Autonomous Vehicles

The outlook for Autonomous Vehicle sales and their impact to 2050

LMC Automotive
November 2018
Introduction

The automotive sector has entered the most significant period of change since its inception in the early 20th Century, when cars powered by internal combustion engines began their era of growing dominance across the world, reshaping our cities and offering personal freedom and mobility to a substantial proportion of the world population.

Today’s Light Vehicle fleet, at over 1.2 billion, continues to expand as ownership rises and population grows. But as urbanisation trends drive the ongoing expansion of cities, and ever more people own and use cars, it is vital that personal mobility changes in order to address the growing unsustainability of the current ownership model.

A number of trends are challenging the status quo. Sharing of vehicles is increasingly mainstream in many locations, while connectivity of vehicles is likely to grow and become ubiquitous on new vehicles within just a few years.

But it is through the deployment of key technologies — in electrification and vehicle autonomy — that a path to sustainability, and the realisation of many other benefits, is now envisioned for the sector.

In this document, we put forward our views on the possible directions the industry will take, over the next 30 years, to 2050.

“It is vital that personal mobility changes in order to address the growing unsustainability of the current ownership model.”
About LMC Automotive

- Independent industry-leading source of market intelligence for over 25 years
- Focused on global automotive forecasts: sales, production, powertrains and electrification

- Responsive and flexible support for OEMs, suppliers, financial firms and government institutions
- The smart choice for automotive intelligence and insight into market dynamics, economic, regulatory and technological change
Executive summary - Autonomous Vehicles

Autonomous Vehicles (AVs) will start to be deployed, at SAE Level 4 (see SAE Level definitions on page 8), in the 2019-2022 period. These applications will, however, be primarily proofs of concept, and learning arenas, for both technology and operational models.

Significant strides towards wide-scale adoption of AVs for Shared and Owned AV usage are beset with uncertainties, in terms of time and scale, and can only be addressed through the use of scenarios.

The scenario assuming breakthrough progress in AVs on a global scale assumes that, by 2030, just over 8 million AVs will be sold per year. A scenario for adoption constrained by technological, commercial and regulatory barriers would see annual sales reach 2 million units by 2030. Our central case assumes over 4 million units per year by 2030.

LMC does not believe that significant deployment of Level 5 AVs – that is, fully autonomous in all situations – can happen in any scenario before 2030.

From a geographical perspective, we assume that the current early lead in AV development enjoyed by the US will be fairly quickly eroded (see page 10). Not only are European competitors advancing, but China is also making AV development a key part of its industrial strategy. That point, taken together with vast scale opportunities afforded by its large population, not to mention the potentially more decisive policy environment, implies that China will become the largest AV market in the world by 2030.

Sales of Owned Light Vehicles should not be significantly impacted before 2030 and the requirement to build large fleets of Shared AVs implies a period of doubling up during which total vehicle industry sales volume might be positively impacted. In the longer run, however, substitution of ownership through Shared AV usage, combined with more efficient use of vehicles in general, will become a headwind for automotive industry volume growth, and will ultimately lead to volume decline.

“LMC does not believe that significant deployment of Level 5 AVs — that is, fully autonomous in all situations — can happen in any scenario before 2030.”
Why AVs are inevitable

The key enabler for AVs has been the rapid technological advancement in computing capabilities, combined with already established techniques in artificial intelligence. This has led to the notion of feasible deployments of increasingly autonomous vehicle features and the prospect of a transformation in personal mobility through high vehicle autonomy at Level 4 and above.

The range of potential benefits of successful development of AVs is large and includes:

- Dramatic improvements in road safety
- Reduced congestion through sharing and traffic management
- More efficient usage of Passenger Vehicle assets
- Reduction in land required for parking in cities and associated journeys
- Inclusive mobility for the young, old and disabled
- New services and opportunities in developing AV ecosystems
- Increased time for productive and/or leisure activity during transit.

Technology companies are threatening to upend the existing automotive sector through the creation of AVs, and Shared AV opportunities, leading to a race towards autonomy with traditional industry participants increasing activity and, in some cases, leading the way.

Taken together, technology, opportunity, market and competitive forces make a move to high autonomy all but inevitable. However, a broad array of obstacles must be overcome before the potential of widely used AVs can become a reality, leading to an extended timeline for widespread deployment.
Shared mobility services continue to grow across the globe. The rise of Uber, Lyft, Didi Chuxing, Grab, Gett and a host of other mobility providers and shared services offered by OEMs has proliferated, merged and adapted as a result of increased opportunities offered by, primarily, app-based booking systems.

