediately when the front truck applies the brakes, we're applying the brakes on that rear truck. Before that front truck even physically slows down, we're applying the brakes on the rear truck. So it feels, when you're riding in the truck, it feels like it's just simultaneous braking in the two trucks. This lets us prevent a lot of accidents. The most common accident for trucks is a frontal collision—just not reacting in time, and you hit the vehicle in front of you. And very importantly, it lets us bring the trucks much closer together than what's typically safe, and then they're basically drafting one another, similar to like a race car or a cyclist. They're getting aerodynamic improvements, reducing wind resistance and saving a lot of fuel. In tests with fleets and the federal government, we've measured about 10% savings on the rear truck, and surprising to most people, you also save fuel on the front truck from aerodynamic improvements, you save about 4-½% on that front truck.

So a freight operator in the United States typically spends per truck per year $80,000 to $100,000 on diesel fuel. So when you save you know 5% to 10% of that, that can transform your profit. So this is, in the levels of automation, this is Level one. Often in Silicon Valley, I feel like if I say, you know, we've developed a Level-one system. It's kind of like, you know, we're not the cool kids who just talk about Level four and Level five. The cool part, though, is that we can ship product now, bring value to customers now, get revenue now and then use that as a launching point for these higher levels of automation.

Robert: Ryan, where are municipalities across the country in terms of sort of their readiness to accept and start working with electric buses, and sort of how are they thinking about what the timeline is for adoption of the technology?

Ryan: The early phases of implementation are going to take a long time and they're going to be very small and you're going to have to spend a lot of effort searching through the haystack finding those needles in terms of the very few industrial customers that will be early adopters. So anybody's going to try out a new app or a new GPS running watch or any Fitbit or something like that. But if you if you're thinking about the industrial markets where you live or die in terms your quarter based on being operationally excellent, and you think about how lean and how perfected a lot of these industrial systems are, they don't have a whole lot of interest in talking to companies from Silicon Valley until they know it's not going to take down their core business. So, for our market it was very, very small up until 2015, and in 2014, I think we booked less than 10 electric bus sales.

So, we basically had a couple discrete orders where a few customers said "I'll take a few." In terms of risk removal, the customer wanted to know, number one: is it safe? Number two: is it safe? Number three: is it safe? And then number four: does it actually do what you said it was going to do? There have been so many false starts in industrial technology. Just in the transit side, they've tried methanol, ethanol, bio diesel, LNG, CNG, parallel hybrid, serial hybrid, and the one thing all those technologies had in common for them was that they didn't quite save as much money, or they didn't quite improve their environmental footprint as much as they were promised. So, there's a lot of skepticism. It's a very flat beginning of the S-Curve, but, if it works, the copycat behavior in industrial markets is way faster than consumer markets.

So the technology diffusion that occurs in these markets is very quick, and I think it's one of the reasons why analysts have a real problem predicting uptake for industrial technologies because no one wants to make that crazy prediction in 2014 that the market would grow by more than an order of magnitude going into 2017. And I think it's one of the reasons why industrials are hard to understand. They are operationally conservative, so you assume that means kind of a flat steady growth in technology diffusion. It doesn't mean that at all. It means the pilots are well-thought out, conservative and cautious, and they're valuable. So in our market, there's about six customers, and today we're we've got orders from over 60 transit agencies or 10% of the US transit markets. And just to throw some examples out there: our first market is California in terms of size, then it's Washington state. Our third largest market, though, is Texas.

We have multiple customers in California and Washington state and one in Georgia now where, based on their experience with the technology and their successful pilots, they locked in a vision to completely transform their fleet to electric by anywhere between 2022, which I think is Park City, Utah and 2034, which is going to be Seattle, Washington. Once these technologies work, if they're really saving money per mile, they will massively increase their use of it. I think that in all these markets, be patient in the beginning, but if you nail it in terms of the actual value prop, you're going to see a rapid adoption rate probably to 60% to 70%.

And then in our market we think that last tail probably gets covered by the regulators who start saying: I don't care whether or not you understand electric technology, or I don't care whether or not you trust autonomous. All of the other fleets are safer and cleaner than yours, so I'm taking that analog or that dirty option off the table. So you'll see some of these technologies become the equivalent of best- available control technology, and the laggard of the tail of the market just gets swept up by regulators.

