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Q-Series

Who will win the race to autonomous cars?

Equities

Global
Automobiles

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Autonomous vehicles is a $1.3-2.8trn market in 2030E

In spite of recent incidents with autonomous vehicles (AV) in test runs, we expect the technology to become mass-market ready over the next ~10 years. In 2030, we expect AV to represent a $1.3-2.8trn net revenue pool across various parts of the ecosystem, additional to global car sales worth ~$2trn today. And this is a snapshot of what is still an early phase of adoption, because just ~5% of all miles driven will be autonomous by then. Read on to find out who is likely to win and how to best invest in the theme.

What is unique about our work?

Two things: (1) we have conducted in-depth interviews, based on a structured questionnaire, with 22 executives and experts drawn from the entire AV ecosystem; (2) we have developed a proprietary interactive model that analyses the 2030 AV-related revenue opportunity company by company in our global autos and tech coverage.

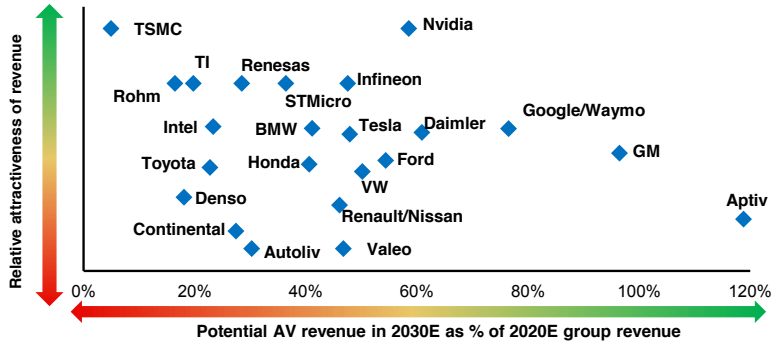
Our six most controversial conclusions in this report

(1) Google/Waymo will likely dominate the AV operating system (ex China), so gaining the strongest foothold in in-car time monetisation. (2) Existing ride-on-demand leaders (Uber etc.) likely need to evolve in a robotaxi world as AV supply becomes concentrated (supply winners are likely to be regional champions driven by regulation) – consumer brand adoption and their aggregation role (similar to online travel model) are likely key to success. (3) A few OEMs (premium and the largest volume/lowest-cost makers) will be net beneficiaries from AV, but for many, it is a net loss game. (4 and 5) Chip and auto suppliers should benefit from strong content growth (also near term), with sensor and AI semi producers in the strongest position. (6) Lidar-based AV is likely to win on a 5-10-year view (potentially negative for Tesla's camera-centric autopilot system).

How to play the theme: Identifying the key winners

Waymo will most likely be the biggest beneficiary from AV in absolute terms, and the opportunity is significant enough (~80% incremental revenues by 2030) to further drive Alphabet's investment case. Nvidia, Intel and Infineon stand out on the semiconductor side (stock-wise, we prefer Intel and Infineon). In autos, GM as leading volume maker and Daimler as leading premium play stand out as best positioned, even after the loss in revenues through selling fewer privately owned cars. In our global auto supplier coverage, Aptiv screens as biggest beneficiary. Many other mass OEMs and lower-tech auto suppliers (not shown in the chart below) will likely be net losers as global car sales are likely to be negatively affected by robotaxis after ~2025.

Figure 1: Size and attractiveness of AV-related revenue opportunity



Source: UBS estimates

www.ubs.com/investmentresearch

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Executive Summary

Who will win?

Who is likely to win in a world of autonomous vehicles? You have asked us: Are traditional carmakers going to survive in a world of autonomous vehicles (AV)? Will Waymo or ride-sharing platforms (Uber etc.) take it all? When will robotaxis become a reality and who will be leading in the field? Which are the most and least attractive business models?

22 experts provide their answers

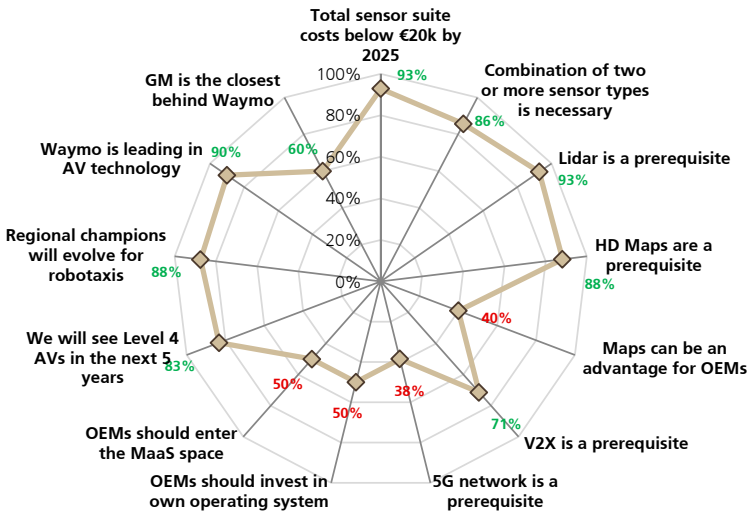
To answer these questions, UBS global research has interviewed a panel of 22 senior experts and executives drawn from the entire AV ecosystem. Together our with global tech research colleagues, the global autos team has analysed the industry landscape. Based on a structured questionnaire, we interviewed 22 thought leaders in the AV space.

Figure 2: UBS AV expert interview word cloud

Source: UBS interviews with 22 AV experts
Note: Bigger font size means more frequent mentions.

Our analysis was focused not (only) on the question of who will be the first, but more importantly, who will have the best business model that gives access to the most attractive revenue pools, with the lowest risk of commoditisation, and the most visible returns on investment.

Figure 3: Key takeaways from our AV expert interviews



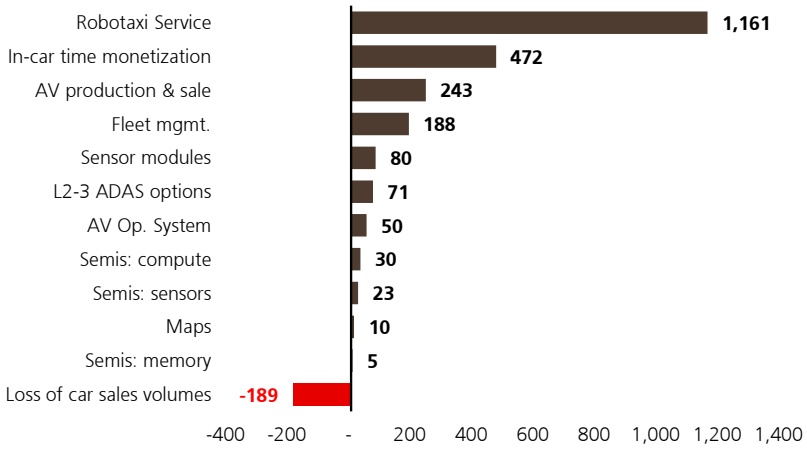
Source: UBS AV expert interviews

What will be a winning business model in AV, and who is leading?

$1.3-2.8trn net revenue pool in 2030E

In 2030, we expect 12% of all new cars sold to be robotaxis, even though robotaxis will represent only 2% of globally registered passenger cars by then (UBS base case). While the exact AV take-off year is hard to predict, we expect a steep increase in AV penetration thereafter as robotaxis begin to replace car ownership. Therefore, the 2030 revenue pool forecasts shown below are just a snapshot of what is still likely to be an early phase of AV adoption. The biggest potential revenue pool is most likely the sale of the mile in an AV. But we don't think it will be the most attractive part of the AV ecosystem.

Figure 4: Revenue pools in an AV world ($bn, 2030E)



Source: UBS estimates
Note: For a definition of the different levels of autonomous driving (L1-5), see the Appendix.

We derive **six key conclusions** from our deep-dive analysis, which are the subject of fierce debate in the financial community.

Waymo is the #1 center of gravity

(1) The AV operating system will be the strategically most relevant centre of gravity. Those owning it will be able to capitalise on it in other areas of the ecosystem. Because **Waymo is widely seen by industry experts as a leader in this area, we see a high likelihood that Waymo gains a dominant role in in-car time monetisation**, with ~60% of the total projected revenue pool in 2030. Unlike most auto players, Google focused on L4/L5 from the very beginning – more than five years before the auto industry started working on it. China is a different story, where Baidu has emerged as the local leader.

Only a few OEMs can be net winners from AV

(2) Only the **premium and largest mass auto OEMs** are well positioned to be net beneficiaries from AV, because they will have a sufficient return on the high, duplicative investments they are doing. Strong **partnerships** will be key to reduce the upfront costs. Leading OEMs will be able to enhance their returns by expanding into robotaxi services and/or the management of robotaxi fleets. A **Foxconn-type business model** (Foxconn produces Apple's iPhones) will likely not work for most of the mass OEMs, given the relatively fragmented industry structure, and the loss of volume in the traditional OEM business model adds to the threat. Chinese players like **Geely** or **Great Wall** appear well prepared for white-label AV assembly, but also other global OEMs with experience in the EM budget segment could become relevant. As a general negative theme for the OEM space, the transition to AV will likely cause **significant restructuring** along the way.

Ride-on-demand platforms will face challenges

(3) Existing leaders in ride-on-demand are by no means the 'natural winners' in **robotaxis.** Working in favour of those companies will be their existing brand awareness and adoption among consumers. In our view, the pure 'matchmaking' component of those businesses (and their respective apps) could become less valuable should other platforms and providers scale and choose to invest behind their own consumer facing service. What is a large unknown is whether those companies will scale their own autonomous efforts (Uber) or merge/partner with other existing ecosystem players over the next 10 years, as the end market ramps towards more ubiquitous robotaxis.

Semiconductors: Intel is our preferred play

(4) **The semiconductor space** will be a strong content growth story, particularly on the sensor side near term as the penetration of L2/L3 cars will rise rapidly. On the sensor side given the likely need to have all three sensor technologies (at least initially), we see **Infineon** as well positioned with a strong position in Radar today and investing in lidar. On the compute side, we believe that both **Intel** and **Nvidia** are well positioned but this is less priced in for Intel. We also see this as helpful for the memory market although only to a limited extent (potentially adding 1-2% to overall demand on DRAM/NAND).

Aptiv leads by wide margin among tier-1 suppliers

(5) **For auto suppliers,** the rapidly increasing number of sensor modules is a content growth opportunity, particularly for **Aptiv, Conti, Denso** and **Valeo.** However, competition is likely intense and investments are high, which bears the risk of low returns. Also, as the capabilities of the sensors improve and as AV algorithms are becoming more reliable, the number of sensor modules could decrease again, given a more than 10-year view. Lidar is the sweet spot in sensors, and the leaders are likely to enjoy profitable growth.