While sharing has undoubtedly been received with great enthusiasm, it has also disrupted local taxi and public transportation incumbents, but has yet to threaten the traditional model of vehicle ownership. The ongoing requirement to employ, or contract with, drivers in many shared mobility services, implies limited gains in competitiveness with existing transport options until shared services merge with high-level AVs to provide autonomous shared mobility services. This is, of course, the explicit destination for a number of shared mobility companies.

At the same time, increased vehicle connectivity offers new functionality for vehicle owners and users. The first waves of connected vehicles have come with new and expanded services in terms of entertainment, journey planning, vehicle servicing, safety etc. Future vehicle generations will expand these features further, but a key future aspect of connectivity in vehicles will be as an enabler to high levels of autonomy. An unconnected AV would be significantly inferior to one imagined with strong connectivity. And so the benefits for AVs in being connected – to one another, to their local environment, and to broader control and information systems – should be seen as a key enabler for AVs to reach their ultimate potential.

“The first waves of connected vehicles have come with new and expanded services ... An unconnected AV would be significantly inferior to one imagined with strong connectivity.”
Development paths in vehicle autonomy

Now and in the early stages of development of AVs, discussion about the viability of Level 3 vehicles — requiring hand-off to human drivers and so always requiring a present human driver — addressed the issue in a binary form. It was either: (1) possible and safe to evolve autonomy progressively through to high autonomy*; or (2) required for safety reasons to jump from already-achieved Level 2 standards to high autonomy because disengaged drivers might never be able to re-engage at a critical time.

It has now become clearer that multiple paths to high autonomy will be pursued, with some AV developers choosing, as a matter of principle, to jump to Level 4 (1). Others are choosing to offer Level-3-capable vehicles (2), sometimes while, in parallel, aiming directly at Level 4.

Use cases are likely to be an important determinant in the path chosen. Shared AV developers, for example Waymo, require, as a minimum, Level 4 AVs in order to create robotaxis. Alternatively, autonomously feature-rich vehicles from Premium brand vehicles are already being offered, albeit with some claimed functionality disabled at first.

Highly constrained Level 4 deployments are likely to take place, essentially on a trial basis, in the 2019-2025 period, which will demonstrate feasibility and also represent the first of several stages of deployments, which can grow in scale and reach over time. This stepwise approach will help break down into more manageable chunks the large array of barriers to widespread adoption of AVs. Note that recent AV problems (Uber crash, Tesla Autopilot issues) may lead to more hesitant testing.

* High autonomy defined as being at or above SAE Level 4.

SAE Vehicle Autonomy Levels

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Human roles</th>
<th>Vehicle roles (typical)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>None</td>
<td>All driver control</td>
<td>No autonomous functions</td>
</tr>
<tr>
<td>1</td>
<td>Limited + Safety</td>
<td>Almost all driver control</td>
<td>ABS, traction control, ...</td>
</tr>
<tr>
<td>2</td>
<td>Limited, Active Safety, Convenience</td>
<td>Mostly driver control</td>
<td>Lane keeping, emergency braking, adaptive cruise control, parking assist, ...</td>
</tr>
<tr>
<td>3</td>
<td>Significant Autonomy</td>
<td>Driver can disengage completely sometimes</td>
<td>Advanced controls in simple conditions (highway, slow-moving congestion, good weather)</td>
</tr>
<tr>
<td>4</td>
<td>High Autonomy</td>
<td>Driver not needed in some locations/conditions</td>
<td>Full conditional autonomous capabilities, more difficult conditions/locations not autonomous</td>
</tr>
<tr>
<td>5</td>
<td>High/Complete Autonomy</td>
<td>No driver needed</td>
<td>Autonomous driving in all locations/conditions possible, driver controls (brakes, steering wheel) not necessary</td>
</tr>
</tbody>
</table>
A first-glance appraisal of the requirements for viable AVs might imply that the main task is to create vehicles with self-contained technology that is capable of replicating, more safely, the skills of a human driver.

However, this remarkably complex target is just one of many equally important areas to be addressed. They go well beyond the confines of the vehicle itself and most, or all, such issues must be substantially developed for AVs to work well.

Furthermore, the holistic development and management of these complex factors and inputs is, in itself, a new and enormous challenge.

The technical task of developing a highly autonomous vehicle is progressing. However, deployment in real-world situations immediately brings AVs into contact, and requires their engagement, with a variety of complex and dynamic external systems.

Human factor issues are among the most unpredictable components of the solution, creating substantial potential for either slower development of AVs, or for their failure to meet expectations. People already have personal transportation options, albeit imperfect ones, so AVs must be at least as good in most situations in order to be viable.

With full costs of deployment not fully known, commercial realities for AV use cases cannot yet be understood – hidden costs of real deployments are largely being neglected in discourse. For example, how many redundant vehicles are needed for AV fleets to meet peak demand, or to be constantly cleaned and maintained, in a satisfactory way?