Robert: Go ahead, Josh…

Josh: You know, the way I look at it is, they have net margins typically, you know, a big fleet might be 1%, and they're happy with that because, in the United States, it's like you know, an $800-billion-of-freight industry. So, 1% of that is pretty good. So they are happy with 1%. What that means is, if you can save them money, you know, like 5% fuel savings is you know multiple percent of their operating cost. Fuel is like 35%, 40% of their operating costs, you're talking, like, 2% operating cost reduction. That will transform their profit. At the same time, if they have 1% net margins, and you cause them 1% downtime, you have eliminated their profit entirely if all the expenses stay the same, right.

So that's why they're conservative; they have to keep their core business working. But if they see that something works and doesn't disrupt their core business, then they're just leaving cash on the table if they don't adopt it quickly. And in contrast to the consumer market, they can make large centralized decisions very easily. So they can decide on the case of a fleet, they can decide to roll out platooning everywhere just by, you know, making one decision. They can decide to buy all electric buses. So those are some of the characteristics we like about that sector.

Robert: And Ryan, maybe you could just quickly touch on the economics on an electric bus today because, I think a lot of us look at the light vehicle industry, and we're not quite there yet in terms of cost parity between an EV and an internal combustion engine. But, just on the bus side, I think that's a little different, and maybe you could talk about that and just why it's a little different.

Ryan: It is a two-by-two Matrix. The vertical axis is a vehicle's miles traveled, and the horizontal axis is gallons per mile or the inverse of miles per gallon. Fuel efficiency technology makes the most sense in anything that's in the upper right hand corner. You drive a lot of miles, and the application requires a lot of fuel per mile. So short of a bulldozer or a tank, a city bus or a school bus is the least efficient vehicle on the road. It's a stop-start urbanized application. Some of our customers on their diesels; they get 3.8 miles per gallon, or they use a quarter gallon of fuel per mile.

So you're talking about you needing 40 to 60 cents of fuel per mile. Believe it or not, city buses are actually less fuel efficient than Class Eight trucks because combustion engines do not like to start and stop, and heat up and cool down. So, what I would consider the EV arbitrage is the strongest when you're going stop-start, heavy vehicle, high mileage. So they're saving 40 to 50 cents per mile on fuel. We have about a six-year operating history. We estimate based on early usage that the maintenance savings—the spare parts and the labor savings—is equal to the energy savings. So when we started out, we thought we were marketing a fuel saving value prop and a green or environmental sustainability value prop. We totally underestimated the maintenance impact, especially as it relates to downtime.

Quick example: New York City has something like 5,500 heavy-duty transit buses. It's the connective tissue of their rail infrastructure any given day, 10% of those buses are parked. And when you're talking $500,000 of asset value per vehicle, you have to have a whole another fleet just there to make up for the fact that transmissions break all the time.

Another one of my customers in Nevada. They have a two-person team that continuously rebuilds automatic transmissions. So, as soon as they finish the one that they're working on, there's another broken one on the shelf, and it's lifetime employment for two guys who rebuild Alison transmissions. Great model for Allison selling spare parts, and great model for a transmission mechanic. Terrible operating pattern for the actual end user. To cut to the chase for our customers, they're going to save anywhere between $25,000 and $50,000 per year on what we call energy and O&M [operations and maintenance].

What we've seen though is some of our customers understand that arbitrage, and they're cranking up the mileage on the EV's and reducing the mileage on the diesels. Park City, Utah is a great example. They have six vehicles on a bus rapid-transit system. We put those in, in April. In April, they were running each vehicle about 50,000 miles a year. Today, they're running them 18 hours a day, and some of the vehicles will exceed 140,000 miles in a year. They are very smart, and they've realized the more they use the electrics, the more they pull in the payback, and they're leaving the diesels parked.

So, it's an industrial payback of probably two-to-six years on a 12-year asset. We think it's about a 15% IRR [internal rate of return]. It gets to an interesting problem. I probably shouldn't be offering a customer more than a 15% IRR. So I don't want to reduce my prices any more. I want to look at models like just lease them the battery packs because Park City has figured out basically how to print money with these assets by leaving diesels parked.

Robert: Dragos, thinking about adoption of new technologies—obviously Uber and Lyft in the ride-sharing world—it feels like it's been very rapidly adopted. But, obviously as a percentage of global miles traveled, it's really still in its infancy. How do you think about sort of ride sharing? How does that change sort of the products and services that Ford is going to need to offer to the world? Are there business models that we would sort of not have associated with OEM's [original equipment manufacturers] in the past that we're going to in the future? And then also maybe talk a little bit about how that varies around the world? We think of it as being sort of in the cities here but maybe that's not an application everywhere.

