Executive Insights

Volume XIX, Issue 58

Mapping the Road to Autonomous Vehicles

There's no doubt that over the long term, autonomous vehicles (better known as self-driving cars), combined with electrification and shared mobility, will have a massive impact on society.

Many pundits debate the extent and speed of the expected effects. Will autonomy act as a "lighter fluid" for the spread of shared mobility services? How soon will urban real estate developers be freed from the need to provide space for parking? What will the impact on logistics do to retail?

We like to say that these potential long-term effects depend on how we get "from 1 to 100" — that is, from the launch of self-driving cars to a day when autonomous mobility is ubiquitous. But while prognostication is fun, the map to that destination is still far from clear.

What is becoming clearer, however, is the first leg of the journey, or how we get "from 0 to 1" — from where we are today to the successful commercialization of the first fully self-driving vehicle.

Three key challenges

Going from 0 to 1 requires solving three key challenges:

1. Technological: Achieving full autonomy (i.e., Level 4 or 5 on the SAE International automation scale — see Figure 1)

2. Regulatory: Creating the conditions for safe and effective operation

3. Industrial: Discovering and organizing the right business model to produce a commercially viable product

While these challenges are significant, they will eventually be overcome. The path forward on No. 3 in particular (creating a business model to produce a sellable product) is just becoming clear.

Figure 1
SAE International's definitions of automation levels for on-road vehicles

- **Level 0: No automation** (full driver control)
- **Level 1: Driver assistance** (vehicle controls either steering or speed under certain conditions)
- **Level 2: Partial automation** (vehicle controls both steering and speed under certain conditions)
- **Level 3: Conditional automation** (total vehicle control with expected human intervention)
- **Level 4: High automation** (total vehicle control with no intervention under certain conditions)
- **Level 5: Full automation** (total vehicle control with no intervention under all conditions)

Source: SAE International

Mapping the Road to Autonomous Vehicles was written by **Robert Haslehurst** and **Alan Lewis**, Managing Directors, and **John Moran**, Senior Manager, at L.E.K. Consulting. Rob, Alan and John are based in Boston.

For more information, contact **strategy@lek.com**.

L.E.K. INSIGHTS@WORK

Racing to commercialize an autonomous vehicle

For years, automotive and technology companies have raced to develop self-driving vehicles separately — and myopically.

Tech companies have viewed autonomous vehicles as a tech challenge, one that offers the potential to disrupt incumbent "dinosaurs" in a mature industry and create enormous value, much as smartphones have done.

Large auto original equipment manufacturers (OEMs), on the other hand, have viewed autonomy as an evolution: developing and adding incremental new features to their own existing vehicles over time (first on premium cars, then gradually trickling down through their portfolios).

