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Autonomous Vehicle Ecosystem Assessment 2023 Report

Spring Edition
2023

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Executive Summary

The analysis herein summarizes current forecasts, activity, and stakeholders in the autonomous vehicle (AV) market. Starting with a timeline for commercial viability, this analysis assesses sales and fleet adoption rates, revenue forecasts, investment trends, fundraising, acquisition, and industry activity. Sources at the Victoria Transport Policy Institute, McKinsey, and Strategy& agree there will not be commercially viable SAE (Society of Automotive Engineer) level 4 AVs until 2030, however several use-cases for passenger and goods movement will emerge sooner. The Victoria Transport Policy Institute projects level 5 automation to account for 2-5% of sales during the 2030s and only becoming a standard by 2060. Even though the U.S. is currently leading in AV deployments–with over 300 pilots and deployments recorded by the United States Department of Transportation (USDOT) to date–uptake will differ between adopting nations and, by 2035, level 3-5 vehicles will account for 16% of new vehicle sales in the U.S., 29% in Europe and Japan, and 34% in China.

It is estimated that the global AV market revenue will grow from $54 billion in 2019 to more than $2 trillion by 2030. This revenue estimate comes even as commercial adoption of AVs may not be viable until 2030. This demonstrates the scale of the potential, and number of revenue models that may exist. There has been $106 billion invested in AV development since 2010 with peak spending occurring in 2017. Investments are starting to increase again after a brief slump; however, investment figures have been recalibrated to account for the COVID-19 pandemic and current estimates from AlixPartners put cumulative investments from 2020 through 2025 at $79 billion. According to a McKinsey survey of industry experts, $1.5 trillion of investment will be required to bring AV tech to market, potentially more for more complex operations. The massive development challenge is not keeping investors away as equity spending since 2017 has reached $11.5 billion. Dozens of deals and acquisitions have been made each year since 2017 as well, with notable acquisitions including Intel's purchase of Mobileye for $15.3 billion and Amazon's purchase of Zoox for $1.2 billion.

A summary of market trends focuses on customer demand, technology, and regulatory actions. According to a McKinsey survey of industry experts, 19% say customer demand is a bottleneck to AV adoption–the least threatening barrier–whereas over 70% of respondents say regulation and technology development are the biggest bottlenecks to adoption. However, regulation and technology is developing, and with standards and policy being created in the U.S., Europe, and China, AV companies will be able to confidently accelerate development as they attempt to appeal to customers.

Finally, automated driving system (ADS) and service key stakeholder groups are briefly described, before providing a detailed summary of the automated driving system and vehicle developers. Key stakeholder groups are broken down into Public and Private entities, highlighting the unique needs and motivations for pursing AV adoption. ADS developers are segmented by the target market they serve: Passenger, Trucking, Urban Delivery, and Logistics/Aviation.

The last decade has produced significant milestones for AV development. As a result, multiple small-scale commercial adoption programs are underway. Despite the consolidation of companies we've seen in the past year, significant activity and investment continues for AVs and is expected to accelerate in the coming years. There's also national level regulations emerging. There is also an increasing number of potential stakeholder groups, client types, and ADS developers. Despite this progress, three major bottlenecks for adoption remain in regulation creation/adoption, technology development, and customer demand, which will all take time to solve. As a result, the mainstream adoption for AVs is expected to occur in the 2030s.

Autonomous Vehicle Guidance and Definitions

SAE International first drafted the levels of driving automation, known as J3016, in 2014. SAE has since gone through several revisions and J3016 was last revised in May 2021. It serves as the leading taxonomy and definition for driving automation systems. This standard has guided the understanding, design, and conversation around AV capabilities since its adoption. The National Highway Traffic Safety Administration (NHTSA) has referenced J3016 since 2016 in its Federal Automated Vehicles Policy, the guiding document that brought us AV 4.0 and the AV Comprehensive Plan. These documents describe an approach to transparent and collaborative ADS development and the definitions of AV-related concepts and processes. The following table describes the definitions of each level of automation as well as the responsibilities of a human driver.