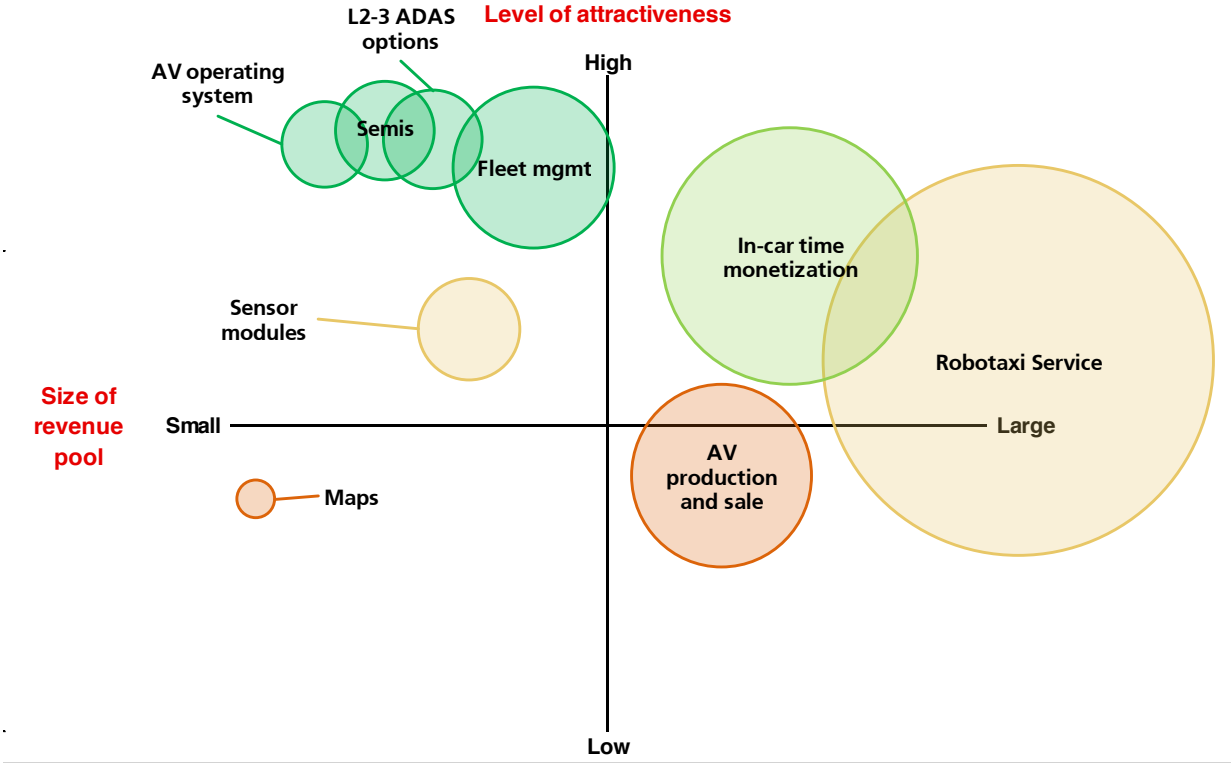
Lidar a must-have

(6) **Lidar wins over camera-centric systems.** For the next 5-10 years, a lidar-based system (lidar stands for light detection and ranging, ie, a laser scanner), combined with cameras and radar, will likely win because it offers more layers of redundancy than a camera-centric system, which will be a key requirement of regulators. Lidar costs should drop by 80-90%, mainly on economies of scale. While a camera-centric solution can gain relevance in the very long term, we do not see a camera-based L4/L5 system at scale for the next 10 years. This could put Tesla at a disadvantage, in spite of its leadership in terms of collected data from its fleet on the road.

The UBS AV "bubbles"

The chart below depicts the respective revenue pools in terms of both size and relative attractiveness. The attractiveness rating is based on our analysis of the competitive forces (ie, profit potential) in each area. The AV operating system, semiconductors, fleet management, and in-car time monetisation look the most promising, whereas running a robotaxi screens relatively poorly.

Figure 5: Ranking the attractiveness of the AV revenue pools



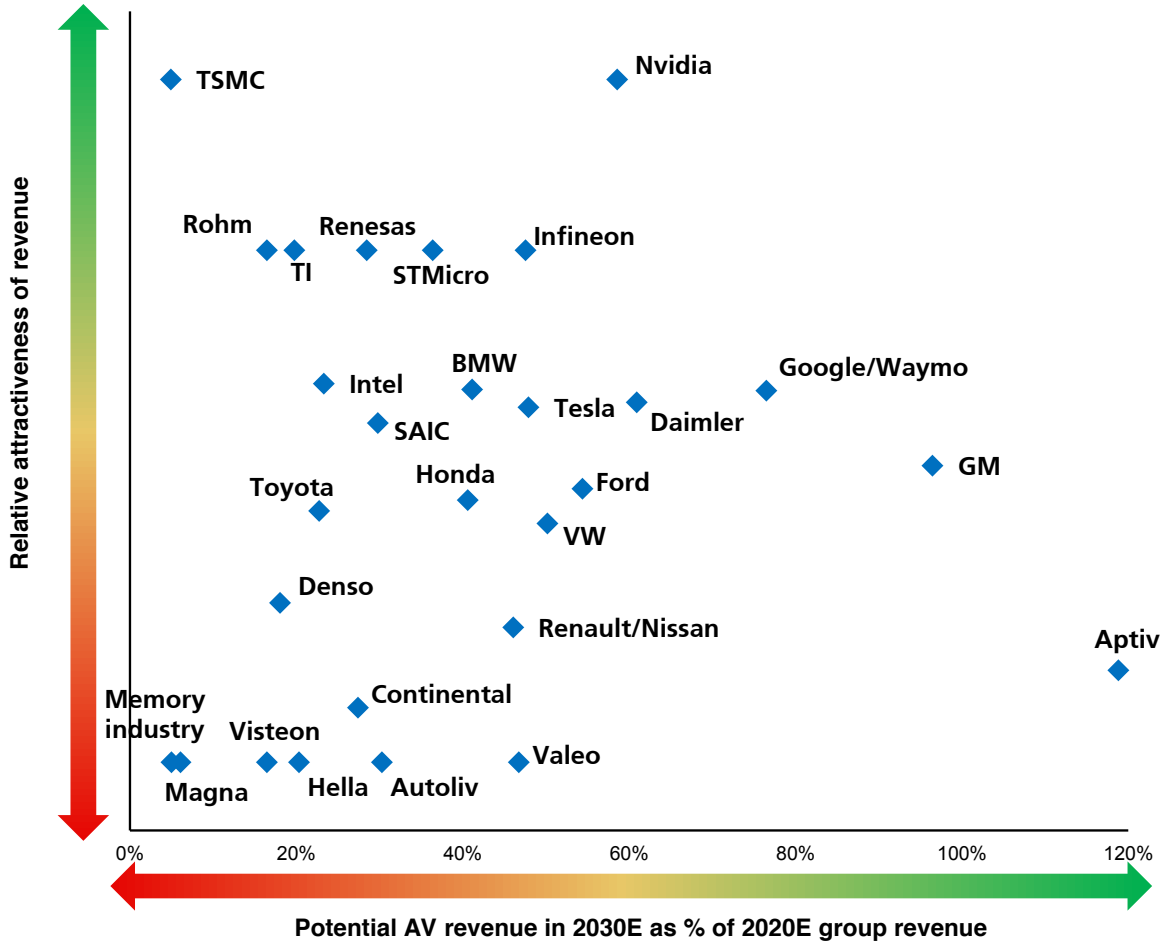
Source: UBS

How can I play the AV theme best in global autos and tech?

Interactive model

We have developed an interactive model that forecasts the size of the revenue pools in 2030 (our base case assumes a 'take-off' of robotaxis at large scale, starting 2026). Based on estimated market shares of the key players, the model provides an AV revenue forecast for all AV-related stocks in our global autos and tech coverage. We put this into the context of 2020 estimated revenues, to illustrate the extent to which the AV opportunity moves the needle for each investment case.

Figure 6: Who wins in a world of AV?



Source: UBS estimates

- **Internet: Waymo/Alphabet** stands out as the key winner, with an AV opportunity in 2030 representing ~80% of 2020E group revenues. We see Waymo/Alphabet being dominant in the AV operating system with a substantial share in in-car time monetisation.

Alphabet,

- **Auto OEMs: GM** is ahead of the OEM competition in terms of AV technology and among the leaders in rolling out a robotaxi service. **Daimler** screens as best positioned among premium OEMs, with a leading position in mobility services today. **Tesla**, while it undoubtedly has the best AV software know-how among the OEMs, could be challenged in its decision not to use lidar technology.

GM, Daimler,

- **Semiconductors:** In our global semis coverage, **Nvidia** and **Infineon** are among the players most impacted by AV. However, we think **Intel's** AV opportunity (while smaller relative to group revenues than Nvidia's) is not fully reflected in the current share price.

Intel, Infineon, Nvidia

- **Auto suppliers: Aptiv** is, by a wide margin, the best positioned AV play in our global coverage. In aggregate, suppliers rank below the leading OEMs in our analysis because a significant part of the sensor market is likely to face intense competition – lidar stands out positively.

…and Aptiv are best positioned to benefit from the AV theme

We highlight that this summary focuses on the potential net winners from the AV revolution. Several mass carmakers and auto suppliers will be net losers, because, while they do not benefit on the upside from rising AV sales, they will suffer from the AV-induced decline in new car sales. The more basic the content provided by the suppliers, the more negatively they are likely to be affected by a structurally declining car ownership rate in the decades ahead.

Previous flagship research published on the topic

Q-Series: Silicon for deep learning – a primer; If "data is the new oil", is AI the ..." – 4/2018

Back to School with MIT Part VI – 3/2018

Global autos: Feedback from UBS autos day at CES – 1/2018

Tech Coast Auto Panels Highlight AV & Ride-Sharing Opportunities – 11/2017

Q-Series: How disruptive will a mass adoption of robotaxis be? – 9/2017

Q-Series "UBS Evidence Lab electric car teardown: Will EV and ADAS add..." – 5/2017

Q-Series: UBS Evidence Lab Electric Car Teardown – Disruption Ahead? - 5/2017

Global Autos: Feedback from UBS autos day at CES – 1/2017

Tech Coast Panels Highlight AV & Big Data Opportunities – 11/2016

Q-Series: New era for auto tech – who wins and who loses? – 9/2016

Q-Series: Global Auto & Tech – how will big data revolutionize the auto industry? – 9/2016

Figure 7: Stocks impacted by the theme

	Positively/ negatively impacted?	P/E (2018E)	Price (lc)	UBS Analyst
Tech				
Alphabet	Positively	31x	1,048	Eric Sheridan
Infineon	Positively	23x	23	David Mulholland
Intel	Positively	13x	53	Timothy Arcuri
Nvidia	Positively	29x	239	Timothy Arcuri
Renesas	Positively	27x	1,063	Kenji Yasui
Rohm	Positively	23x	10,360	Shingo Hirata
STMicro	Positively	18x	19	David Mulholland
Texas Instruments	Positively	19x	105	Timothy Arcuri
TSMC	Positively	15x	224	Bill Lu
Yandex	Positively	29x	34	Ulyana Lenvalskaya
Auto OEM				
BMW	Positively	9x	92	Patrick Hummel
Chang'an	Positively	6x	10	Paul Gong
Daimler	Positively	7x	66	Patrick Hummel
FCA	Negatively	6x	19	Patrick Hummel
Ford	Positively	6x	11	Colin Langan
GM	Positively	5x	37	Colin Langan
Great Wall Motors	Positively	7x	8	Paul Gong
Honda	Neutrally	6x	3,619	Kohei Takahashi
Renault/Nissan	Positively	6x	89	David Lesne
PSA	Negatively	9x	20	David Lesne
SAIC Motor	Positively	10x	34	Paul Gong
Tesla	Positively	-59x	294	Colin Langan
Toyota	Neutrally	9x	7,201	Kohei Takahashi
VW	Positively	6x	173	Patrick Hummel
Auto suppliers				
Aptiv	Positively	17x	93	Colin Langan
Autoliv	Positively	20x	140	David Lesne
Continental	Positively	13x	227	David Lesne
Denso	Positively	14x	5,675	Kohei Takahashi
Hella	Positively	15x	53	Julian Radlinger
Magna	Neutrally	9x	60	Colin Langan
Schaeffler	Negatively	8x	13	Julian Radlinger
Valeo	Positively	15x	57	David Lesne
Visteon	Positively	19x	125	Colin Langan

Source: UBS estimates

Deep dive into the AV opportunity

We analyse in detail the various revenue pools directly related to AV, in order to determine the size of the pools, the attractiveness of the business, and who is best positioned to be a leader. We integrate the feedback from our interviews with 22 senior AV experts and executives into our analysis. We would like to thank all our interview partners for their valuable contributions.