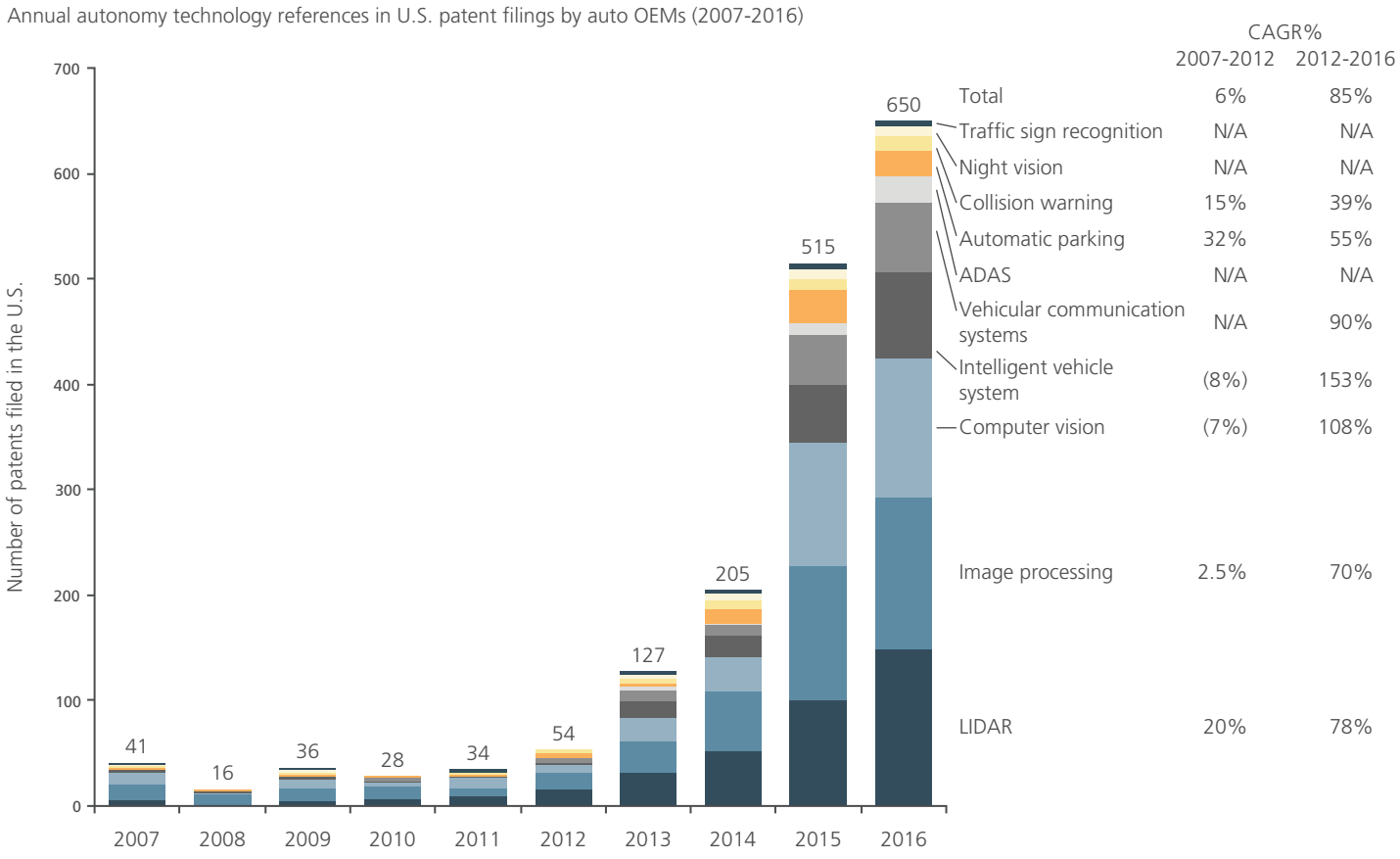
With their parallel, but limited, perspectives, both sides were failing to consider the whole picture: Auto OEMs weren't taking the technology — or the achievability and subsequent potential of full autonomy — seriously enough. And tech companies were failing to acknowledge how much more difficult cars are to manufacture reliably compared with smartphones or laptops.

That's finally changing. A challenge as advanced as commercializing a Level 5 autonomous vehicle suggests a strategy as old as Adam Smith: specialization.

Tech companies are forgetting the "body" and focusing on the "mind"

Unlike consumer electronics, cars have tens of thousands of hardware components, all of which need to perform according to extraordinary safety and quality standards. Over the past 100 years, automakers have refined their ability to deliver new cars — more than 90 million[1] annually — across several hundred models

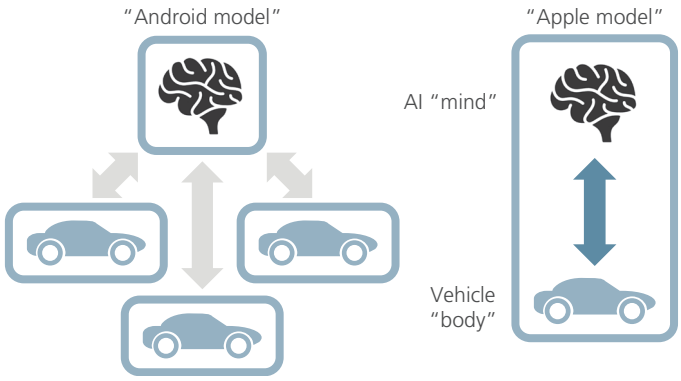
Figure 2
The pace of auto OEM autonomy patent filing is exploding



Source: L.E.K. analysis, USPTO. OEMs included here are BMW, BYD, Daimler, Faraday Future, FCA, Ford, General Motors, Honda, Hyundai, Isuzu, Mazda, Mitsubishi, Nissan, PSA Group, Renault, Suzuki, Tata Motors, Tesla, Toyota, Volkswagen and Volvo.

