



EXECUTIVE INSIGHTS

Framing the Investment Opportunities Along the Long Road to Fully Autonomous Vehicles

Not long ago, futurists offered up a bright vision of near-term mobility. Autonomous vehicle (AV) technology would transform the U.S. car fleet, virtually eliminating human error on the road and negating the need for most people to own automobiles. Workers could live farther from their place of work. Higher utilization of AVs would make current electric vehicle technology economically attractive and reduce fuel emissions. Fewer and less severe collisions would save tens of thousands of lives every year. And all this would become reality in just a few years.

That was the narrative circa 2016. Today, progress on AVs continues but only partial autonomy is commercially available. In this *Executive Insights*, we'll unpack the conditions that will determine the pace at which fully autonomous vehicles become available commercially. Along with discussing the successive waves of development that lie ahead for autonomous vehicles, we will also outline potential investment opportunities during the transition to full autonomy.

Rolling out the technology

There are six levels of autonomy but only in Level 5 does the vehicle control all aspects of driving in all conditions.

Level 0 requires the driver to be fully responsible for all aspects of the driving tasks.

Level 1 technology includes cruise control and lane departure warning systems.

Level 2 capabilities control the vehicle's steering and braking under certain conditions such as adaptive cruise control and lane-keeping assist systems.

Level 3 allows the vehicle to control all aspects of driving under certain conditions, with a human standing by to intervene as needed.

Level 4 is where the technology controls all aspects of driving, but the driver is present and able to take control, though human intervention isn't expected to be required.

Level 5 brings us to full autonomy. The vehicle controls all aspects of driving in all conditions.

The long road to Level 5 autonomy

While AV technology advances, several difficult hurdles must be overcome before Level 5 AVs become available at scale. First is affordability. An autonomous vehicle requires a multitude of sophisticated sensors, a human-machine interface and control systems. Together, they determine the vehicle's position and execute the commands that drive the vehicle and communicate with the driver. Currently, the incremental cost of a Level 3 autonomy package is approximately \$15,000 while a Level 4 or 5 package would cost tens of thousands of dollars in incremental technology per vehicle. These costs will decline as technology improves and economies of scale come into effect, but it will take time before it is affordable on all but the most expensive vehicles.

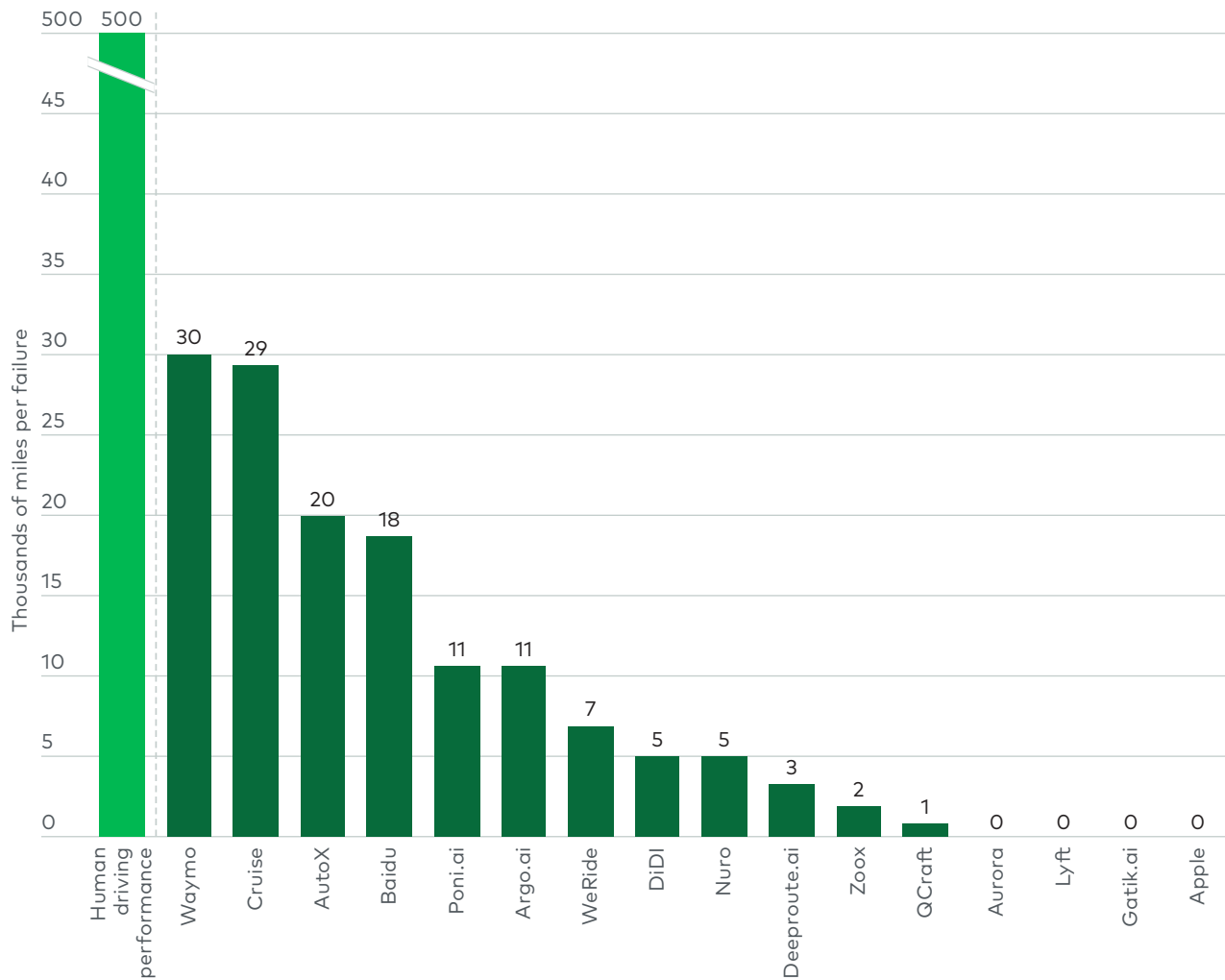
Second is the performance of autonomous driving technology. Technology is not yet at the point where it can perform autonomously in a wide range of sometimes unpredictable circumstances. As Figure 1 shows, none of the major AV companies are close to replicating the performance of human-driven vehicles.