We conducted interviews with 22 AV thought leaders

Figure 8: The UBS AV expert panel – our 22 interview partners

Americas
Anne Widera – founder and managing director at Tycho Partners, and former Waymo executive
Bryan Reimer – research scientist in the MIT AgeLab and associate director of The New England University Transportation Center
Dan Galves – senior VP, chief communications officer at Mobileye – an Intel company
Evangelos Simoudis – founder and managing director at Synapse Partners
Jason Doran – council member at GLG, and former senior strategy and operations manager at GM
Marco Pavone – assistant professor of Aeronautics & Astronautics at Stanford University
Sasha Ostojic – former senior vice president, engineering at Cruise Automation, Inc
Sertac Karaman – associate professor of Aeronautics & Astronautics at MIT
Seval Oz – former head of global strategic partnerships of Waymo
APAC
Zhang Kai – head of vehicle intelligence R&D institute at Great Wall Motor
Liang Fenghua – head of vehicle intelligence department at Chang'an Auto
Kiana Shi – former deputy general manager of the autonomous driving unit at Baidu
Shaoshan Liu – founder of PerceptIn and former Baidu senior architect
Baidu Apollo – discussion with executives at Apollo 2.5 version launch ceremony
A senior analyst in the autonomous driving department of a global OEM China unit, who prefers to stay anonymous
Tsuguo Nobe – director and chief advanced service architect at Intel
Naoki Suganuma – head of Kanazawa University's Autonomous Vehicle Research
Europe
BMW – answered via e-mail from the AV expert team
Dr Miklos Kiss – head of Pre-Development Driver Assistance Systems at Audi
Hans Adlkofer – vice president Automotive System Group at Infineon
Ralf Herrtwich – head of the HERE maps Automotive Business Group
Wilko Stark – vice president Daimler and Mercedes-Benz Cars Strategy, and head of CASE

Source: UBS

What is needed for an autonomous car?

UBS VIEW:

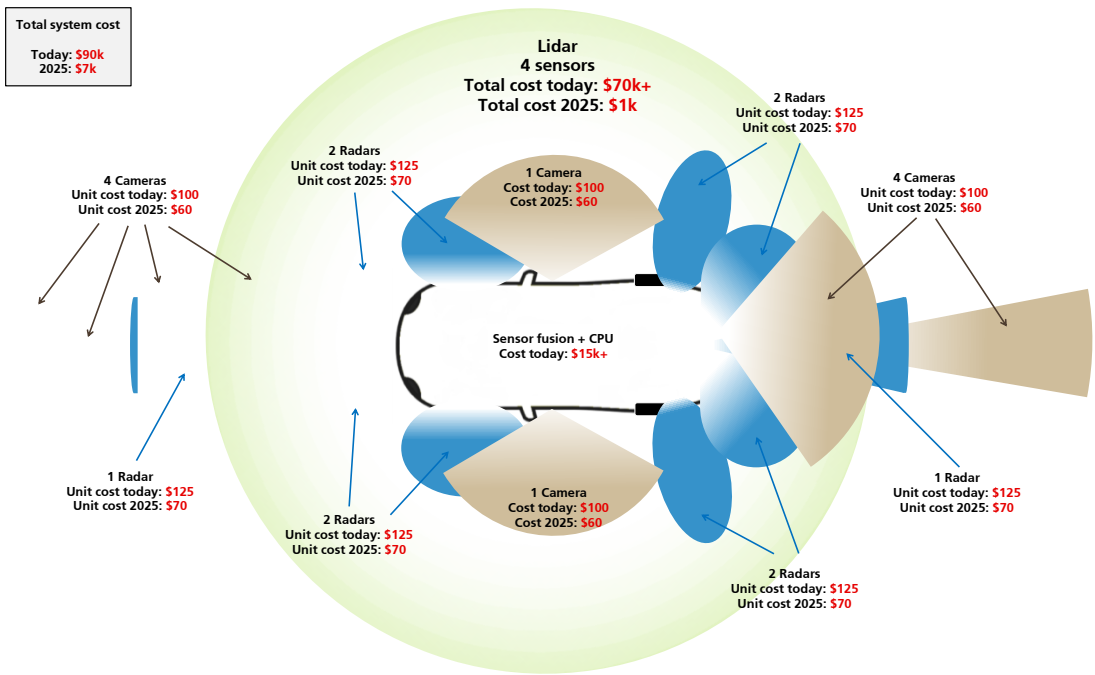
- **Lidar-based system likely prevails for the next 10 years**
- **<$10,000 AV system cost in 2025, versus $100,000 today**
- **Camera-only (and AI) AV system is cheaper, but has less redundancy. Regulators' approval could be an issue – potentially negative for Tesla**
- **V2X communication and 5G networks not a must**

The hardware part – all about sensors and computing power

The exhibits below give an overview of the required equipment and the estimated cost. A Level 4/5 autonomous car (high/full automation; for a detailed definition of the different levels of autonomy, see the appendix of this report) requires several sensors of the same type: we expect the prevailing sensor suite to include **up to 12 cameras, six lidars and six radars** (Waymo is using eight cameras, three lidars and five radars). Lidar is by far the most expensive sensor type at present. At the same time, it has the greatest cost reduction potential and we do not see lidar cost as an obstacle on the road to L5. Economies of scale will solve the cost issue, in our view. The experts we interviewed considered ~$250 per lidar unit as most realistic on a 2025 view, versus $100k today (four units will be required, ie, ~$1,000 in total). Further, a HD map is required for route planning, and to compare the positioning of the car with the sensor data. On top, there will be additional content in the interior of the AV, given the new use case (time spent in the car can be used to work, consume, interact, and so on), which is not included in this analysis.

AV hardware suite costs to decrease from ~$90k today to ~$7k in 2025, mainly driven by lidar

Figure 9: What hardware is required in an AV – lidar and HD map-based system (includes camera and radar as well)

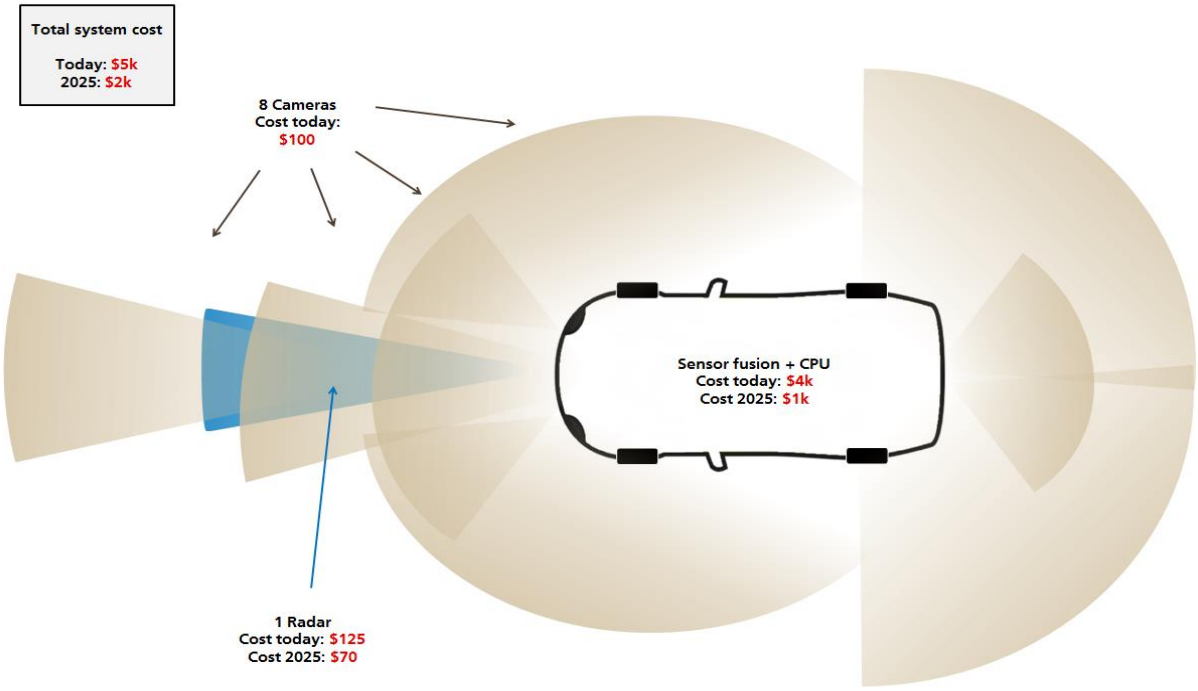


Source: Infineon, UBS. Note: Excludes ultrasonic sensors for near-distance object detection (parking) – a minor cost item. Green = lidar, blue = radar, brown = camera.

The alternative **camera-centric system, which Tesla is using, is based on eight cameras, one radar and 12 ultrasonic sensors.** For now, it only performs semi-autonomous driving tasks. We are concerned that Tesla's system may not gain the approval of regulators for the foreseeable future when it comes to L4/L5 driving, due to less redundancy. That said, it will be cheaper than the lidar-based system, also with a 2025 view. However, this cost difference hardly matters for a robotaxi business case. In the total cost of ownership (TCO) of a robotaxi, moderately higher sensor costs that are depreciated over the vehicle's life (three to five years) will hardly move the needle.

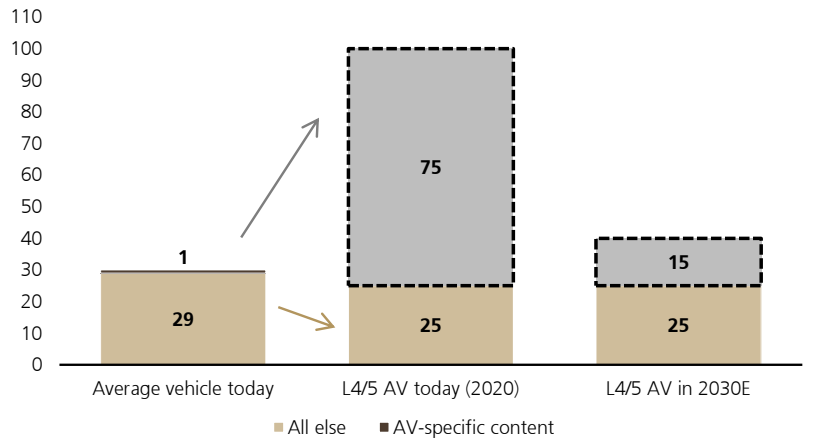
Alternative camera-centric approach is cheaper, but has less redundancy

Figure 10: What hardware is required in an AV – camera-centric system (Tesla autopilot 2.0)



Source: Tesla, UBS
Note: Excludes ultrasonic sensors for near-distance object detection (parking) – a minor cost item.

Figure 11: Price tag of a L4/L5 car in comparison ($ selling price)



Source: UBS estimates

Figure 12: Vehicle sensing technologies

Component	Description	Strengths	Weaknesses	ADAS applications
Radar	Using radio waves to detect moving or stationary objects (e.g. human body, cars) in all weather conditions, and provide direct measurement of distance and relative speed.	Highly capable in all weather conditions. Can be used to calculate relative velocity.	Difficult to classify objects due to low angle resolution. Reflections off multiple objects can lead to errors.	Active Cruise Control Emergency Brake Assist Forward Collision Warning Blind Spot Detection Lane Change Assist Rear Cross Traffic Alert
Lidar	Similar to radar, but based on laser light rather than radio waves.	High resolution, both horizontal + vertical. Good at classifying objects (width + height classification).	Highly affected by weather. Dirt significantly reduces performance.	Emergency Brake Assist – City Emergency Brake Assist – Urban Emergency Brake Assist – Pedestrian Crash Imminent Braking
Camera	Using a camera to build an image of the world around the vehicle, then using advanced algorithms to interpret the environment and the potential obstacles.	Can recognise environment and classify objects. Can be used to calculate sizes as well.	Less capable at higher distances. Needs high contrast and relies on model assumptions.	Intelligent Headlamp Control Lane Departure Warning Lane Keeping Support Traffic Sign Assist Forward Collision Warning Emergency Brake Assist Road Profile Estimation

Source: UBS

Multiple sensors of each type required – the number might go down in the long term

As we will discuss later, our experts had a range of comments as to what sensor content would be required, particularly when it comes to the number of each type of sensor. We believe that the number of sensors could go down in the long term as the performance of each sensor improves and as software gets better.