Figure 3
Two business models emerging to develop and commercialize a fully autonomous vehicle

The "Android model" versus the "Apple model"



Source: L.E.K. analysis

with different, evolving feature sets. In other words, there are myriad reasons why there hasn't been a new automaker of scale in decades (and Tesla's not there yet).

Tech companies like Apple and Alphabet, parent of Google, have now realized that they don't need to build hardware to win the autonomy game. Their collective conclusion is that they will never beat the auto industry at making a car — the "body" — and instead should focus on what they do best: building revolutionary software platforms — the "mind" — this time in self-driving AI. To that end:

- **Waymo**, the self-driving car unit of Alphabet, scrapped the development of its own custom vehicles last year and formed an initial partnership with Fiat-Chrysler to use the automaker's Pacifica minivans
- **Apple's** Tim Cook announced recently a major pivot with regard to Project Titan, its stealth car venture, to focus on making an autonomous platform as opposed to an actual vehicle
- **Uber**, it was recently revealed, has considered a collaboration with a major automaker on its self-driving project
- **Baidu**, one of China's largest tech companies, said recently that it will open-source a self-driving software platform after being inspired by Google's approach with Android
- **Nvidia** unveiled in January a partnership with Audi to use its vehicles to bring the tech company's AI driving platform to market
- Next-gen startup **Faraday Future**, as part of a strategic shift, just abandoned plans to build a Las Vegas auto plant

These tech companies are leveraging their software resources and experience to master machine learning so that their AI platform minds can not only sense the environment but also independently learn how to make more intelligent decisions about vehicle operation. Any aspirations to compete head-to-head with the automakers in making an actual vehicle have fallen by the wayside.

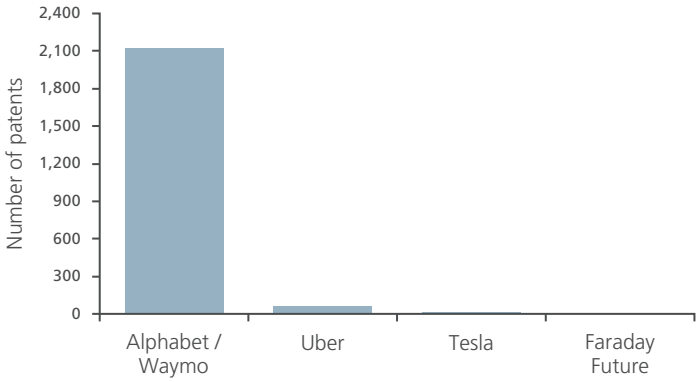
Automakers are getting serious about full autonomy

Meanwhile, the traditional automakers are no longer simply working on adding self-parking and other driver-assistance technologies to luxury cars. Perhaps concerned that they will become hardware manufacturers subservient to powerful operating systems providers, as we have seen play out in other industries, they are now preparing for a future of full autonomy.

Some are signaling the seriousness of their intentions through high-profile personnel changes: For example, Jim Hackett, the former leader of Ford's autonomous vehicle efforts, was recently named CEO of the automaker. Others are taking their intentions directly to investors and the public, such as when GM's CEO Mary Barra recently told The New York Times, "We definitely want to be first" to develop a fully autonomous car. GM is now mass-producing self-driving Chevy Bolts to create the largest fleet of autonomous vehicles to date.

Figure 4
Alphabet's (Google) Waymo has the clear lead among tech players

Total autonomy-related U.S. patent filings, select tech players (2007-2016)



Source: USPTO, L.E.K. research and analysis

To prepare for a future of full autonomy, auto OEMs have significantly stepped up their investments in self-driving vehicle research and technology. The pace of auto OEM autonomy tech U.S. patent filings is exploding, more than tripling from 2014 to 2016.

Two models emerge: "Android" and "Apple"

We see two business models emerging to develop and commercialize a fully autonomous vehicle.

The first model is centered on a division of labor between hardware and software; call it the "Android model" (see Figure 3). Tech companies are fighting to build the winning mind — an AI platform to operate autonomous vehicles — while a set of auto OEM partners and their suppliers will build the vehicle bodies.