Dragos: The original launch of autonomous vehicles—which we still hope is going to be by 2021—it will be car share, basically robot taxis, Level four in certain urban areas. And yes, we're looking at them as being the most efficient in very dense urban areas because: A) we can make a big difference in people's lives and allowing them to move more and more easily from point A to Point B; but also, from a financial point of view, you want these vehicles to be used as much as possible to make sure that they make up for what we expect to be, at least in the beginning, a much higher cost per vehicle due to the sensors and computer platforms and all that. So initially, we're not going to be able to sell them to consumers for financial reasons, but also for reasons that we want to make sure that we accumulate that data, that we learn from that, that we aligned the sensors properly which is again something that is new to the automotive industry.

There are different business models throughout the world. What fascinates me is that we had some discussions with some Japanese ministers who see autonomous vehicles being actually deployed in exactly the opposite direction—in sparse rural areas because of the aging populations. Because the young population is moving to urban areas, you end up with remote cities where you have mostly the elderly and allowing them that mobility means typically today putting them in either buses or trains which are again inefficient and involve a large expenditure.

So if the government can actually subsidize autonomous vehicles to take the elderly shopping and doctor and all that, that's not a business model that makes sense. So it will really vary by region. Even in the United States, vehicles are being used very differently, depending on if you are on the east coast or west coast. So it would be important to understand the various subtleties in that intersection between technology and society and financials to understand what is the best way to make money with this fleet of autonomous vehicles.

Robert: Chad, we're seeing a lot of testing all over— San Francisco, Phoenix, Pittsburgh—by a lot of different companies. GM has been making a lot of noise lately about their crews testing in San Francisco. They're talking about being on their third iteration of hardware in 14 months of the autonomous "Bolt" testing vehicle. Normally, these companies have refreshed hardware every seven years. GM is talking about doing it every seven months. As they start doing this, do the previous miles that they've driven become less valid? We've got new hardware going on to every iteration. So how can simulation help solve that problem? Every time I make a change to my vehicle, which I'm trying to do faster and faster and faster, my old data is not as valid as it used to be.

Chad: In many ways, when you make updates to the system, it invalidates the previous system—that the previous tests that you did no longer are valid, that you truly need to exhaustively test everything again. And by that that you need to build an infrastructure around that. This is very akin to modern software engineering. Every night, you run your unit and functional test suites, and you know, if there's any regressions, that they're picked up and changes that are made. If anything is broken, then it's fixed immediately, and that you're continuously accumulating the tests that you run over time based on the evolution of your software. Autonomous systems is going to be the same thing, but even more so. In traditional software development, there's an understanding, there's a logic, you know, changing if-then statements, that there's this understanding of how the system changed. Neural- network-based development, it's much more fuzzy. That's in itself another, you know, billion-dollar industry as the companies that are able to bring more intuition to how neural networks have changed.

So if you change your training sets, and you make an update to your black box, you need to exhaustively go through. Thus, exactly why you have to have those millions of tests a night. Where it's even, you know, goes further to being, you know, more interesting, is the fact that you've still got now this software world and a hardware control based world and you want to really be able to functionally subset and separate how you test. So our focus is, as a business, is very much on the subscription- based, software-in-the loop testing. If you're able to come up with many, many virtual test cases and parameterize and Monte Carlo them—that you're able to take parameters like pedestrian behaviors and time of day and all of these various things—and then test exhaustively for all these different approaches and be able to, you know, find unique boundaries and edge cases for your systems and you're able to on the software side, you know, identify these problems and rule out specific problems, and you're able to hand that exhaustively tested software piece over to your physical testing team, you've now eliminated a lot of problems. You don't have to solve a software and hardware problems at the same time when you're doing a very limited amount of physical testing. You're able to rule out a lot of pieces first, and that simulation can provide a lot of value going forward.

Robert: So Josh, you're focused on the truck world. You know there's a little bit of conversation about sort of autonomous trucking; everyone breathlessly awaits Elon Musk showing an electric truck. Who knows what bells and whistles he'll claim to have on there for autonomous capability? What's the difference between doing something in like the Class Eight world for autonomy versus the light vehicle world? I mean I think they're got a different set of issues there.