Third, Level 5 autonomy will require federal- and state-level regulation to address AV design, testing and construction. In addition, policymakers will need to resolve issues related to data privacy, cybersecurity and accident liability. The U.S. government has issued several sets of guidelines regarding AVs, but these are recommendations, not laws or regulations. In the absence of federal policy, many states have taken up legislation, resulting in a patchwork of inconsistent laws.

Fourth, AVs will require the appropriate infrastructure to be in place. Necessary infrastructure upgrades range from road markings and signage to vehicle-communication infrastructure and high-definition mapping of roadways. Those are in addition to basic repairs and maintenance to U.S. roads, which will require significant investment.

Fifth is consumer demand. According to L.E.K. Consulting's annual Global Mobility Study, 30%-40% of U.S. consumers are interested or very interested in fully autonomous vehicles today, unconstrained by price or other considerations. Many consumers have reservations about

Figure 1
AV failure reports by company vs. human driving performance

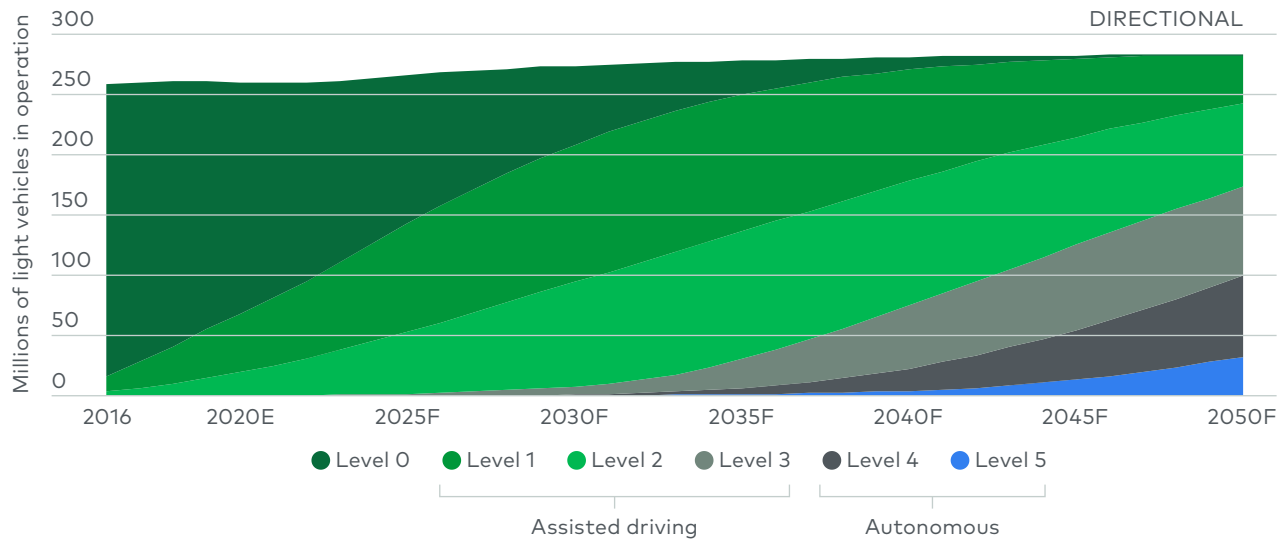


Note: AV disengagement is measured by number of driven miles for each system failure, which is indicative of an AV's ability to outperform a human driver; based on 2019 CA disengagement data
 Source: California Department of Motor Vehicles; TheLastDriverLicenseHolder.com; L.E.K. interviews, research and analysis

the safety of autonomous vehicles. Other consumers indicate a preference for operating the vehicle themselves – a key hurdle to adoption that may require significant time to overcome.

Still, signs of progress have emerged. Level 3 autonomous capabilities have arrived, and the number of vehicles with this technology will slowly increase. However, for the reasons outlined above, it is expected to take a decade before they become a noticeable portion of the U.S. car parc. Levels 4 and 5 autonomous vehicles will follow approximately a decade later and are expected to become a meaningful proportion of new car sales thereafter. The key takeaway is that Levels 4 and 5 autonomous vehicles are not expected to be sold or become a meaningful part of the U.S. car parc for a significant time to come (see Figure 2).

Figure 2
 Estimated US AV penetration of car parc by autonomy level (2016-2050F)



Source: L.E.K. analysis of analyst reports; CCC Crash Course; Ptolemus; IHS; Just Auto; BTS

How a self-driving future is expected to unfold

The road to Level 5 autonomy can be described as unrolling in four waves (see Figure 3), transitioning from basic driver-assistance introductions in Wave 1 to an acceleration of assisted driving features and capabilities in Wave 2, the introduction of autonomy in Wave 3, and then full adoption of autonomous vehicles in Wave 4.