Figure 13: Sensors required for level 4/5

	Radar	Camera	Lidar
Google/Waymo	4	1	5
Intel	6	12	6
Uber	1	20	5
BMW	4	5	3
GM	21	14	5
Renault/Nissan	5	7	3
Toyota			8
VW	5	5	1
Aptiv	10	1	9

Source: Company information, UBS

Key takeaways from our expert interviews

Most experts believe lidar is a must-have for the foreseeable future

There is a fundamental debate between experts about the AV system layout. The 'Tesla camp' believes that cameras, combined with artificial intelligence (AI), are the most promising way, whereas the majority of experts we interviewed believe that lidar, combined with a HD map, is essential. A concern of several experts is that most regulators will not approve a L5 car that does not have three layers of redundancy in the system for safety reasons, which is why the lidar-based approach is likely to win over the next 5-10 years. Or, as one expert put it: "With a camera-based system, good luck on a foggy day". Another expert also highlights that Tesla's AV approach to training a deep learning neural network, based on footage with millions of miles and no crashes, is like feeding a "black box". Instead, a combination of heuristics ("if, then" programming rules) and AI as applied by the other OEMs gives clearer action rules. Tesla's strategy is widely seen as riskier. If it works, however, it would be a superior system from a cost perspective.

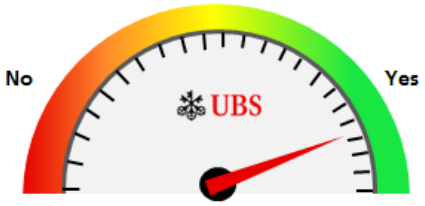
Most experts think that a lidar suite well below $1,000 is unlikely to materialise before 2025, because there is a trade-off between costs and better lidar performance (more rows) that will be required. Economies of scale and the move from rotating to solid state are seen as key cost drivers. One expert already believes that the bill of materials for one lidar scanner is only $100 today. Another expert thinks that the cost of lidar will drop faster than the algorithm will evolve for camera-based systems. "Once unit numbers are in the millions, prices will drop 80-90%." On average, our expert panel considers ~$10,000 for the entire sensor suite and the computer as realistic, versus ~$100,000 today.

Lidar cost could drop by as much as 90%

Most experts believe that AVs need to work independently from V2V/V2X communication, because the first movers will not be able to rely on it. While it is seen as a useful tool to gain information outside of the range of the vehicle sensors, it will take decades before one can rely on it (the car parc needs to be replaced over time). Therefore, it is not seen as a pre-requisite, except by one OEM. Related to that, the majority of experts consider 5G networks not to be a necessity for AV, even though some experts highlight that it will help the speed of communication. The reason is that only a limited data flow is needed between the cloud and the AV to perform the driving tasks.

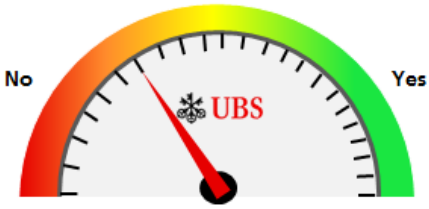
5G and V2X are not seen as must-haves – at least not initially

Figure 14: Expert panel – is lidar a pre-requisite?



Source: UBS AV expert interviews

Figure 15: Expert panel – is a 5G network a pre-requisite?



Source: UBS AV expert interviews

The software part – what kind of AI capability is required?

No AV without AI

With advancements in deep learning, algorithms now have the ability to take large sets of data and learn more like the human brain. This learning creates a positive feedback loop, whereby the more data available, the better the inferences that can be made, which ultimately leads to better outcomes. In theory, in the case of autonomous driving, this means improving safety, which should lead to increasing adoption (and, thereby, more data). Simply put, left to prior technology centered on rules-based algorithms, we would likely never achieve a world of fully autonomous vehicles.

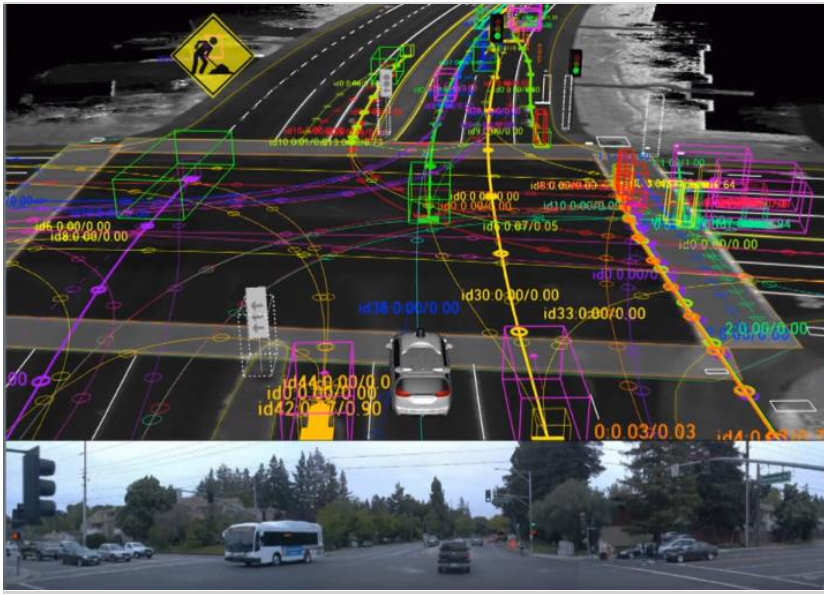
"For each road user, technology is able to make predictions about their movements in the future, just like a human would. Except that while a person may only be able to do this for a handful of objects in front of them, we can do this for literally hundreds of objects simultaneously all around us."

– John Krafcik, Waymo CEO

AI improves the quality of predictions about the trajectories of traffic participants

In the image below, the bottom portion is a camera view of the forward roadway (similar to what a human driver sees), and the top portion is what the autonomous vehicle sees. Via sensors and tracking, it can recognise every object around the vehicle and make predictions about the future. The more experience an AV system has, the better at making predictions it can get. This is the power of deep learning in an autonomous vehicle.

Figure 16: Deep learning allows for improving predictability of surroundings



Source: Waymo

As discussed above, there are two primary approaches in getting to L4/L5 autonomy: (1) camera centric, where the input source is an image upon which decisions are made; and (2) map based, which uses a reference map image and compares it with what is being picked up real-time by the car (typically using lidar). In the case of the camera-centric approach, this is more evolutionary from highway ADAS to full L5 over time, and is the primary approach being pursued by the likes of Tesla (initially via Mobileye). The map-based approach is geared to go directly to full L5 autonomy (because if you do not have a fully built-out reference map, you cannot drive at all), and is being pursued by the likes of Waymo and GM's Cruise Automation. Both of these approaches will require both training (likely in the data centre) and inference for the actual real-time on-board implementation.

What are the biggest and fastest-growing revenue pools, and when will the inflection point come?

UBS VIEW:

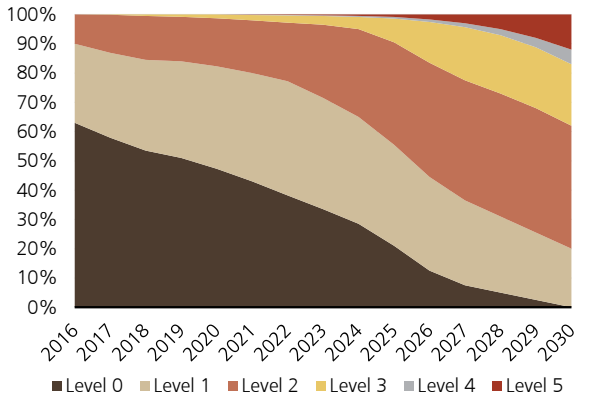
- **Large-scale adoption of L4/L5 AV to begin ~2026. Great uncertainty about timing of inflection point, but steep adoption curve thereafter, depending on regulatory environment**
- **We forecast a $1.3-2.8trn total AV net revenue pool in 2030, vs. ~$2trn total auto revenue pool today. After that, it will grow in multiples**
- **Robotaxi negative impact on new car sales ~5% in 2030E**

We expect AV (and thereby robotaxis) to take off in scale over 2025-30. In our base case, we expect 12% of all passenger cars sold in 2030 to be robotaxis, which implies 26m robotaxis on the road globally by then. We also forecast another 5m privately owned cars to be sold with L4 AV technology on board. While our estimates are on the high side of market expectations (which have come down after the most recent incidents involving test vehicles), we think that once one provider has proven that its technology is reliable and safe, AV penetration will likely take off rapidly in megacities around the globe. Nonetheless, based on our estimates, only 2% of passenger cars registered globally in 2030 will be AV. Therefore, our 2030 AV revenue pool estimates only show the 'tip of the iceberg', and AV-related revenue pools can still grow in multiples after 2030. However, the exact timing is hard to predict, which is why our interactive model enables the AV take-off year to be flexed.

Depending on the take-off year of AV, 12% of car sales could be robotaxis by as early as 2030

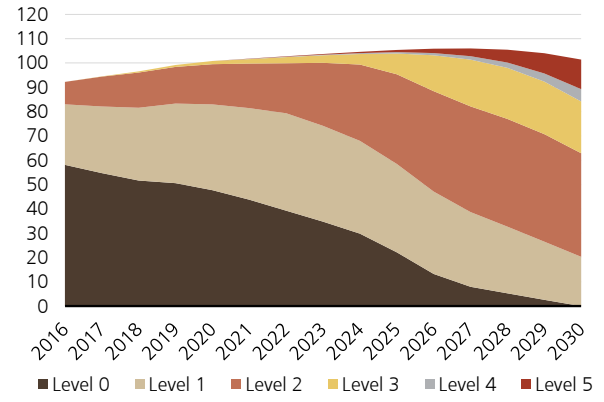
One important remark on the charts below: L5 stands for robotaxis. It is realistic to assume that many robotaxis on the road in 2030 will have to operate in geo-fenced areas for regulatory reasons (within city borders etc.). Under the SAE (Society of Automotive Engineers) definition, these cars would be considered L4 because they cannot go anywhere, any time. However, from a content or revenue pool opportunity, there is no difference between L4 and L5.

Figure 17: AV adoption curve by ADAS level – in % of global new car sales



Source: UBS estimates

Figure 18: Global new car sales (m units) – robotaxis likely to have moderate net negative impact starting in 10 years

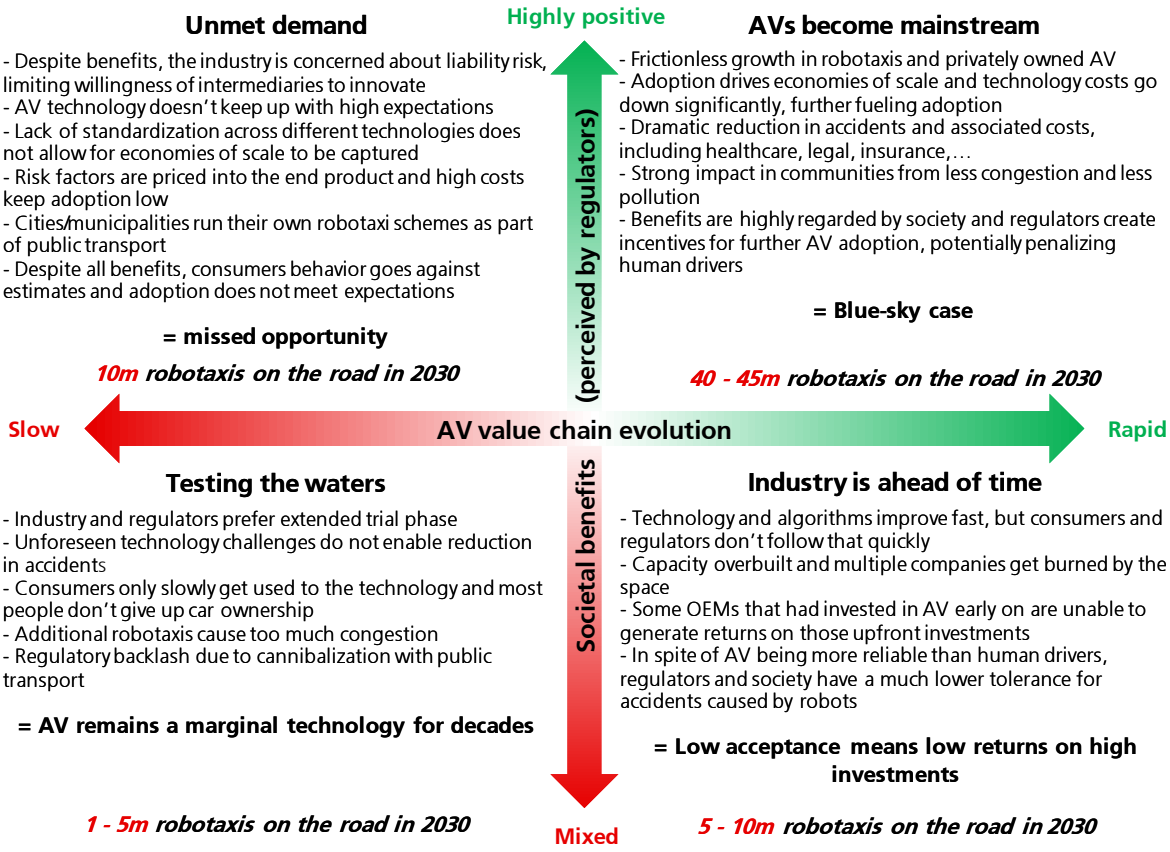


Source: UBS estimates

We see **two axes of uncertainty** in terms of AV penetration:

- **AV value chain evolution:** In this area, the uncertainty comes from the readiness of the technology itself (achieving cost and reliability milestones).
- **Societal benefits and disadvantages as perceived by regulators:** AV will disrupt the way we get from A to B, and therefore the impact in large cities will be significant. Regulators will have a key role in terms of how quickly AV penetration rises. This includes certification of AV, liability legislation, organizing the marketplace etc.