Exhibit 1: SAE J3016™ Levels of Driving Automation

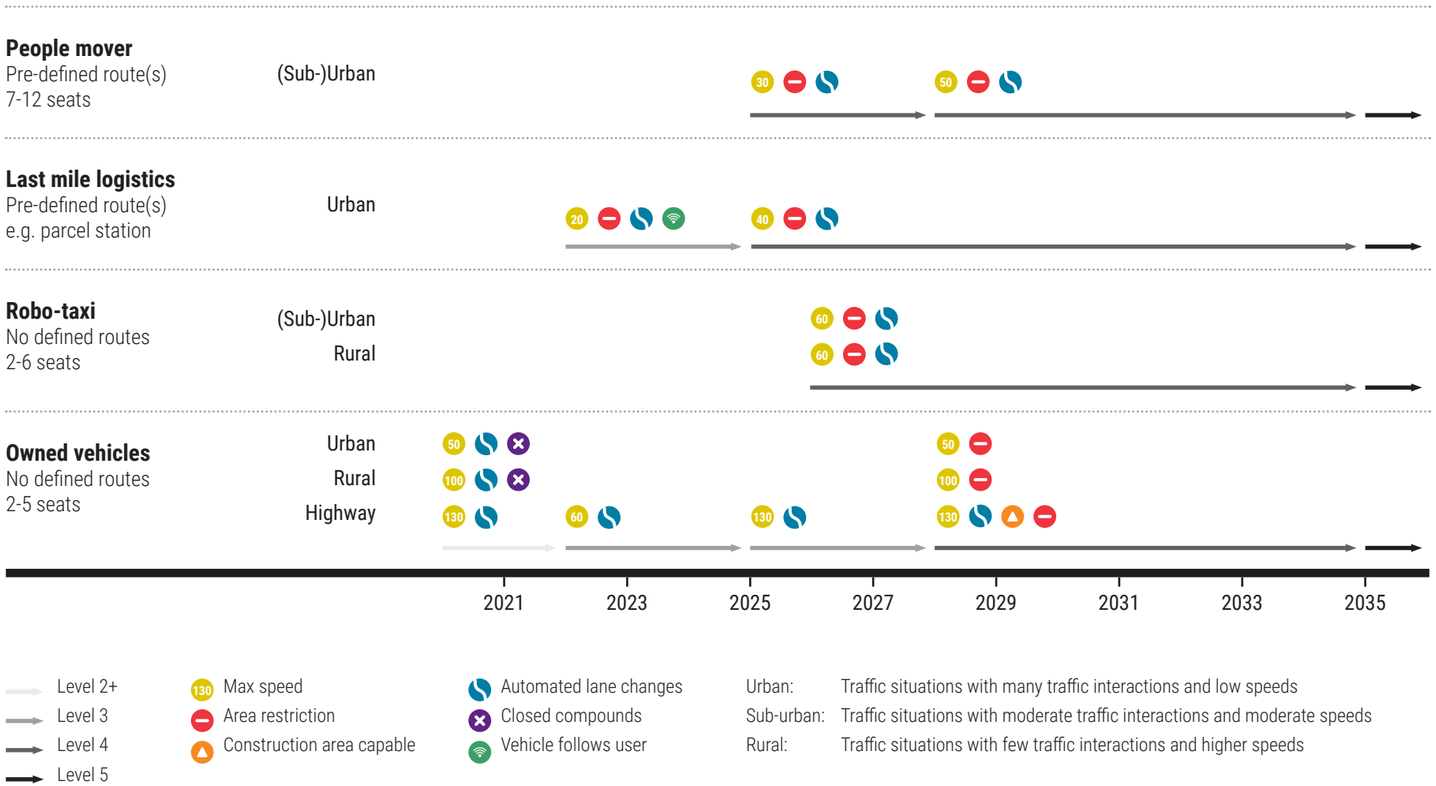
	SAE LEVEL 0	SAE LEVEL 1	SAE LEVEL 2	SAE LEVEL 3	SAE LEVEL 4	SAE LEVEL 5
What does the human in the driver's seat have to do?	**You are driving** whenever these driver support features are engaged - even if your feet are off the pedals and are not steering.			**You are not driving** when these automated driving features are engaged - even if you are seated in "the driver's seat".		
	You must constantly supervise these support features; you must steer, brake, or accelerate as needed to maintain safety.			When the feature requests. You must drive.	These automated driving features will not require you to take over driving.	
	These are driver support features			**These are automated driving features**		
What do these features do?	These features are limited to providing warnings and momentary assistance.	These features provide steering **OR** brake/ acceleration support to the driver.	These features provide steering **AND** brake/ acceleration support to the driver.	These features can drive the vehicle under limited conditions and will not operate unless all required conditions are met.		This feature can drive the vehicle under all conditions.
Example Features	• Automatic emergency brake • Blind spot warning • Lane departure warning	• Lane centering **OR** • Adaptive cruise control	• Lane centering **AND** • Adaptive cruise control at the same time	• Traffic jam chauffeur	• Local driverless taxi • Pedals/steering wheel may or may not be installed	• Same as level 4, but feature can drive everywhere in all conditions.