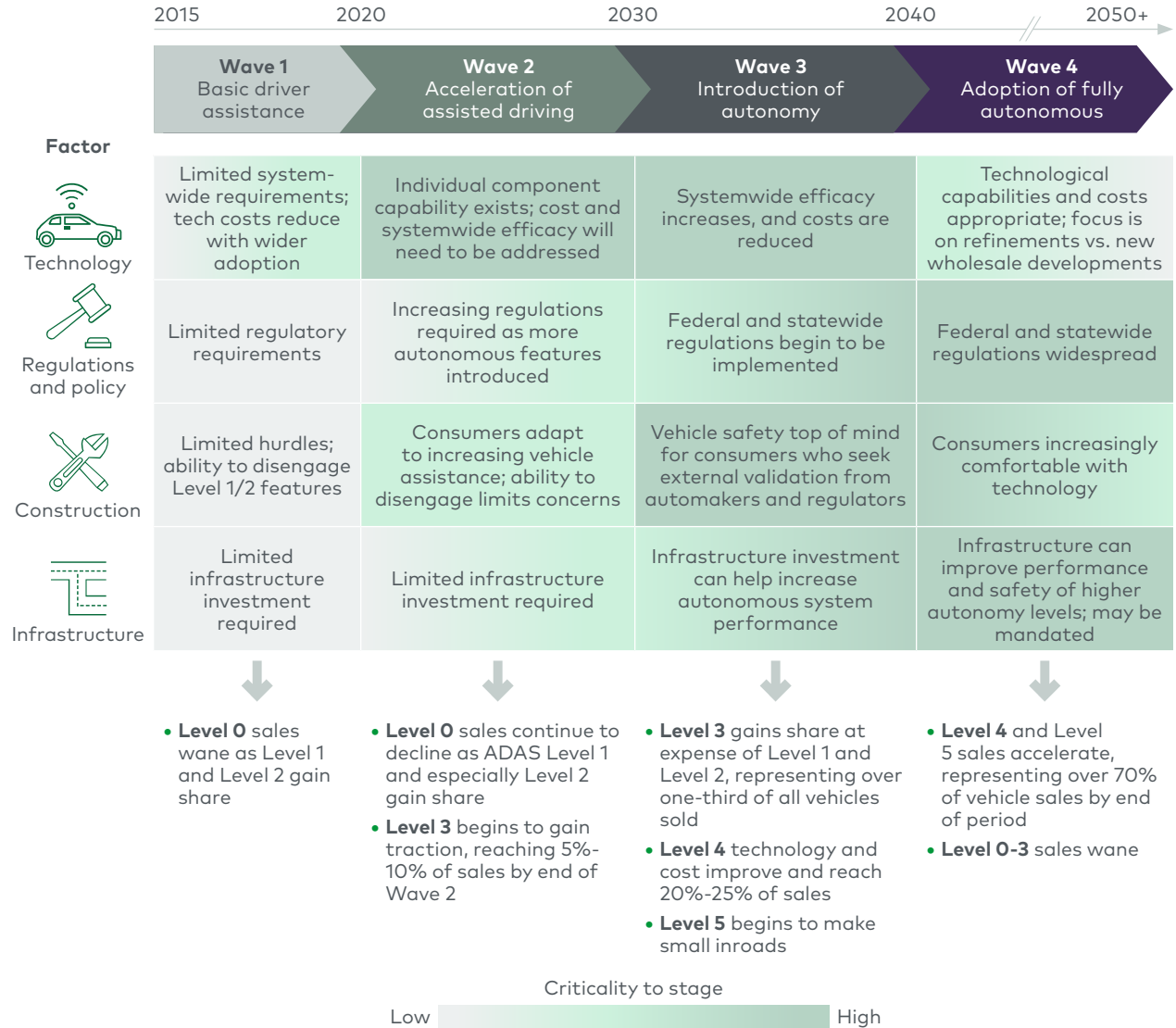
The relative importance of different factors for AV adoption varies across each wave. For instance, infrastructure investment will be more important in Wave 4 than in earlier waves because it will be key to the performance and safety of higher autonomy levels. By the same token, technology cost and systemwide efficacy improvements will matter more during the second and third waves because that’s what it will take to get to the advanced driver-assistance system (ADAS) and consumer acceptance that will launch Wave 4.

Where to find near-term investment opportunities

What does this mean for investors? In the remaining years of our current Wave 2, look to three areas of investment.

Electrical and control systems and sensors. Advancing autonomy will require more precise and reliable cameras, radars, lidars, and other sensors that will need to be available at commercially attractive prices to provide assisted and autonomous driving capabilities.

Figure 3
Waves of AV adoption



Source: L.E.K. research and analysis

There will also be a need for powerful microchips to manage the growing complexity of ADAS features as well as cabling with higher bandwidths to transmit data between systems.

Vehicle services. All those sensors will need diagnostic and recalibration services and certification, which could be sold in different forms. The sensors will also need software to collect and validate data they generate so the vehicle can make sense of its surroundings and prepare to take action. Expect car repairs to get more expensive as a result, potentially leading to an increase in the sale of finance and insurance products.

Infrastructure upgrades. Although meaningful investments in AV infrastructure aren't likely during Waves 2 or 3, opportunities exist for continued investment in basic improvements. Consider that nearly half of U.S. roadways are in poor or mediocre condition. To make them fit for autonomous vehicles, they'll need basic maintenance along with more durable, luminous road markings and signage so vehicle systems can effectively interpret and navigate within the vehicle's surroundings.

Exit ramp is ahead for the car as we know it

While a U.S. fleet comprising fully autonomous vehicles is many decades away, there are opportunities to invest in the transition across the various waves of development. Electrical and control systems and sensors, vehicle services, and infrastructure upgrades are examples of promising areas. These opportunities center on product, cost and service developments surrounding autonomous technologies.

However, we are only at the beginning of the journey to fully autonomous vehicles, and as we continue into the next waves, new investment opportunities will arise. This may include investments in advanced infrastructure (e.g., vehicle-to-vehicle communication), new ownership models (e.g., car sharing and robo-taxis), monetization of vehicle data, new insurance/liability management models, etc.

Understanding the wave of development in which we find ourselves and where we are heading will enable investors to make the right bets and increase their chances of winning the race.

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