Josh: The first thing is, to be valuable; you have to be able to go at highway speeds. So I think in a lot of this sort of press and hype about autonomous passenger cars, what gets lost a little bit in the shuffle is almost all of the development currently is at low speeds. They may be thinking about high speeds with the testing, but the development is really focused on low speed, and that means, for example, that the reliable distance over which you have to perceive obstacles is a lot shorter. It's not just half the distance at 30 miles than it is at 60 miles an hour. It's dramatically farther, right? So then you take a truck on the highway versus a car—it's even farther. So I think there are challenges that exist in terms of, you know, range. If you're talking about a LIDAR [light detection and ranging], you know most of the LIDAR's today don't have enough range to go highway speed as you're only sensor. Maybe you combine it with radar, combine with other sensors. So there are challenges like that.

At the same time, highways are a lot more structured environments than urban environments. Most of the passenger-car work is urban environments because that's where people want to take their taxi. So more structured—meaning, you know, especially if you constrain it to divided highways. You get one direction of travel, you have on ramps and off ramps rather than intersections, if you constrain it that way. You have constraints on how sharp the road can curve, both, you know, side to side and up and down, and things like that, to make it a lot simpler in terms of interaction with other traffic. And then you don't have pedestrians and you don't have cyclists, etc. on those roads. So those things make it sort of simpler, but then the higher speed and the longer braking distance, you know, adds some challenges.

I think it's unlikely the hardware cost will ever matter much on a truck application, meaning, LIDAR costs are coming down quickly enough for the passenger-car world that I think it's going to be compatible with a with a truck operation. You know, if you spend, call it, you know $80,000 a year on the labor for that truck, you repay the hardware cost pretty quickly on that truck.

A couple other things: One is, today, trucking operations are limited quite a bit by hours of service limitations on their drivers. So, meaning the drivers can only drive 11 hours out of every 14. They have to take rest breaks, etc. What that means is that fleet is not utilizing their trucks as fully as they should, or as they would like to. As you add above, platooning levels of automation, you can increase that utilization of the truck, which is another dramatic savings for the fleet beyond just the direct labor savings, and that's valuable even when you're not automating the entire journey.

So if you drive from here to Los Angeles, you might drive manually or platooning out to the interstate, then you drive a few hours autonomously, then the driver retakes control. You know, in a passenger car application, that might be a convenience feature, it might be nice. In the trucking world, it means that driver only used part of their hours of service. You only had to pay them, likely, for the time they were driving, and you get dramatic savings. And we see that being possible long before the sort of door-to-door, Level-five application.

So we're really excited about Level one—you know, the platooning with the driver behind the wheel; then Level four—automated following, which is where we still have a pair of trucks, but the rear truck is fully automated and then move on from there, further in the future.

Robert: Ryan, so we we're going to have just swarms of extremely cheap perfect driving autonomous ride-sharing vehicles by 2021, right?

Ryan: Yes.

Robert: How does that potentially change sort of the need for buses in cities if, you know, the option to take private transportation theoretically comes down in terms of cost per mile?

Ryan: This is one of those questions where I actually think somebody could do a really interesting set of simulations or almost war games around how this is going to play out, because there are a lot of different supplies of personal transport, and there are a lot of different buyers of personal transport.

A great example of where this model could really break down, especially if we if we think that sort of swarms of private operation or a privately owned and operated taxis, are going to do everything is that the fires we just had in Napa [Valley, California]. I was actually at a dinner party and it's a pretty harrowing story. One of the families was at a winery. They took an Uber from San Francisco to the winery, and then, Sunday night, as this smell of smoke started wafting through the vineyard they were at, they realized they had not driven there.

There wasn't much transit. And sure enough, no driver for Uber was interested in driving in the direction of 35,000-acre fire that was burning at about 600 degrees. And whether you have a driven vehicle or an autonomous vehicle, that same situation is going to occur. The only scenario I know where the government can actually force vehicles to do something—like evacuate people that are in the way of a hurricane as happened with Miami Dade [Florida]—is a situation where the government has some involvement.

So I definitely think the vehicles are going to change a lot. I know, when I was a VC at Kleiner, and we were an early investor in Segway, and somebody actually thought that 10 years—I think it would have been five years ago—everybody was going to get in around the city on a Segway. And so cars were gone. Buses were gone. And like the entire world was going to be an episode of Arrested Development, and we lost all our money on that investment.