Similarly, with light-touch regulation appearing to be the norm in earlier stages of testing, the shape of future regulatory systems is being assumed by many to be of low importance. This is not the case: a fully functioning framework of laws, norms and standards will need to be developed for AVs to be adopted in large numbers.
**Scenarios for the adoption of Shared AVs**

With significant uncertainties relating to the timing and scale of adoption, market forecasts for Shared AV sales can only be on a scenario basis at this point in time. We have chosen three potential scenarios.

**Breakthrough.** Early 2020s trials are successful in demonstrating safe and competent, though limited, AV operation. Second-phase trials during the mid-2020s expand scale further, representing higher performance and utility. By the late 2020s, proliferation of commercial applications starts to take place, offering a flexible template from which widespread deployments take off. None of the potential barriers prove insurmountable.

**Constrained.** A number of technical, regulatory and human factor barriers prove difficult to solve. Progress is slow and patchy, though momentum remains. Some AV developers quit, waiting to return later, or disappear. By the early 2030s more significant progress is demonstrated, but use cases are not as broad as originally hoped. This limits uptake to more AV-friendly locations, in some cities with favourable policy, infrastructure, weather and other conditions. Take-off is increasingly evident from the late 2030s.

**Central.** Our balanced forecast assumes real progress is achieved in early trials, though some difficulties lead to delays in deployment of next phases. In the context of years of expectation build-up, initial mobility service user experiences are mixed owing to limited use cases stemming from slower development of real-world AV driving capabilities. Sluggish development of regulation also holds back early rapid progress. But by the mid-2030s, successful templates for deployment are rolled out.
Alongside the development of Shared AVs, a number of larger OEMs are expected to develop Level-3-capable vehicles with subsequent generations, perhaps from the mid-2020s, effectively being Level 4 AVs. Such vehicles are designed for owner-buyers in a linear development of the traditional ownership model. They might also not operate up to full design capabilities from the outset, depending upon other critical factors such as availability of appropriate external support systems (maps, infrastructure, ...) and the legal and regulatory permissions of fully driverless vehicles within different geographies.

The scenarios for Owned AVs would be influenced strongly by the same factors driving Shared AV scenarios, as developments that enable or constrain their success would be largely the same.

As with almost all technology feature inclusion in Passenger Vehicles, historically, the newest, best and highest-cost features would initially be adopted at the higher end of Premium brands, in recognisable models.

Specific AV models are also likely, though they would need to retain the traditional vehicle layout, including the centrality of a human driver, until Level 5 vehicles become a reality, something we do not envisage as being likely until after 2030 under any scenario.

Significant changes in the interior would take place, for use when self-driving is engaged, with new communications, productivity, leisure and consumer technologies included.
The impact of AVs on Light Vehicle markets

There will be a point in any specific location when there are sufficient numbers of efficiently operating Shared AVs that they will enable a component of the current owner-buyer cohort to forgo ownership and rely completely on AVs alongside other forms of mobility (walking, cycling, bus, taxi, rail and car).

The substitution of ownership through vehicle autonomy will be a defining feature, and one which should enable greater efficiency of vehicle use, of the coming transformation. And yet the substitution ratio – the number of owned vehicles replaced by each Shared AV – remains highly uncertain. In the earlier stages of deployment, when AV numbers are below a critical mass that facilitates this switch in behaviour, and before AV capabilities are deemed acceptable, AV numbers will be additive to total vehicle volumes: there would be little substitution and some minor increase in overall vehicle numbers. Once these thresholds have been cleared, however, a reduction in total new vehicle demand would be inevitable.

Substitution rates are likely to vary across different locations as AVs compete with pre-existing forms of transportation which, themselves, have varying degrees of effectiveness. Our scenario modelling implies that, at one extreme, large numbers of owned vehicles might be dropped while, at the other, AV numbers could prove additive. However, our view, between these boundary conditions, is that there will ultimately be a significant reduction in sales of owned vehicles as a consequence of increased vehicle sharing that AVs will enable. This is not likely to happen to any significant degree globally before 2030, though some local pockets would see higher substitution.

It is possible to quantify the volume impact of AVs, relative to the non-AV world – effectively a continuation of the current ownership model. If there were no evolution in the industry, annual global vehicle sales would continue to rise as adoption and ownership increases. The development of AVs means that this is not now expected.