Figure 19: Axes of uncertainty – AV adoption



Source: UBS

What are the different scenarios and how do we derive the 2030 revenue pool estimates?

We have defined **four scenarios**, as described below. We apply **different AV take-off years** (ie, the time when large-scale adoption of robotaxis kicks in) for each of the scenarios as an input for our interactive model. The steepness of the adoption curve is not modified. Based on the **output from the interactive model**, we provide the **estimated number of robotaxis on the road in 2030** and the total **net revenue pool for each scenario** from the various parts of the AV value chain and ecosystem. The details about how we derive the respective revenue pool sizes are explained later in this report. We also highlight that with a **2030 view, the global AV market will most likely be limited to developed markets incl. China.** Other EM, where the cost of a driver is significantly lower and traffic situations more complex, are likely to follow later.

(1) Our **AVs become Mainstream** scenario, which factors in a take-off of robotaxis in scale already in 2024, results in 40-45m robotaxis on the road by 2030. The biggest AV bulls are in this range. 12% of all miles driven globally would already be in robotaxis, resulting in a net revenue opportunity of $2.8trn. This scenario, however, assumes that all stakeholders pull in the same direction with no setbacks on the technology/reliability side.

(2) In the **Testing the Waters** scenario, robotaxi fleets would take off in scale not until 2030, resulting in 1-5m units on the road, mostly in pilots. <1% of all miles driven would be autonomous. The net revenue opportunity would still be $1.3trn, because ADAS penetration rates keep still keep rising (positive for semiconductor and sensor sales) and the negative impact on new car sales would be more muted.

(3) The **Industry is ahead of Time** scenario factors reflects an AV adoption scenario that is slowed down by regulation and/or reluctant consumers. We assume a 2029 take-off year for robotaxis, resulting in ~5-10m robotaxis on the road in 2030. The corresponding revenue opportunity would be $1.4trn. It is worth highlighting that in this scenario, the return on AV related investments would be the lowest, meaning that the OEMs investing the most in own AV technology (GM, German premium OEMs) would be at a disadvantage compared to the OEMs not investing heavily.

(4) Finally, the **Unmet Demand** scenario depicts a society that is embracing innovation faster than the industry, which we would consider rather unlikely. Usually, technological innovations create demand rather than the other way round. In this scenario, ~10m robotaxis would be on the road in 2030, resulting in a $1.6trn total revenue pool.

Our base scenario assumes that technological readiness is achieved around 2025, and that regulators are generally supportive, albeit with significant regional differences. Therefore, our base case would be vertically in the middle and horizontally slightly to the right on the axes of uncertainty.

We see several critical areas that could cause delays in the AV adoption curve:

- Further casualties involving AV test vehicles could (rightly or wrongly) make regulators and consumers conclude that the technology will not be sufficiently safe for a long time to come (the tolerance for failure will be lower than for human drivers who cause thousands of casualties around the globe every day).

Accidents will happen, even if the technology becomes better than a human driver

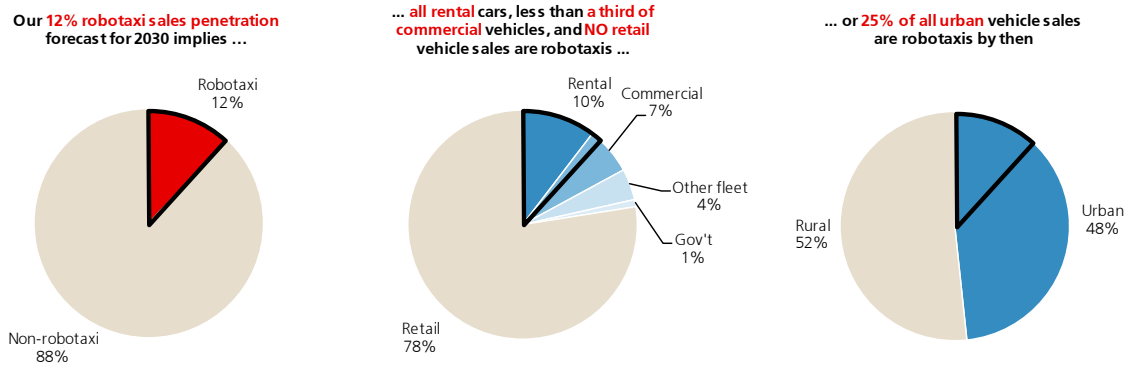
- AV (more specifically, robotaxis) could initially increase traffic and congestion rather than reduce it, in particular if not well integrated into public transport systems. Municipalities might therefore request extended trial periods.

More cars on the road rather than fewer?

- Over the past few years, the industry has failed to deliver on some very ambitious promises (in 2015, an L5 car by 2020 was considered realistic by some key players). Reaching the cost targets for AV hardware (lidar in particular) and getting the reliability of algorithms up to the required levels might take longer than we currently expect.

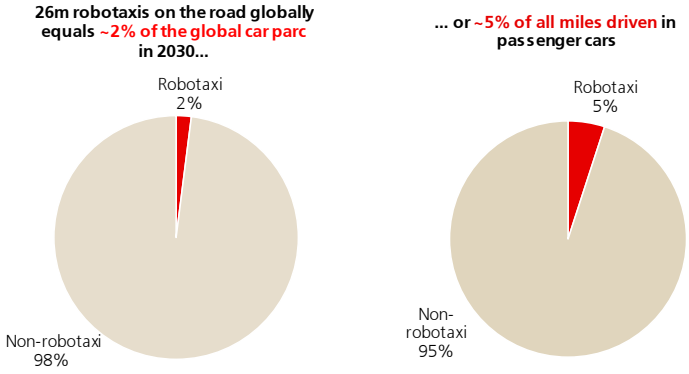
Over-promising, under-delivering?

Figure 20: Putting our 2030 base-case scenario into the context of global passenger car sales today…



Source: UBS

Figure 21: …and into the context of the 2030E global car fleet and miles driven

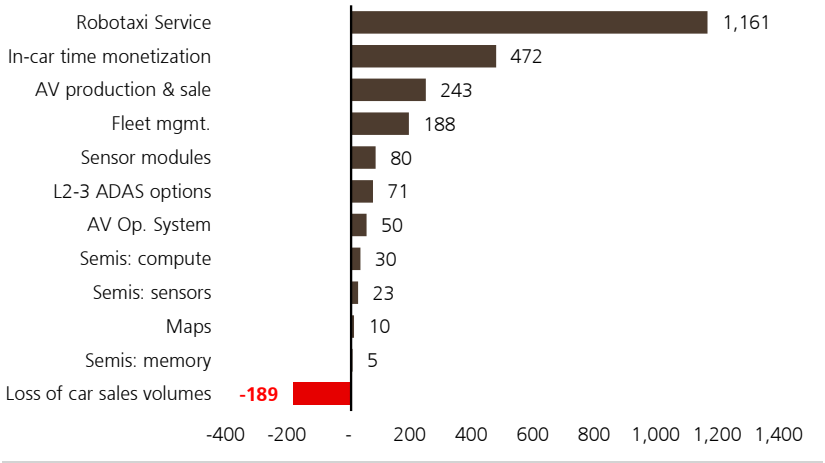


Source: UBS

On our base case, the 2030 total revenue pool in passenger cars and related services will be ~2x the size of the new car sales revenue pool today, even though 2030 just marks the beginning of the AV era. We think the incremental revenue and profit pools will be strongly skewed to very few parts of the AV ecosystem. We dig into the details later in this section. The figure below provides an overview of the AV revenue pools.

$2.1trn AV net revenue pool in 2030 is UBS base case

Figure 22: ADAS/AV revenue pools 2030E ($bn)



Source: UBS estimates

Robotaxis will be the biggest revenue pool, but not necessarily the most attractive

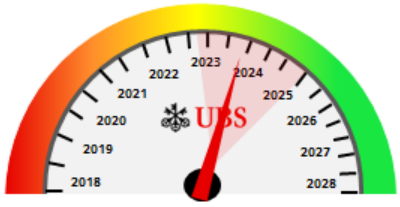
We see the robotaxi service business model as the largest AV-related revenue pool as early as 2030. Note that the revenue pool calculation is based on an exclusive use of a robotaxi, ie, it would be lower in shared robotaxis. From a strategic viewpoint, however, the center of gravity with most of the value-add, and therefore highest return potential, is likely to be the AV operating system. And linked to this, the monetisation of time in the car. In the meantime, semi-autonomous cars will be the main source of growth for technology providers (chip producers, auto suppliers and (premium) OEMs) over 2018-25. We expect 26 million robotaxis on the road in 2030, driving up to 1.3trn miles p.a. As robotaxis will most likely reduce car ownership rates in urban areas, we expect a ~5% net negative impact on global car sales by 2030, in spite of more miles being driven in passenger cars globally.

Key takeaways from our expert interviews

A key conclusion is that L5 at scale is further away than consensus thinks, but L4 wide-scale testing will happen in less than 5 years. Because, as one expert said, "if we don't have L4 by that point, the technology will simply not work". EVs are seen as the logical fit in a world of robotaxis, but "AV does not need EV", in the words of another. Depending on the region, government approvals/safety regulation could slow down L5 penetration. Experts highlight that L5 "is much easier to implement in suburbs vs. cities, but there is no business case in these areas". Once the technology is ready for more complex environments, L5 robotaxis are seen taking off in scale in 2026-29.

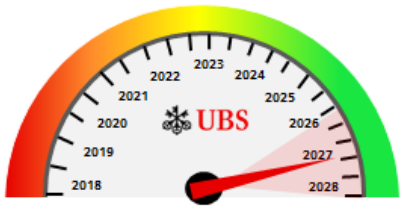
True L5 is >10 years out, but L4 also enables a viable robotaxi business case

Figure 23: When Level 4 cars will take off in scale – expert panel view



Source: UBS

Figure 24: When Level 5 robotaxis will take off in scale – expert panel view



Source: UBS

Who is in the race to be a leader in AV?

Five different types of player are in the race to develop a winning business model in a world of AV: Big Data, auto OEMs, ride-on-demand platforms, tech hardware players and auto suppliers. The strategic approaches within the technology stack range from a vertically integrated business model in a closed system (Waymo) to open platforms (eg, BMW/Intel or Baidu/Apollo) aiming at the highest possible economies of scale and cost-sharing. The positioning of the players is not static: the common theme at this point in the industry lifecycle is that whichever direction they are coming from, companies recognise the importance of trying to control their own destiny and hedging their bets. Therefore, we expect companies to grow into additional strategically important areas, be it organically, through partnerships or M&A.