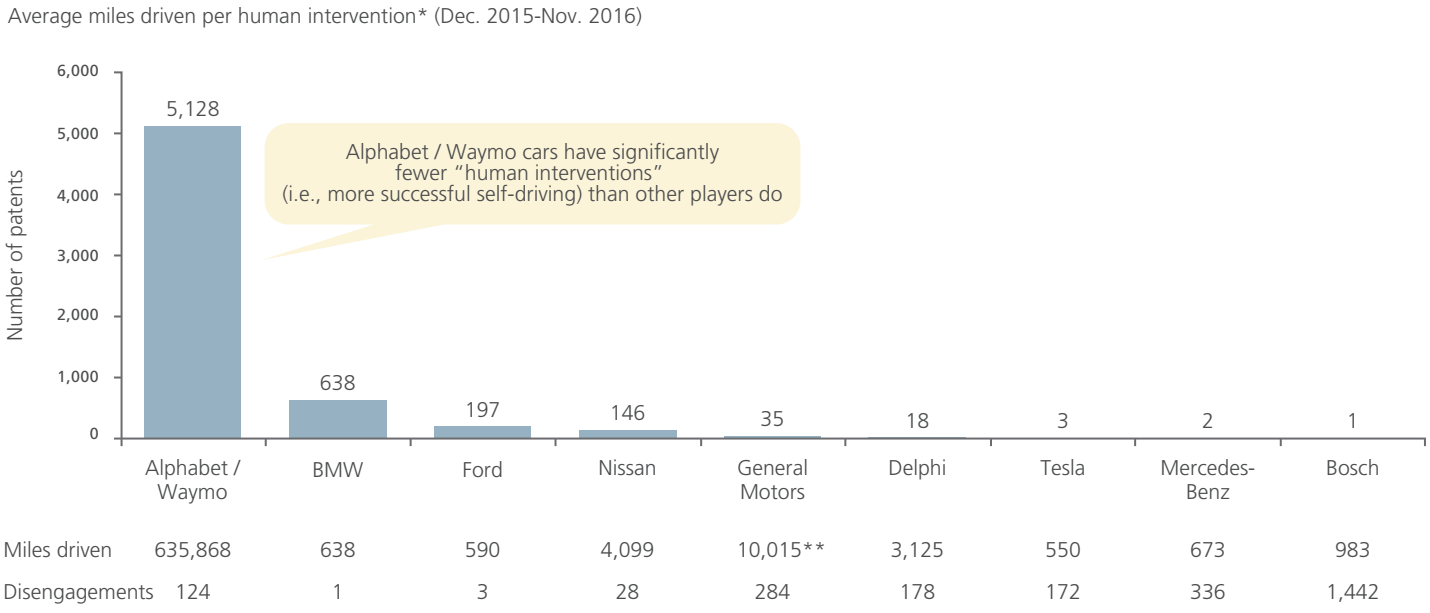
The industrial structure will likely follow the same pattern seen with Google/Android in mobile devices or Microsoft/Windows in PCs, with a dominant platform running on a range of OEMs' hardware. As with so many other types of technology platforms, autonomous AI is likely to tend toward a winner-takes-all model because machine learning platforms get smarter as more vehicles use them and more data are collected. The result is a virtuous cycle where the leading platform extends its advantages, including safety, and pulls away from the rest.

With the self-driving mind outsourced to a leading tech player, however, a wide range of auto OEMs will have to partner with the platform and produce competitive self-driving vehicle hardware. The potentially huge demand and range of uses for autonomous vehicles could support a wide range of producers of the bodies — again, similar to the range of PC and smartphone OEMs running Windows and Android, respectively.

But a second model may also be emerging, led by prominent players like Ford, GM and Tesla. These OEMs are unwilling to relinquish the operating system and focus only on hardware. Rather, they have doubled down on both the mind and the body. Call it the "Apple model," with each player integrating hardware and software in an attempt to produce a better overall product, avoid dependence on a critical partner — and reap the financial rewards.

The only problem? In smartphones and PCs, there was only room for one successful integrated player: Apple. In autonomous vehicles, there are a number of players vying to be the dominant alternative to the Android model. Not all can succeed.