The chart shows not only the non-AV projection, but also how the Central AV scenario forecast leads to a levelling off of vehicle volume from 2030. However, as AV usage matures, from the mid-2030s, their numbers will also grow, leading to a recovery in total vehicle volumes. This happens as a result of continuing urbanisation over the coming decades with ever-greater numbers of inhabitants of cities using shared autonomous transportation. A simultaneous expansion in public transport volumes must also result, as Shared AVs integrate into transportation systems in order to avoid a dystopian future in which current growth in congestion levels, caused by human-driven vehicles, is replaced by that caused by Shared AVs. Note that today’s new shared transportation models, such as Uber, have already led to increased vehicle movements as they compete with public transportation, and far less with vehicle ownership, in effect causing more road journeys through Passenger Vehicles at the expense of efficient use of public transport. This growth is unlikely to go unchecked even without the advent of AVs.

The overall impact of the widespread adoption of AVs is to reduce overall Light Vehicle demand by around 10% in the Central scenario, relative to the non-AV case. Significant ownership of vehicles, even those that become increasingly autonomous, prevents a deeper negative volume impact.
Notes on forecast assumptions and scenarios

There is little precedent in the automotive industry for the kind of change likely to be caused by the introduction of AVs. The forecast approach we have adopted, therefore, cannot rely on historical examples or relationships in a causal quantitative model in the way that many other forecasts can be constructed. Instead, we have taken, as a starting point, adoption curves with varying degrees of uptake, as defined by our Constrained, Breakthrough and Central scenarios. This approach is more commonly used for entirely new areas of market and product activity. The curves have been informed by research on the state of technology, and various other factors, to build an assessment of the attack of each scenario curve. In the early years, some milestones have been openly discussed at a high level, for example certain AV developers’ (traditional and non-traditional OEMs) public announcements on their AV testing plans. These can form the basis for near-term projections. But further intelligence is required from the broader network of AV-related parties, areas of relevance for which are shown in the Challenges in the development of AVs section of this document. There remains a huge array of questions to be answered with respect to the way in which AV market projections will evolve in the future. LMC will continue to monitor the environment, engaging with those involved in the development of AV systems, in order to seek to narrow the range of possibilities in these uncertain areas.

With a specific market curve forecast in mind, it is possible to assess the pros and cons of a given location for AV deployment. Factors that influence choices in different geographies include: presence of AV developers or other AV-tech leaders; legal/regulatory and policy environment; maturity of Light Vehicle market and industry; maturity of relevant technology and manufacturing; road conditions; population density; climate; quality and development of mobile network; and so on. While it has not been possible to conduct detailed analyses of all of these factors for all markets in the world (the scope would be unmanageable), judgements as to which markets will adapt quickly or slowly have been made using these types of criteria.

Once the Shared AV adoption curves are assumed, for different scenarios, it is possible to model the Shared fleet size for each case. Assumptions on annual driving distances were made to create a survival curve for each market, which, in turn, leads to the fleet size. (An intensively used AV is unlikely to survive for as long as an owned vehicle.) This fleet size is then used to assess the extent to which ‘normal’ owned vehicles can be substituted.

The substitution rate is also a moving target. AVs launched in the next ten years will be inferior to ones launched ten years later, and so on. The latter vehicles will be more capable and more able to allow for substitution to take place. There will also need to be a large number of Shared AVs in operation for there to be any significant substitution in any location. We would expect the substitution rate to start small, and then grow for a variety of reasons. Resistance to change – noted as a challenge to AVs – will likely result in many people retaining their vehicles, and their transportation choices, simply because they are happy with the current combination of transportation solutions and will not adopt AVs at all. Others will be recruited to AV usage over a period of time, as the vehicle capabilities and ubiquity grows.

We have developed a clear distinction between Shared AVs and Owned AVs for specific reasons. Once Shared AV volume and impact considerations have been assessed, it is only then possible to consider the impact on owned vehicle demand. We expect that autonomously capable owned vehicles will be offered in similar timeframes to Shared AVs, as some of their features will be highly desirable in owned vehicles. For example, the Audi A8 launched in late 2017 is stated to be Level 3 capable, though this facility is not yet ‘switched on’ and is waiting for appropriate permissions etc. We assume that the same solutions that enable Level 4 Shared AVs will also be mostly applicable to owned vehicles. By implication, we would then assume that an increasing number of vehicles, likely first in Premium segments, will be offered at Level 4 during the mid-2020s, even if they do not operate significantly in that mode at first. Such vehicles would be considered in the Owned AV category.

LMC is continuously monitoring AV development and will, in the future, launch a forecast service to address this sector as it matures. If you have any specific requests now, please contact us.
To find out how LMC Automotive can help your organisation contact:
forecasting@lmc-auto.com
lmc-auto.com

Oxford    +44 1865 791737
Detroit    +1 248 817-2100
Bangkok    +662 264 2050
Shanghai   +86 21 5283 3526

For experts by experts