Big data, OEMs, ride-on-demand platforms, semiconductor manufacturers and auto suppliers are in the game

Figure 25: Who is in the race to be a leader in AV, and who is doing what?

	Internet	Semiconductors		Ride on Demand			OEMs							Auto suppliers			
	Alphabet/ Waymo	Intel	Nvidia	Uber	Lyft	Didi	BMW	Daimler	Ford	GM	Renault/ Nissan	Toyota	VW	Aptiv	Autoliv	Conti	Valeo
Partnerships		BMW, GM	Audi, Daimler	Daimler	Ford	Toyota	FCA				Mitsubishi		Audi	BMW	Volvo	BMW	
OEMs		Ford, Renault	Tesla, Toyota	Toyota	GM	VW											
		Tesla, Volvo, …	Volvo, VW	Volvo													
Suppliers		Valeo, Aptiv	Bosch, Conti		Aptiv		Aptiv, Conti	Bosch				Aisin Seiki					
		Magna	ZF		Magna		Magna				Oktal	Denso					
Technology	Intel	Baidu, Waymo	Baidu, Aurora	Nvidia	Intel, Waymo		Intel	Baidu	Argo AI,	Cruise	DeNA	Amazon	Aurora	Baidu		Baidu	LeddarTech
		nuTonomy			nuTonomy			Nvidia	Baidu, Intel	Intel	Intel	Nvidia	Nvidia	Intel		Nvidia	Lero
Ride-hailing	Lyft	Lyft	Uber					Uber	Lyft	Lyft		Didi, Uber	Didi	Lyft			
Mobility Services																	
Subscription				+	+		+	+	+	+			+				
P2P ride sharing				+++	++	++		++	+			+					
Ride sharing							++	+++		+	+		+				
Ride- hailing	+			+++	+++	+++	++	++	+	+	+	++	+				
Multi-modal mobility				++			+	+++									
Total consolidated users	+			+++	++	+++	++	++	+	+	+	+	+				
DMV miles per disengagement '15 -'17	+++		+				++	+	+	+++	++			+			+
Maps	Google/ Waze	Here	Here/ TomTom	Google/ TomTom	Google	AutoNavi, in-house	Here/ TomTom	Here/ TomTom	Here	Here/ Cruise	TomTom	Here/ TomTom	Here/ TomTom	AutoNavi	TomTom (Zenuity)	Here	
AI operating system	In-house	Mobileye	>300 partners	In-house	In-house	In-house	In-house	In-house/ Bosch	Argo AI	Cruise Automation	In-house	TRI-AD	Aurora	In-house	Zenuity	In-house	In-house
Vehicle used (commercial or testing)	FCA Pacifica, Jaguar i-Pace	Ford Fusion	Lincoln MKZ	Volvo XC90	Ford Fusion, BMW 5-series	Qoros5 SUV	BMW iNext	Mercedes F015, EQ	Ford Fusion	Chevy Bolt	Renault Symbioz	Toyota concept-i	VW Cedric	BMW 5-series	Lincoln MKZ	CUbE	Mercedes C, VW Passat, …
Expected launch L3			2018				2021	2019			2020	2020		2018		2020	2018
L4/5	2018	2021	2021	2019	2021	2022	2021	2022	2021	2019	>2022	>2022	>2022	2020	2021	>2022	2020
Number of sensors																	
LiDAR	5	6		5			3			5	3	8	1	9			
Radar	4	6		1			4			21	5		5	10			
Camera	1	12		20			5			14	7		5	1			

Source: Company data, UBS

Semiconductors

UBS VIEW:

- **Significant increase in semiconductor content, along with the shift to electric vehicles, particularly on the sensor side near-term as the penetration of L2/L3 cars will rise rapidly**
- **Semiconductors in sensors (~$615 per AV): Infineon the biggest beneficiary, followed by STMicro and Texas Instruments**
- **Compute content (~$1,000 per AV): Intel and Nvidia the biggest beneficiaries, but less priced-in for Intel**
- **Memory (~$290 per AV): Limited impact in the context of the global memory market**

There are essentially three key areas of content opportunity from a semiconductor perspective: **sensor** content to provide the eyes and ears of the car, **compute** content to provide the brains and **memory** content to store information and put it into context. Below we examine each of these areas, outlining the size of the content opportunity and identifying which companies we see as best positioned.

What's the semiconductor opportunity in sensors?

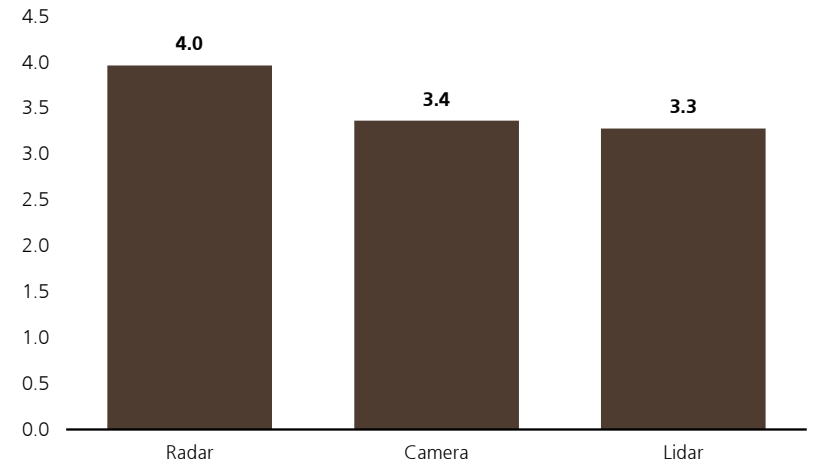
$615 semi content for sensors

Looking ahead to 2030, Infineon estimates that the total semiconductor content in a Level 4/5 vehicle could be as much as $860 (ADAS content – not the full vehicle). We believe Infineon has a good view of the opportunity on the **content side for the sensor technologies ($615)**, but that Intel and Nvidia might be a better read on the compute side, which we discuss below.

While the semiconductor value is significantly higher today (in low volume), we estimate that in mass production, and in order to achieve the level of penetration that we expect L4/L5 vehicles to achieve, the semiconductor content of a radar module by 2030 will need to come down to around $25 (roughly split 50:50 between a 32-bit microcontroller and the radar sensor chip itself), a camera module to $25 and a lidar module to below $200. Using our 17% base-case estimate for the penetration of L4/L5 vehicles by 2030 (17.2m vehicles), this equates to a revenue opportunity on the sensor side of $10.6bn in 2030 – a significant opportunity in the context of the ~$34bn size of the autos semiconductor market currently, and this is before even considering the compute requirements or the memory content.

Given the pace of change in the semiconductor market, we do not attempt to say who will be the leading provider of these sensor technologies by 2030, and indeed there are significant variations in how many of each sensor content will be needed. However, we see **Infineon** as well positioned, given its leadership position in radar and also investments in lidar, but would expect the trend to be beneficial to most sensing-exposed analog semiconductor companies that have been investing in the space.

Figure 26: Relative value in AV (L4/5) sensors ($bn, 2030)



Source: UBS estimates

How much compute capacity is required?

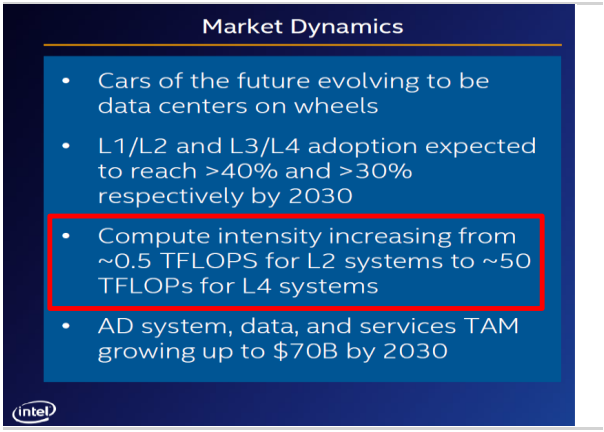
Superprocessors for neural network model

The compute capacity required for a successful autonomous vehicle is determined by the needs of the neural network model used to identify objects in the vehicle's surroundings (for a primer on compute and infrastructure for deep learning, see our April 2018 Q-Series *Silicon for Deep Learning*). The neural network model is deployed in the car on a supercomputer that processes images captured by cameras and sensors to determine the identity of objects that the car will drive towards or avoid.

Autonomous vehicle platform leaders think 50 to 100 "TOPS" of computing power will be required for Level 5 autonomy

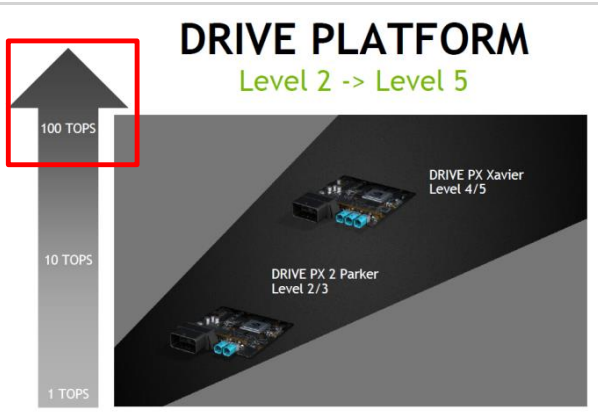
Identifying hundreds of objects in real time with human-like accuracy requires an extraordinary amount of computing power – 50 to 100 deep learning inference tera-operations per second ("DLTOPS" or just "TOPS"), according to Intel and Nvidia (see Figures 27 and 28). Latency matters here: at 60 mph, a car must identify objects 88 feet away in well under one second, then re-compute its trajectory and, if necessary, change course. The greater the number of objects in a car's environment, such as in urban areas, the greater the number of computations required.

Figure 27: Intel thinks approximately 50 TOPS of processing power are required for Level 4 autonomy



Source: Intel 2017

Figure 28: Nvidia roadmap for Level 5 autonomy suggests 100 TOPS required



Source: Nvidia 2017

Nvidia and Intel's upcoming products suggest 320 TOPS and 24 TOPS respectively, albeit at significantly different power budgets. While Nvidia's solution exceeds the computing threshold alluded to by both companies, an extremely high power budget (500W) hinders its commercial viability. Both Intel and Nvidia also have products in the 24-30 TOPS range, not enough for Level 4/5 autonomy, but with significantly lower power budgets. We can see a clear path to 50 TOPS by 2020 from currently, given benefits of further shrink and design optimisation over the next several years.

Nvidia and Intel's roadmaps show a clear path to 50-100 TOPS, the assumed threshold computing power for Level 4/5 autonomy, by 2020

Figure 29: Currently available autonomous driving platforms

	NVIDIA DRIVE Pegasus	NVIDIA DRIVE Xavier	Intel EyeQ5
TOPS	320	30	24
Power	500W	30W	10W
# of Accelerators	4 Volta GPUs	1 Volta GPU	2 EyeQ SoCs
Process	12nm	12nm	7nm
# of CPU SoCs	16x Custom ARM Cores	8x Customer ARM Cores	8-core Intel Atom
1st Silicon/Sample	3rd Quarter 2018	Now	3rd Quarter 2018

Source: Company reports

How much money could be made selling compute capacity?

Much development work is still being done regarding the amount of compute capacity that will be required for a fully autonomous L4/L5 vehicle. This will depend on numerous factors (sensor system design, architecture, how much compute is done locally at the sensor) that we cannot quantify today. The algorithms are also likely to become more efficient over time, as machine learning becomes more refined and establishes defined rules for what happens in certain circumstances, reducing the 'live' on-the-road compute required in a vehicle.

Despite this uncertainty, some key participants have already said what they think the compute content will be for an L4/L5 autonomous vehicle. Nvidia, for instance, estimated in 2017 that an L4/L5 vehicle will present it with an opportunity of $1,000 per vehicle.