Source: Society of Automotive Engineers

Deployment Forecast

Multiple sources including the World Economic Forum and Victoria Transport Policy Institute, indicate that the projected timeframe for commercial viability and broad deployment of AVs is 2030. Select level 4 use cases are likely to emerge earlier, such as parking and highway pilots for passenger cars, which could emerge by 2024 or 2025 according to a recent McKinsey survey. However, they also expect that it will be 2030 before driverless trucks on full-journey trips would emerge, illustrated by Strategy&'s Digital Auto Report 2021 to the right. Note that this chart indicates the start of availability, not mainstream adoption.

Exhibit 2: Automated driving timeline of commercial road availability

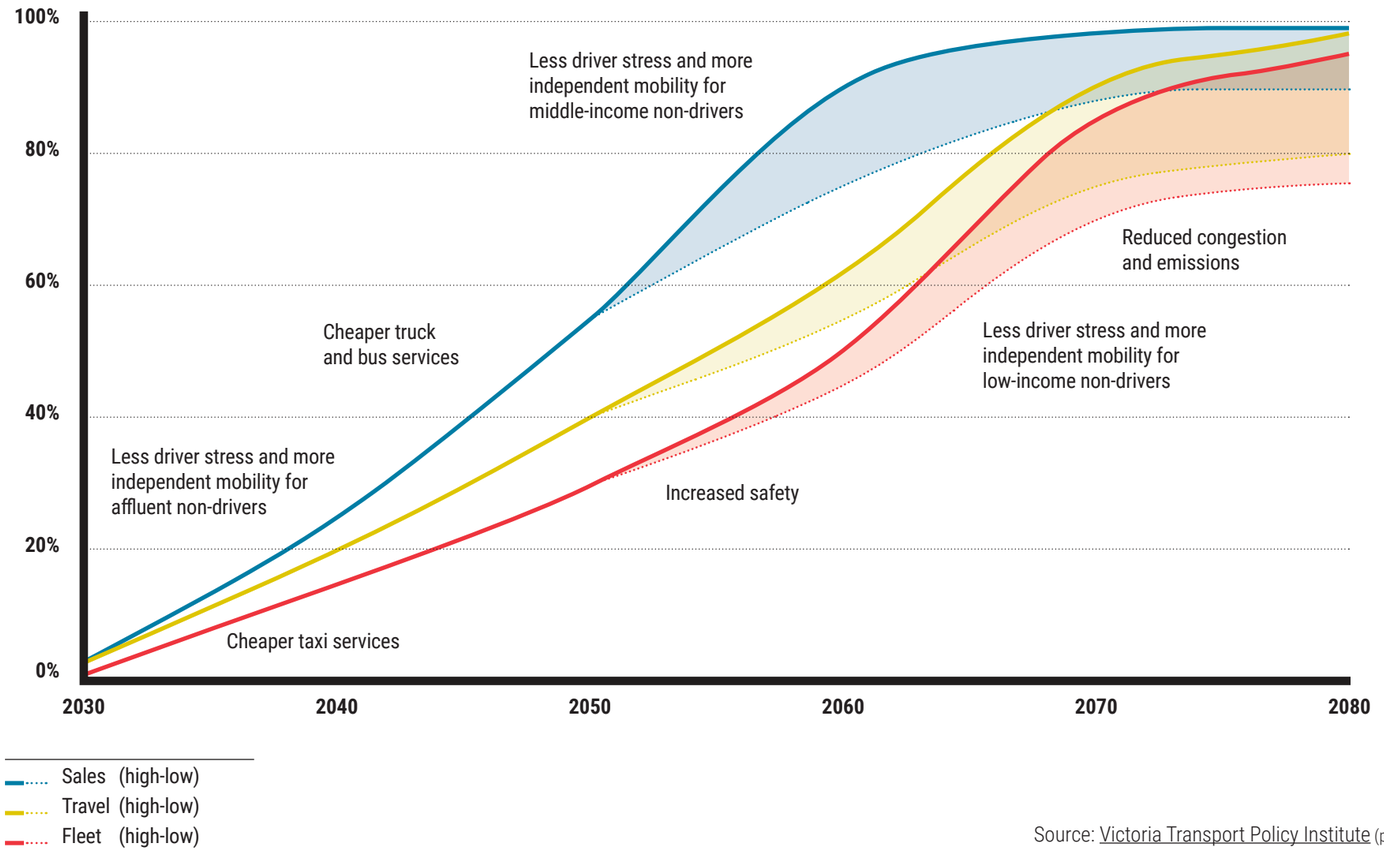


Source: Strategy& (page 37)