So, do you see Segways today? Yeah, absolutely. In particular: shopping malls and at tourist attractions. You still have taxis, you still have buses. The one thing that participating in the transit market has taught me is just how big the transportation market is. So, when I talked to Tokyo Metro, the scale that they're operating at, makes our largest systems seem trivial. And when you look at what mass transit looks like in India or China, it dwarfs Tokyo. So when you're going to move a billion people or Tokyo Metro I think moves something like four million riders, and you watch some of those YouTube videos, metrics like the seconds that it takes for a human being to get on the vehicle and get off matter.

But again going back to that simulation, I think what would be really interesting is if basically if I'm the transit system, you're the autonomous car, you're the car and then you also have the buyers segmented out. You know, I'm the hedge-fund manager [who] takes a helicopter to work at the top of the stack, and at the bottom of the stack, I just lost my job, my car got repossessed, and I can't afford an Uber ride. And you've got your buyers of transportation within there; you have school-age children, you have disabled. What you're going to find is markets logically have segments. So people who have a little bit more time and a little bit less money are probably going to suffer the inconvenience of riding next to another human being because it's going to be cheaper.

Regulators are going to want us to take the same vehicle if we're going in the same place, and then smart businesses are going to create basically versions of premium-to-luxury models. Uber Elevate may exist, but there's no way that someone's going to the V.A. [veteran's administration hospital] in an Uber Elevate, and as a society, I think we'll probably still agree that, like, even poor kids need to get to school, disabled need to get to the hospital. So we're going to have a lot of segments. I think it will be autonomous, I think it will be electric. The bus of the future or the train of the future may be a platooned set of vehicles where vehicle one has a driver and that's the vehicle that an ADA [Americans with Disabilities Act] passenger or child or parent would put a child onto, and then the two or three chase vehicles maybe just overflow capacity.

There are a lot of scenarios. Some would be really good for congestion and the environment. Some would be really bad. And I think a lot of stakeholders will be involved.

Josh: Can I add to that? Often there's this kind of question of when will we have the self-driving car, and I think the real answer is it's not flipping a switch. You know, it's unlikely that the first deployed self-driving car is going to be a Level-five, go anywhere in the world, in any weather condition, any time of day, etc vehicle. It's going to be certain applications that will roll out slowly, and initially, at not as dramatic of a cost reduction as the eventual deployment.

Ryan: Just to add one more point that we actually did a little simulation at work. We had our software group do it, and you can do it actually with a group of people, and you simulate how long it takes for all of us to get into a vehicle, and then for the other vehicles to queue. And even if the vehicles perfectly respond, it breaks down really fast. So I don't know what they're going to be, but for different applications, we're going to have different sized vehicles. In Rio [in Brazil], you're going to have buses with doors on both sides of vehicles, raised platform, and if you aren't on that bus and ready to go within 15 seconds of those doors opening, your life is probably in danger. But it is interesting. If you run a simulation— the friction of passenger loading and unloading in small vehicles blows the system apart. And whenever I make that point, someone will say: the following distance between autonomous cars is going to be so perfect, the road geometry doesn't work. If you blow out all transit because the Age of Aquarius arrives in terms autonomous vehicles, you literally cannot fit all the cars that would simultaneously drop us off when we all start working between 8:00 a.m. and 9:00 a.m. So there's definitely going to be a portfolio.

Robert: Dragos, autonomous and ride sharing. How are you guys thinking about down at the innovation center that changing sort of the human machine interface and the interior of the vehicle?

Dragos: Part of that picture is you know how do we make a brand relevant because, nowadays when you get picked up in an Uber, you don't really care what brand that vehicle is. You don't care what color it is. There isn't that emotional attachment any more that you have with a car that you own.

So the interior then becomes extremely important. The interior that we were thinking of it is something that needs to be surrounded and has to cocoon you, that it's yours. So the more we know about you, the more we can customize that vehicle for you for your use. So it's an environment where we want that end user who is the user of the vehicle to want, to feel, and to obviously desire and ask from the operators. What makes the job more interesting is that now we also have this intermediate customer, which is the fleet operator, and we need to make our vehicles our fleets, more interesting for them. So that means easier to maintain, easier to manage. So providing this transportation operating system, we call it, on which, you can add apps, on which you can add vehicles, on which you can add different modes of transportation. So the easier we make it for that intermediary customer, the more they'll want our vehicle.

At the same time, you know, we may go back to, you know, you can have it in any color you want as long as it's black. So it reduces the number of choices that we need to offer. So instead of having the potential for hundreds of thousands of combinations between options and letting every consumer pick what they want, maybe we'll just have 10 options of the same vehicle and let the fleet operator pick which one they want. So, that reduces our costs in terms of manufacturing those vehicles.