Figure 30: Nvidia AI car opportunity by 2025

	TAM	$ Opportunity	Per vehicle
Self-Driving Cars AI L4/L5	5 million vehicles	$5 billion	$1,000
Self-Driving Cars AI L2+/L3	15 million vehicles	$2 billion	$133
AI Co-Pilot	5 million vehicles	$1 billion	$200

Source: Nvidia company presentation

~$1,000 compute content

We estimate that by **2030 the compute content required for L4/L5 will likely be around $1,000 per AV**. However, this is open to significant debate, considering the Nvidia figure of $1,000 content, while others, such as Infineon, see compute content (which it defines as "sensor fusion") closer to $200 per car.

What memory content is required?

We project autonomous driving (L5) to create demand for ~92 exabytes (EB) of memory by 2030. This works out to a 2030 TAM of ~$3.8bn, or ~$315 of memory content per vehicle.

We use Nvidia's DRIVE platform as an example of the kind of DRAM trends that are likely to emerge. With one Volta GPU on board, DRIVE Xavier likely supports a maximum 16GB of DRAM. Nvidia's next-generation Pegasus platform will likely support a maximum of 64GB of DRAM. Micron Technology has indicated that it expects on average ~18GB-24GB/vehicle of DRAM, and ~1TB/vehicle of NAND by 2021. We also triangulate with INTC comments that ~4TB of data will be generated per vehicle per day. So we think a reasonable starting point for our 2021 estimates works out at around ~24GB DRAM and 1TB NAND per vehicle. Conservatively, we are assuming that most of the stored data is overwritten on a daily basis.

Memory content is only ~$290 per AV

In our projections beyond 2021, we assume the data generated by a vehicle grows exponentially, of which ~25% is stored in the vehicle. Factoring in the increasing penetration of autonomous vehicles (102k/12.2MM units for 2021/30), we get to ~92 EB of memory by 2030. To put this in context, we expect memory demand for 2018 to be ~280 EB. Assuming 15% Y/Y ASP declines for both DRAM and NAND, we see an incremental TAM of ~$3.8bn by 2030. This works out at **~$290 of memory per vehicle by 2030**.

That said, a decade is a long time in the semiconductor industry and we caveat our projections by noting that we have used DRAM as a proxy for volatile memory and NAND as a proxy for non-volatile memory, as the roadmaps for DRAM and NAND more than a decade out into the future are largely unknown, given the technology-scaling challenges. From a DRAM standpoint, Samsung, Hynix and Micron will likely be the major beneficiaries. On NAND, Samsung, Hynix, Micron, Toshiba and Western Digital could potentially benefit from incremental demand.

Figure 31: Estimated per-vehicle memory content

	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Data Assumptions													
Data Generated/Vehicle (GB)	1,500	1,772	2,128	3,180	4,916	7,599	9,787	11,753	14,114	16,948	20,353	24,441	29,350
Growth rate	1%	18%	20%	49%	55%	55%	29%	20%	20%	20%	20%	20%	20%
Data Stored %	20%	20%	20%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
Data Stored/vehicle (GB)	300	354	426	795	1,229	1,900	2,447	2,938	3,528	4,237	5,088	6,110	7,337
DRAM (GB)				24	37	57	74	89	107	128	154	184	222
NAND (GB)				1,000	1,192	1,842	2,373	2,850	3,422	4,109	4,935	5,926	7,116
Autonomous Vehicle Assumptions (L5)													
Global Car sales (MM)	96.6	99.2	100.8	101.8	102.8	103.7	104.6	105.4	105.9	106.0	105.5	104.0	101.4
Growth Rate		3%	2%	1%	1%	1%	1%	1%	0%	0%	0%	-1%	-2%
Autonomous Driving Penetration (L5)				0.10%	0.17%	0.29%	0.49%	0.84%	1.70%	3.00%	5.00%	8.00%	12.00 %
Number of AVs (L5) (K)				102	175	300	514	880	1,800	3,180	5,274	8,323	12,172
Autonomous Driving (L5) Memory Demand													
DRAM (MM GB)				2	6	17	38	78	192	407	810	1,535	2,697
NAND (MM GB)				102	206	552	1,219	2,508	6,159	13,067	26,025	49,319	86,614

ASP	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
DRAM ($/GB)		4.80	4.08	3.47	2.95	2.51	2.13	1.81	1.54	1.31	1.11	0.94	0.80
NAND ($/GB)		0.14	0.11	0.09	0.09	0.06	0.05	0.04	0.03	0.03	0.02	0.02	0.02
Industry Revenue Impact													
DRAM Revenue ($MM)				8	19	43	81	141	295	532	901	1,451	2,166
NAND Revenue ($MM)				10	23	35	63	107	215	374	611	949	1,367
Total Memory Revenue ($MM)				**18**	**42**	**78**	**144**	**248**	**510**	**906**	**1,511**	**2,400**	**3,533**
Memory Content Per Vehicle ($)				**177**	**241**	**260**	**281**	**282**	**283**	**285**	**287**	**288**	**290**

Source: UBS estimates, Intel, Nvidia, UBS estimates

In **China**, there are several start-up companies making chips for autonomous vehicle use. The best-known player is Horizon Robotics (unlisted). Founded by several former Baidu senior R&D engineers, the company focuses on chip and embedded artificial intelligence solutions used in industrial applications and autonomous vehicles. Currently the company has cooperation agreements with Chang'an Auto, Bosch and Audi. Another start-up company with similar products is Eyemore (unlisted), which has also launched a graphics processing chip for a camera-based autonomous driving solution. Today these Chinese companies are still small compared to global leaders, but their access to abundant venture capital and strong government support might be a growth booster going forward.

Maps

UBS VIEW:

- **High investment to ultimately arrive at the same point (full HD coverage); limited scope for differentiation**
- **HD maps won't replace extensive testing in a specific city before a robotaxi provider can offer a commercial service**
- **Owning a map asset is not a competitive edge**

There are open map platforms and closed systems. The open system approach means better economies of scale, while a closed system can, for a certain period, provide a competitive edge. High-definition (HD) maps can also be used in L3 ADAS systems for privately owned vehicles, which is an opportunity for HERE, TomTom and others mentioned below. Ultimately, we expect the mapping landscape to be highly concentrated due to high fixed costs and limited scope for differentiation.

- **Open map solutions:** HERE is the biggest provider of automotive-grade maps, followed by TomTom and OpenStreetMap. We note other players with a less global footprint, like DeepMap or Civil Maps. In Asia, the main map providers are NavInfo (Tencent), AutoNavi (Alibaba) and Zenrin (in Japan).
- **Closed solutions:** Waymo and Uber are key examples of players that use their own maps internally only for autonomous driving. Although Tesla uses different map providers, we believe it develops some proprietary layers. GM has acquired Cruise Automation in order to develop its own map platform, but may be limited in terms of coverage (limited to certain areas).

Mapping – the move to real time and HD

Mapping and associated services are strategically important; 3D/HD maps improve accuracy

We believe mapping and associated services are strategically important for a variety of reasons, as evidenced by the volume of M&A deals in the sub-sector. Data collection is a scale game: the more users on board, the better the product. While traditional 2D maps have been on the market for many years, 3D or HD maps improve accuracy, with cloud-source data and sensors giving more information about the surrounding of the vehicle and enabling it to identify additional features such as roadside barriers and construction areas. This places additional layers on top of maps, leading to an absolute accuracy of 5m and a relative accuracy of 20cm at a distance of 100m, according to HERE (1m and 15cm respectively, according to TomTom).

One of the central discussions given the importance of scale is the standardisation and business models for HD map-making. Intuitively, the best solution would be that all maps are shared with all OEMs so that vehicles can update maps frequently. However, it would then become more like a public service and hard to establish as a profitable line of business. We believe that Toyota declined to invest in HERE because: (1) it believes maps should be shared with all OEMs, not some; (2) HERE's business model has yet to be proven, has operated barely above break-even and is likely to need further investment; and (3) mapping is the technology that OEMs should outsource, given the scale benefits of socialised information.

Figure 32: Highly automated driving requirement and descriptions

Requirement	Examples
Highly detailed	3D lane geometry, markings, centre lines, road boundaries
Highly accurate	<0.5 m longitudinal & <0.15m lateral accuracy
Attributed	Lane level attributes, speed restrictions, divider markings, position landmarks
Tolerant	Ability to adapt to changes in reality or map version
Scalable	Low storage, low processing

Source: UBS, TomTom

Real-time mapping is driven by crowd-sourcing, with users supplying more information about the surrounding area and live traffic, aspects that are critical for the autonomous driving world. To improve maps, there are also different service layers that can be added on top, and we believe this can explain the M&A trend in the industry. As shown below, Apple and Google have been active on this front, with several acquisitions in recent years (Uber also bought the deCarta start-up to improve logistics).

What are the different approaches for precise location?

Looking at the map-making process, we can distinguish between two different camps:

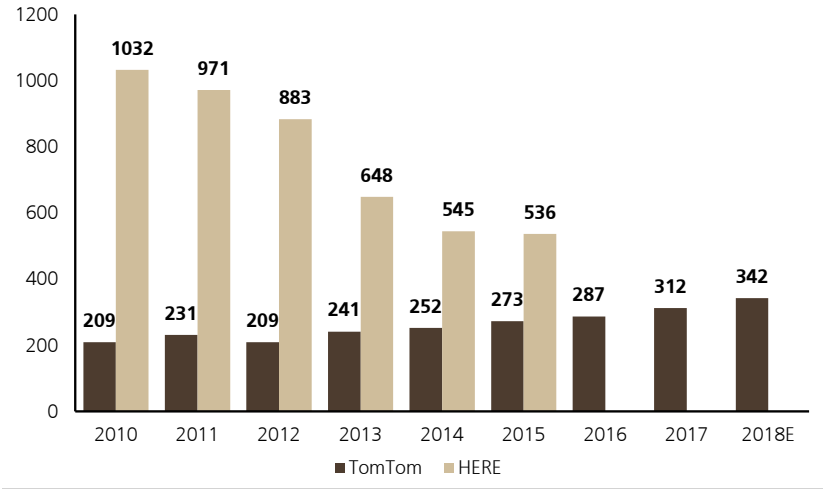
- **HERE:** The HERE Live Roads layer aggregates real-time sensor data (identifying details like road signs or bridges) and compares it with images captured by HERE vehicles.
- **TomTom/Alphabet:** This correlates real-time data collected by the vehicle and the HD map created by TomTom/Alphabet without identifying individual objects, and then calculates the location accurately.

What are the competitive threats?

While the disruptive map-making process risk offers opportunities to new entrants, we believe investments made by companies such as Uber/Apple are focused on placing additional service layers on top of the map to improve their service and to differentiate their offering. Given the expertise of long-term map makers (TomTom/HERE and Alphabet) and the substantial investments they have made over the years (see figure below), we expect these companies to remain the dominant providers of maps on a global scale.

We expect long-term map makers (TomTom/HERE and Alphabet) to remain the dominant global providers, given their expertise and investment

Figure 33: Gross R&D (including capitalised R&D, €m)



Source: Company data, UBS

TomTom and HERE are not the only players in the map industry. Google bought Waze in June 2013, mainly to improve its real-time traffic data, along with other small companies. Crowd-sourced data is crucial for live traffic/maps and the size of the user base will be key to differentiation. It is difficult to assess the quality of maps, but we believe it differs from one region to another. This said, looking at information available on user numbers, countries available or reviews on app stores like iTunes and Google Play, we believe that TomTom and Google have the best traffic solution given the number of users (>450m for TomTom, mainly due to its strategic customer, Apple, which we believe has more than 500m installed-base users). With regard to the maps themselves, Waze, followed by Google and HERE, received the best reviews on the app stores, which we believe is consistent with the investment made. While many people think Google Maps and Waze are the same since the acquisition of Waze by Google in 2013, both are working independently, and Waze maps are based on three sources: community volunteers, municipal sources and smartphone data.