As noted in the McKinsey survey, the timeframe varies depending on whether the application is for private passenger, shared passenger, or freight use. It is also subject to factors such as technology development, regulation, costs, and public perception, which will impact the timing and growth rate of the AV market.

Beyond initial use cases, the expansion of the AV market is expected to be gradual, regional, and in specific categories of transportation. According to the Victoria Transport Policy Institute, the growth rate for AV adoption will be commercially viable by 2030 and grow gradually thereafter. Their projection for level 5 adoption includes new sales of 2-20% in the 2030s, 20-40% in the 2040s, reaching 80-100% with automation as a standard feature on most new vehicles by the 2060s. By 2060, half of the vehicle fleet would be autonomous.

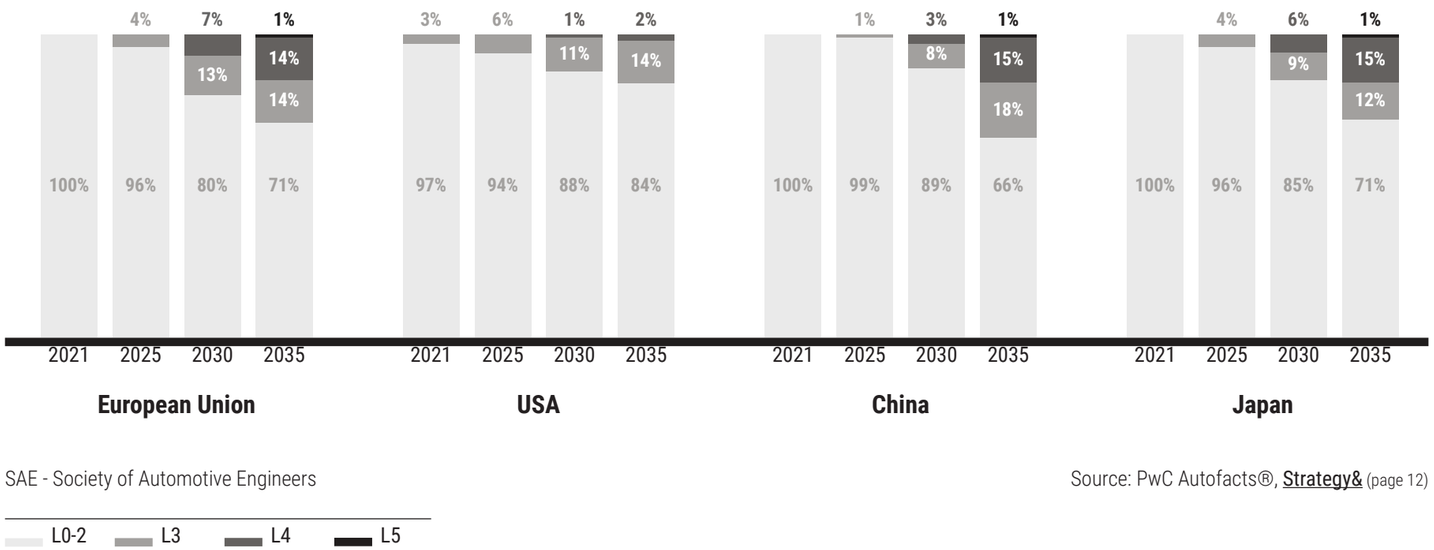
Exhibit 3: Autonomous Vehicle Sales, Fleet, Travel, and Benefit Projections