Robert: Josh, so we've talked a lot about sort of taking the driver out of the vehicle eventually. We've already seen some pretty powerful interests line up against people like Uber as they go into cities, and we've started to hear some rumblings out of Washington [DC] as they've started to look at putting together bills to help regulate how we can do self-driving. We've already seen sort of the powers that be there sort of start to push back because driving, in some capacity, is the number one occupation in this country. So as you are thinking about disrupting this market, what are you seeing? And I know of some large companies that are working with you. What are they seeing as they are trying to sort of disintermediate this labor pool?

Josh: I think the trucking industry has maybe a different answer for this than the cars side, so I'll talk mostly about the trucking side. You know, the trucking union in the United States is still pretty powerful. Most people assume that most truck drivers in the United States are in unions. That was true 30 years ago before deregulation. Now the vast majority of fleets are not unionized, but there are some that are unionized. In Washington, we've seen resistance from the truck-driver unions, resistance against including trucks in the autonomous-vehicle bill that's trying to go through Congress right now and sort of maybe stalling out. And you know for platooning, because we're not replacing the driver, we've gotten very little, if any resistance—a little bit, mostly when unions, you know, didn't understand what we were doing. So, not a big deal for the Level-one system. Now, in the trucking world there's a huge shortage of drivers.

It's estimated—there's different estimates—call it like 100,000-driver shortage today, and it's going to grow to hundreds of thousands of driver shortage over the coming years. Almost every fleet we talked to says if they could hire more drivers, they would haul more freight. That's kind of the limiting factor on their growth. So the way I like to talk about this is, there's a growing driver shortage. As we talked about a little earlier, autonomy, in terms of taking the driver out of the driving equation, so Level four or Level five, is going to come in gradually. That'll reduce the shortage over many years, and it'll be a long time until the number of drivers needed in the trucking industry is below the number we currently have.

So the current drivers are not going to be put out of work. There will just be fewer new drivers coming into the workforce over time.

Robert: A lot of people seem to be able to get their autonomy to be able to handle sort of what I would call being inside the normal part of the distribution of the Bell Curve but those tails are tough. Can you talk about how simulation can help with those tails?

Chad: Hopefully, by now, you know we're given the concept that most miles are boring and uninteresting. You know, particularly you know, highway, you know, miles of that sort. What's most important in the testing is the edge cases, and the cases where you know something is at risk. There was a couple of recent somewhat viral videos of the, you know, the one of Tesla on auto pilot is driving and the lane suddenly ends, and the Tesla hits the wall, and there was no indicator that that was going to happen, you know, no cues for the vehicle. We're assuming a lot of ways that the infrastructure stays the same than it is now which, you know, wasn't true, for instance, when the automobile was originally introduced in the 20s, the infrastructure was completely changed to accommodate for the automobiles. So that's, you know, that's even another layer of complexity on this. But going, going back to it, you know, assuming things staying the same, humans are able to, you know, adapt and figure out, "oh my goodness, the lane is ending, I need to get over." These are the types of test cases. That second one was that case where there was the truck that blended in the color on the horizon, and it was one of the first, you know, fatalities when the car drove into the side of it because it couldn't detect it.

These are the more important edge cases that you need to be able to test for and that are going to push the end of the bell curve, and you need to fill scenario databases full of these. And as you detect new ones, you add them, and you need to continuously be able to test for these types of cases. And until you have that inventory of tests and that infrastructure to be able to test for those all the time, and then be able to rapidly add to those tests, you're not going to be able to successfully test for that tail.

Robert: Ryan, what year is the last diesel bus sold in the muni markets?

Ryan: US market?

Robert: Yeah.

Ryan: Um, 2025.

Robert: Level-five light vehicles?

Robert: The dream Level-five car.

Chad: Everybody or just the first adopters?

Robert: The first ones. What year?

Chad: 2020.

Robert: Level-five truck?

Josh: 2030.

Robert: Level-five car?

Dragos: Let me hedge a little bit and say that I got my Ph.D. thesis in autonomous vehicles in '97, so that was 20 years ago, and fully autonomous vehicles were supposed to be out 20 years. And there was supposed to be 20 years out since the 50s. So, I'm going to keep saying 20 years, on a rolling basis.

Robert: All right guys, thank you. Thanks to all of you.

Host/Richard Banks: And thanks to Franklin Templeton's Robert Stevenson for leading us through this interesting topic. We hope you enjoyed the conversation.

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