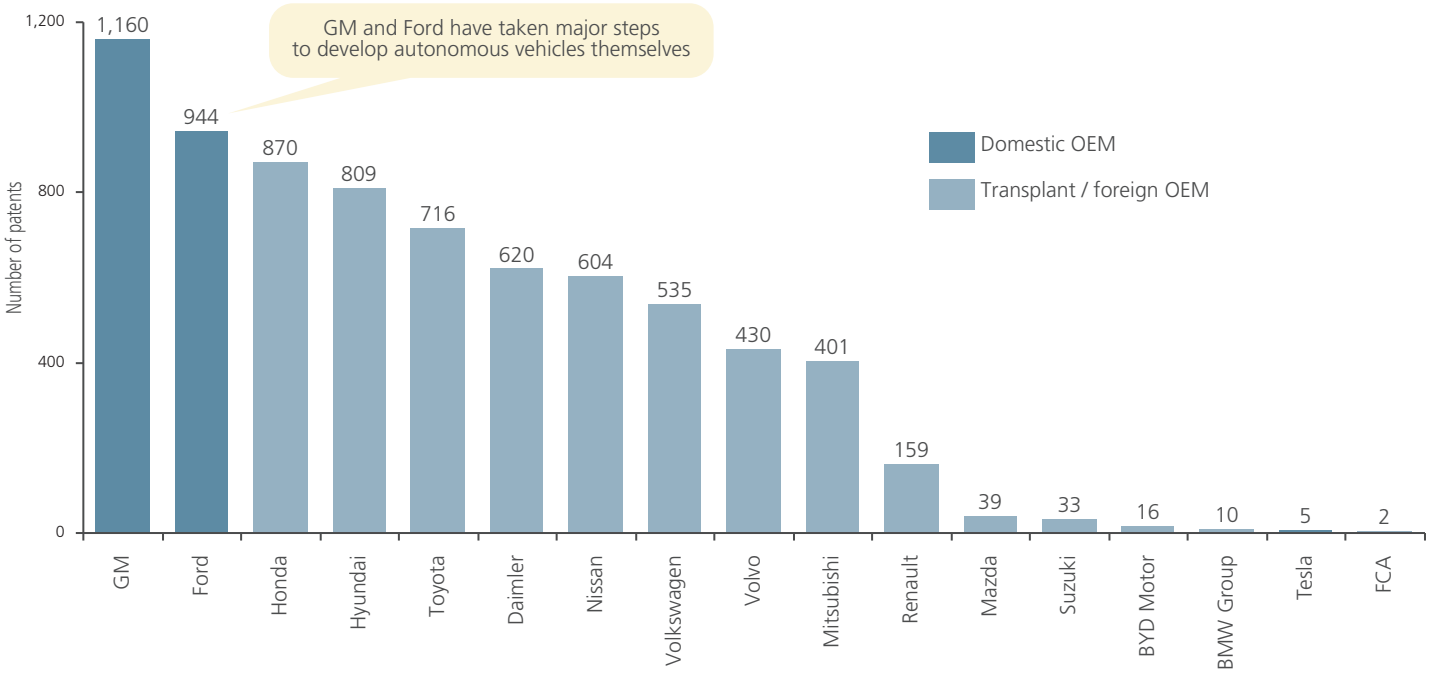
Figure 5
Alphabet / Waymo's cars are self-driving more successfully so far



* California data; Volkswagen and Honda are not shown as they have not yet been tested on public roads ** For the time period of June 2015-Dec. 2016
Source: California DMV, L.E.K. analysis

Figure 6
GM and Ford have committed to developing autonomous vehicles

Total autonomy-related patent filings by OEM, 2007-2016



Source: USPTO, L.E.K. research and analysis

Who's leading the pack?

In the cutthroat race to be the winning AI platform in an Android model, there are several contenders, but Alphabet's Waymo has the clear lead.

Alphabet, a leader in machine learning and processing, has the scale, data chops and infrastructure to win, and has already filed far more patents than any other player (tech or automotive) in the self-driving space (see Figure 4).

Furthermore, its platform is being more heavily road-tested (in addition to undergoing tremendous amounts of virtual simulation) and appears to be more successfully "learning" autonomous driving; California data suggest Waymo's self-driving cars have fewer human interventions than those of any other manufacturer (see Figure 5).