Source: Victoria Transport Policy Institute (page 5)

That being said, the Strategy&'s Digital Auto Report 2021 anticipates that lower levels of automation are already penetrating the market. They project that U.S. new light vehicle sales for levels 3-5 will be 3% in 2021, 6% in 2025, 12% in 2030 and 16% in 2035. Though the U.S. is the first region to adopt automation, it is expected to have a slower pace of adoption than Europe, China, and Japan by 2035. While the U.S. is forecast to account for 16% of new sales by 2035, Europe and Japan are expecting 29% and China is expecting 34% adoption by that time.

Exhibit 4: New vehicle sales by SAE level
(in million units scaled to 100%)



SAE - Society of Automotive Engineers

Source: PwC Autofacts®, Strategy& (page 12)

GlobalData predicts that the market penetration of level 5 will be 1.9% by 2035 in North America, with Europe's market penetration at 1.6% and China's at 3.3%.

Dentons Global Guide to Autonomous Vehicles 2022 identified through a global survey that the majority of people believe widespread deployment of level 5 is still more than a decade away, corroborating the analyses above.

There are specific examples of small-scale commercial adoption already occurring in the U.S. market, such as Waymo One's ride-hailing services in Phoenix (launched in 2020), and GM's Cruise ride-hailing services in San Francisco (launched in 2022). Multiple companies are close behind, piloting or testing in major global cities, including:

- Nuro and 7-Eleven partnered to pilot commercial delivery services in Mountain View, CA (2021)
- GM's Cruise opened its driverless robo-taxi service to the public for free in San Francisco, CA (2022)
- Amazon's Zoox tests its AVs in Las Vegas, NV, and San Francisco and Foster City, CA (2019)
- Waymo launched a robo-taxi service called the Waymo One Trusted Tester program to vetted riders in San Francisco, CA (2021)
- Intel's Mobileye is testing in New York City, NY and Detroit, MI as well as Paris, Shanghai, and Tokyo (2021)
- Baidu is offering autonomous robotaxis in Chongqing and Quhan, China (2022)

For multiple years now, several low-speed automated shuttles have been carrying passengers under different pilot programs. As of 2018, there were already over 260 demos and deployments in cities across the U.S. according to the U.S. Department of Transportation. Since 2018, there have been hundreds more deployments and NHTSA started tracking them in June 2020 as part of their AV TEST Initiative that documents AV deployments across the U.S. in partnership with ADS companies.

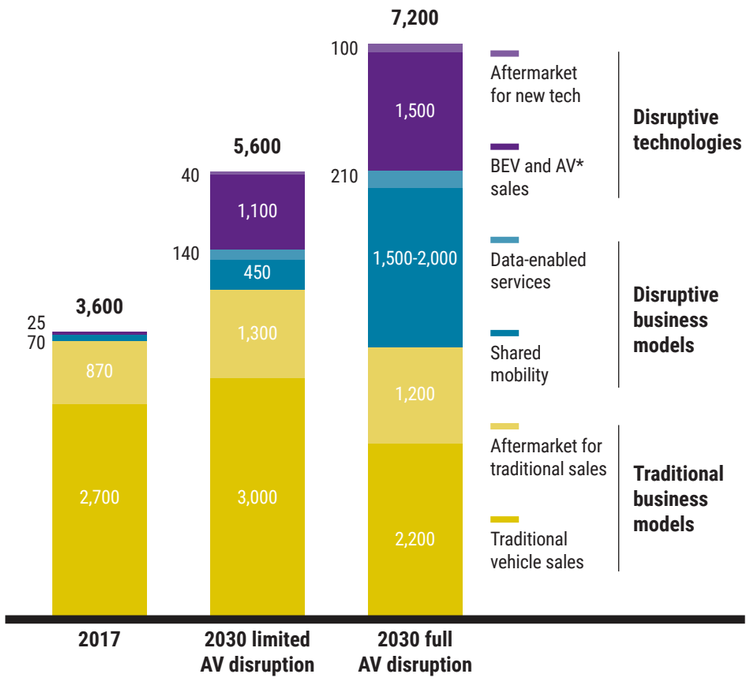
AV technology continues to grow across a range of specific use cases for passenger transport. However, these have been difficult to scale. Therefore, industrial and logistics applications are expected to grow faster.

Revenue Forecast

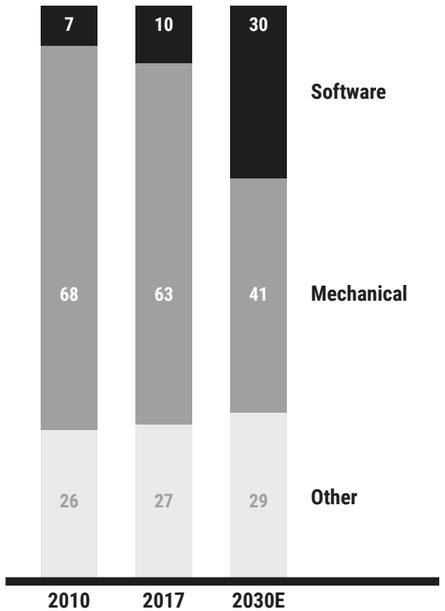
In December 2019, McKinsey forecasted that the global shared autonomous driving market potential in 2030 would be $1.14 trillion with limited AV disruption, and $1.6 trillion with full AV disruption. They forecast growth in revenues due to the combined technologies associated with AVs, connected cars, electric vehicles, and shared mobility services. However, their forecasts assume that level 4 is expected to be technically capable, and address 60-75% of miles travelled in the U.S. by 2025.

Third-party market research firms, such as Research and Markets, indicate similar growth rates for the AV market. In a 2022 forecast, Research and Markets predicts that the global AV market will grow from $76 billion in 2020 to $2.162 trillion in 2030. This equates to a 40% CAGR between 2021 and 2030.

Exhibit 5: Mobility-revenue scenario, based on spend in 2017 and 2030
($ billion)



Average vehicle-component content
(% by value)



Note Figures may not sum to 100%, because of rounding.
*Battery electric vehicle and automated vehicle.

Source: McKinsey (page 116)

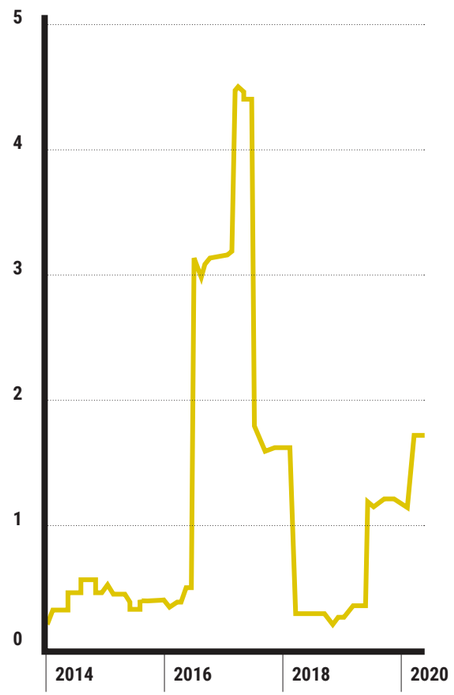
Investment Forecast

According to McKinsey, $106.1 billion was invested in autonomous technologies between 2010 and November 2020, with peak spending in 2017. However, interest has again risen since mid-2019. There have been two clusters in AV development that have experienced significantly increasing investments since 2018—AV integration and software. A chart of the 12-month rolling average of disclosed investment (in billions USD) is provided in the chart to the right.