For OEMs betting on the Android model, there are likely to be multiple winners. But at this point, few have seized the opportunity to strike a deal with Waymo. Instead, several have made bets on other platforms, such as Audi with Nvidia, and Fiat-Chrysler with Intel as part of an alliance with BMW. If Waymo's platform continues to pull away, however, many automakers would be wise to consider committing to it sooner rather than later.

For those betting on the Apple model, the race is tight. On paper, Ford and GM appear to be in the clear lead. Both are enormous and capable auto OEMs, and both have made billion-dollar investments to acquire their own self-driving AI platforms: Ford with Argo AI, and GM with Cruise Automation. Both are also investing heavily in patenting core technologies, particularly in sensing capabilities (see Figure 6). But some argue that Tesla — which lacks Ford's or Waymo's heavy investments in LIDAR and other technologies — could nevertheless pull ahead, given that its active cars already include Level 2-3 autopilot features.

The race to autonomy

As players like Alphabet, Apple, Ford, GM and Tesla race to develop self-driving vehicle technology, we've just quietly reached a major milestone: the emergence of two clear potential business models, and a bifurcation of players committing to each.

Like other major technological shifts, this one is likely to feature a single dominant software platform (an AI mind) partnered with a range of OEMs producing bodies. There may also be room for one or two — but not more — integrated players that combine mind and body in a single entity.

The only questions now are whether Alphabet/Waymo can consolidate its lead into a victory in the next great platform war; which automakers will be forward-thinking enough to strike deals with it sooner than later; and whether Ford, GM or Tesla has the chops to successfully commercialize a fully autonomous vehicle with an integrated Apple-like model.

Of course, the race won't be over once we get from 0 to 1. Instead, it will shift into the next gear as an even wider range of companies — including mobility-as-a-service firms like Uber — fight to make their model of autonomous mobility widespread. In other words, the journey from 1 to 100 will begin.

But while the long-term road map to the future of mobility is still hazy, the first leg of the journey is starting to become clear.

Editor's note:

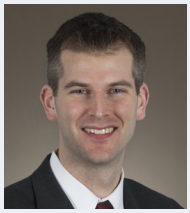
Mapping the Road to Autonomous Vehicles is part of an ongoing *Executive Insights* series on "new mobility" that examines how this unfolding trend affects cars, modes of consumer transportation, infrastructure investments and city planning, and how companies change the way they transport goods. Please see two recently published reports on new mobility to learn more: Beyond the Hype — Making Money in New Mobility and Mobility as a Service: The Next Transport Disruption.

[1] http://www.oica.net/wp-content/uploads//ranking2015.pdf

About the Authors

Robert Haslehurst is a Managing Director and Partner in L.E.K. Consulting's Boston office and is focused within our Retail and Consumer Products practices. He has been with L.E.K. since 2000 and has extensive experience working with both retailers and consumer brands in the U.S. and globally. Rob advises clients on a range of issues, including corporate strategy, consumer insights, new product development, program management, corporate finance, and mergers and acquisitions.

Alan Lewis is a Managing Director and Partner in L.E.K. Consulting's Boston office. He co-leads Edge Strategy® services at L.E.K. and is the co-author of *Edge Strategy: A New Mindset for Profitable Growth*. Alan was selected as a Top 25 Consultant by *Consulting* magazine in 2016 for Excellence in Retail. He has more than 12 years of consulting experience.



John R. Moran is a Senior Engagement Manager in L.E.K. Consulting's Boston office who works in the Retail and Consumer Products practices. He joined L.E.K. in 2005 and has extensive experience in developing and activating growth strategies for major brands, including new product development, brand development and go-to-market strategy.

About L.E.K. Consulting

L.E.K. Consulting is a global management consulting firm that uses deep industry expertise and rigorous analysis to help business leaders achieve practical results with real impact. We are uncompromising in our approach to helping clients consistently make better decisions, deliver improved business performance and create greater shareholder returns. The firm advises and supports global companies that are leaders in their industries — including the largest private- and public-sector organizations, private equity firms, and emerging entrepreneurial businesses. Founded more than 30 years ago, L.E.K. employs more than 1,200 professionals across the Americas, Asia-Pacific and Europe. For more information, go to www.lek.com.

L.E.K. INSIGHTS@WORK