The breakdown of the $106.1 billion in AV spending by company type is:

- $51.5 billion by semiconductors
- $35.8 billion by advanced driver assistance system components
- $9.5 billion by AV integration
- $6.7 billion by simultaneous localization and mapping
- $2.6 billion by AV software

Exhibit 6: 12-month rolling average of disclosed investment amount ($ billlion)

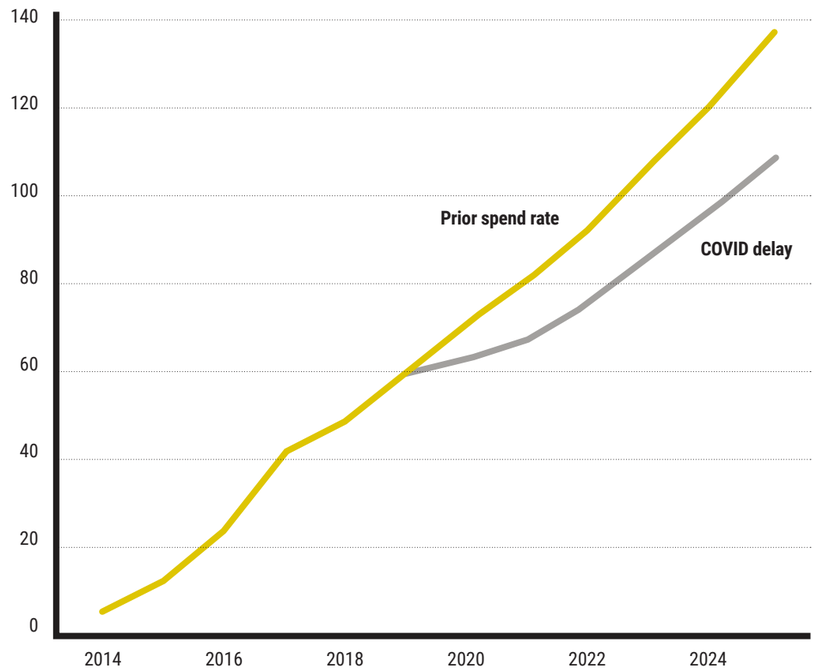


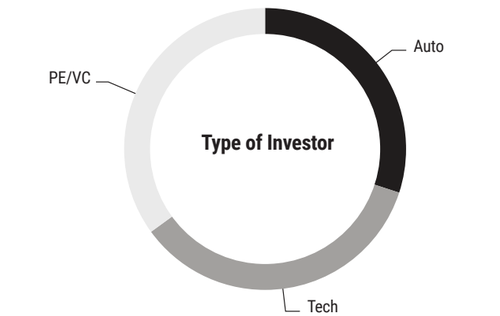
Source: McKinsey (exhibit 5)

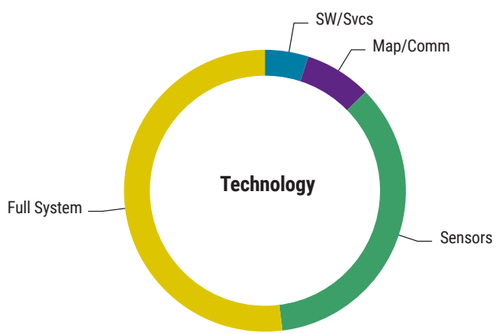
In their 2019 Global Autonomous Vehicle Report, AlixPartners determined that the AV market is anticipated to receive $75 billion in technology investment between 2019 and 2023. In June 2020, this forecast was updated by AlixPartners to state that spending rates would be pared back substantially from the pre-pandemic industry investment forecast to a cumulative of $79 billion between 2020 through 2025. A Financial Times article indicated that the COVID-19 delay was anticipated to lower cumulative investment between 2015 and 2025 from nearly $140 billion to approximately $115 billion.

Exhibit 7: Autonomous vehicle investment

Cumulative 2015-25 ($ billion)







Source: Financial Times