Figure 34: Data by map provider (standard maps)

	Users (m)	Km (m)	Countries	Cars	mean iTunes/ Android stars	Users/ country (m)	Cars/ country (m)
TomTom	>450	47	135	<100	3.5	>3	<1.3
HERE	NA	50	196	400	4.3	<1	>2
Google	>1000	NA	160	NA	4.5	>6	>2
Waze	>50	NA	32	0	4.5	>2	0

Source: Company data, UBS estimates

Figure 35: HD maps – HERE seems to be ahead

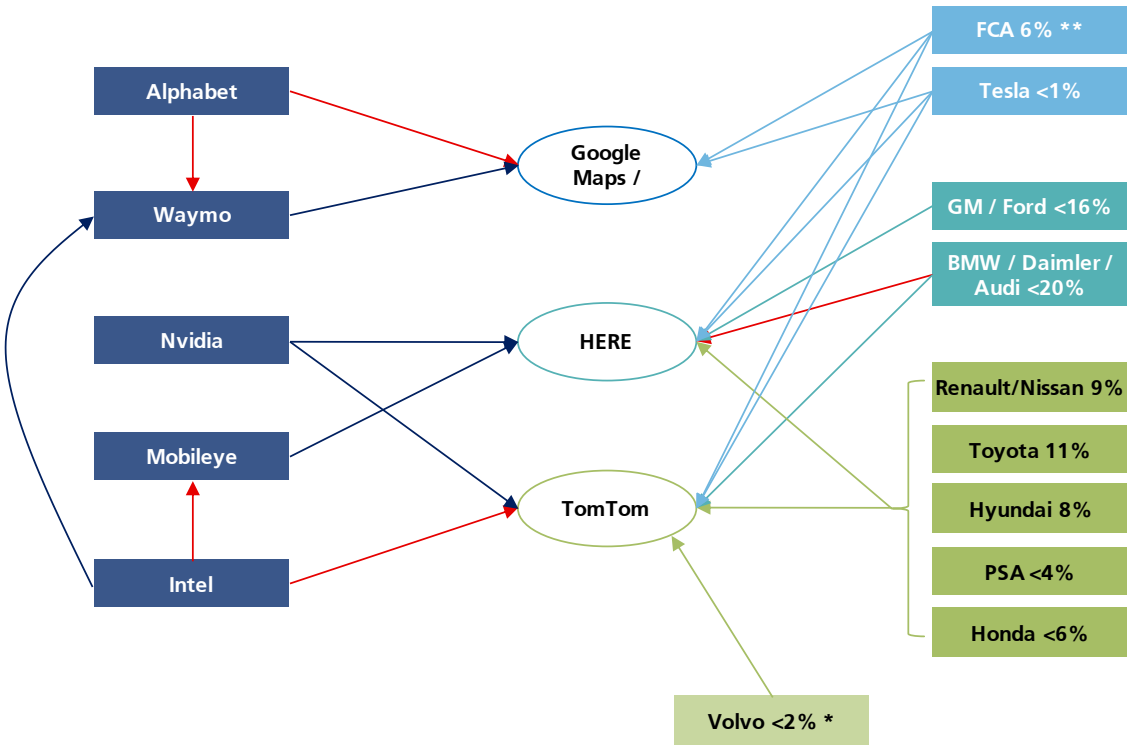
HD maps	Coverage	Locations	Commercialisation
HERE	>555,555km	North America and western Europe, Asia	BMW, Mercedes
TomTom	>380,000km	Europe, US and Japan	NA

Source: Company data, UBS estimates

UBS view: We expect HERE, Google and TomTom to be the main providers of maps and traffic information as in-dash navigation penetration moves structurally towards 100%. TomTom is the last remaining independent supplier, which we believe will enable it to generate interest from major consumer players and car OEMs (as evidenced by recent deals like Volvo in 2016 or an undisclosed US car maker in 2017), but we expect HERE will remain the leader in the space, driven by

its strong footprint. We show below the market size potential to in-dash navigation penetration and map ASPs.

Figure 36: Mapping partnerships and commercial agreements (red line indicates shareholding)



Source: UBS estimates, Company data, *From 2019, ** % represents unit sales market share 2016

We list below the other partnerships that we believe are relevant.

Figure 37: Other key partnerships

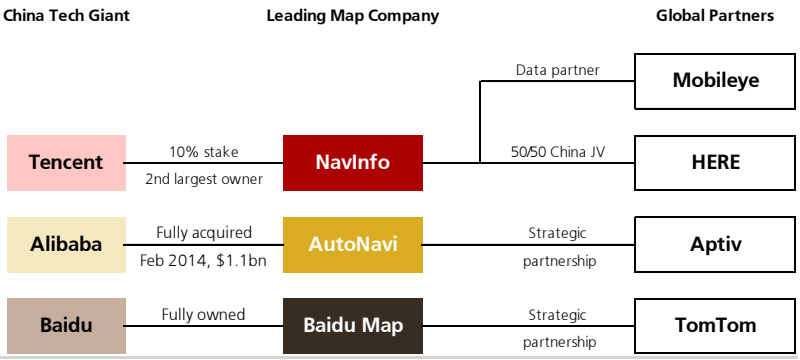
TomTom	HERE	TomTom and HERE
Apple	Continental*	Baidu
Qualcomm	DJI*	Bosch*
Uber	Pioneer*	Microsoft

Source: Company data, UBS estimates
* Stake in HERE.

We expect a few map service giants to emerge in **China** along the way to AV, given regulations that prevent foreign entities from carrying out map-related business. We've identified the three largest and best-funded map companies in China – namely **NavInfo** (002405.SZ, 10% owned by **Tencent**), **AutoNavi** (a fully owned subsidiary of Alibaba) and **Baidu Map** (a fully owned subsidiary of Baidu) – due to their map service licenses, long history in the industry, large client/user base, and sufficient financial backing from tech giants.

AutoNavi and Baidu Map, as fully-owned units under Alibaba and Baidu respectively, primarily face individual users as a loop in each of the tech giants' ecosystems, with a large active user base.

Figure 38: Chinese AV map players

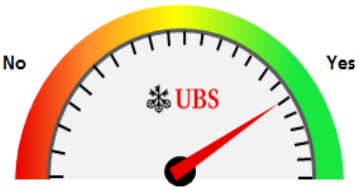


Source: Company data, UBS

Key takeaways from our expert interviews

Most experts we interviewed believe that HD maps will be essential for L4/L5 cars, at least for the foreseeable future. However, differentiation will be difficult long-term; or, as one expert put it, everybody is investing a lot to ultimately arrive at the same point. In the very long term, AV might not even require automotive-grade HD maps any more for positioning. This seems decades away, however. Experts said: "Waymo and Cruise are only operating in areas where they have their own HD maps". "HD maps are an expanded horizon for better decision-making". "A good HD map can dramatically reduce expensive sensors". "With a camera-based approach, the map doesn't have to be as detailed." However, our experts also think that having HD maps available off the shelf from a map provider "will not replace extensive testing in a specific city for the AI feed before sending robotaxis on the road". "Creating HD maps via cloud/getting information from cars on the ground is likely to become mainstream in the future." "Having dynamic data could prove an edge, but not the map itself". Also, only some OEMs will need HD maps for Level 3 highway driving, which is a limited return for the map companies. Others are directly moving to L4/L5, which requires more granular maps for cities rather than highways. There could eventually be four mapping systems, but "no player other than Google will use its own maps." The ownership of HERE by the German OEMs is not seen as a competitive edge by any of our experts.

Figure 39: Are HD maps a pre-requisite for AV? Expert panel view



Source: UBS

Figure 40: Will there be one dominant map provider? Expert panel view

Source: UBS

Figure 41: Will owning a map be a competitive advantage for OEMs? Expert panel view

Source: UBS

Sensor modules

UBS VIEW:

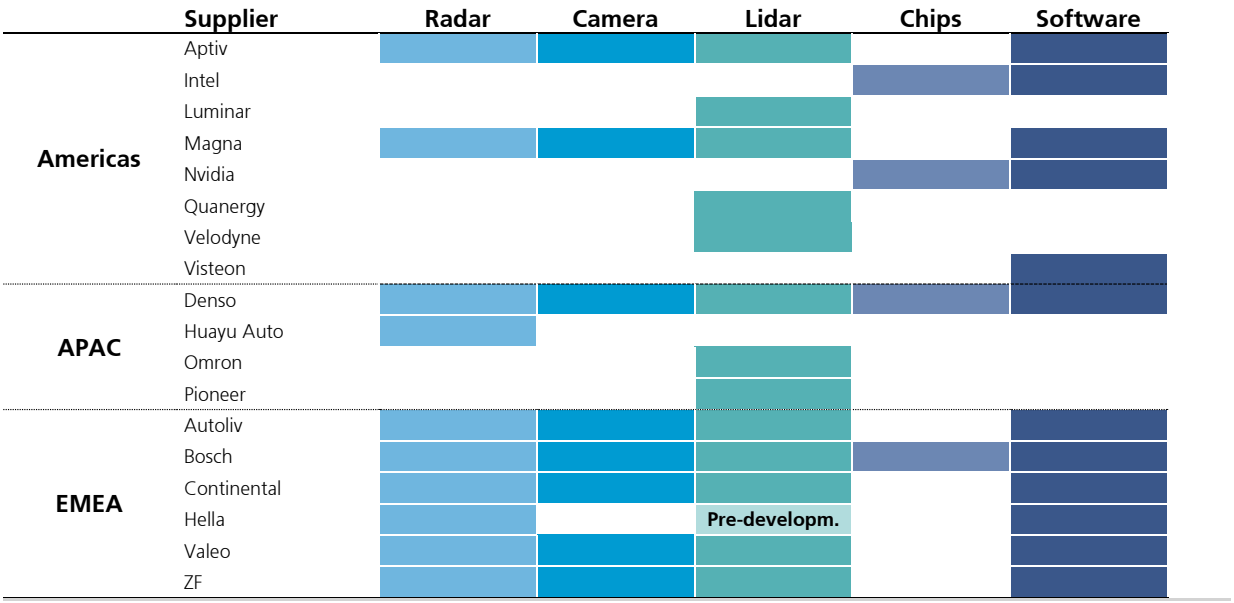
- **Lidar and software for sensors are the areas of differentiation, while radar, cameras and ultrasonic are more at risk of being commoditised**
- **The number of sensors in an AV will go up in multiples, but then go down again long term as the technology matures**
- **Aptiv looks best positioned, followed by Conti, Denso and Valeo. Returns are likely to be highest in lidar, but overall sensor returns are unlikely to be above group-average returns, given high R&D**

Strong growth ahead, but intense competition likely; lidar could be an area of differentiation

The sensor market is, to a large degree, split between the traditional auto suppliers and semiconductor players. Only in camera systems (Mobileye) and lidar (Velodyne) have non-traditional players taken a leading role. Given the rapid growth of the sensor market, we expect players from the electronics industry to make inroads, too. For example, Samsung has entered the race to AVs, working on its own sensor suite and AV platform. The large traditional auto suppliers like Conti, Aptiv and Bosch are also working on integrated solutions, whereas several other suppliers are focused on the production of specific sensors, leaving the sensor fusion to the OEM. High investments and the risk of commoditisation will likely limit the return potential for these players. Lidar stands out positively as a sensor type with high potential for technological differentiation and early-mover advantage, in our view.

Figure 42 shows the key players in the sensor market and their areas of focus.

Figure 42: Key suppliers of AV sensor modules



Source: Company data, UBS

Other lidar suppliers include: TetraVue, Oryx Vision, SteraVision, Xenomati, Benewake, Trilumina, Luminar, Phantom Intelligence, Leddar Tech, Ibeo

System integration/AV operating platform

UBS VIEW:

- **The strategically most important asset, with the potential to expand into other lucrative businesses, such as in-car time monetisation and robotaxi fleet management**
- **Waymo clearly most advanced; ride-on-demand players lagging behind**
- **Only few auto OEMs and suppliers will be able to follow, but with high duplicative investments required**

Does Waymo take it all (outside China)?

We expect Google/Waymo to pursue a dominant role as a provider of the AV "brain" or operating system, similar to Android in the smartphone market. The AV operating system (responsible for (1) perception, (2) behaviour prediction and (3) planning) will be woven into the overall user experience, which would help Google to monetise the time spent in the car. Specifically, this could take the form of a logged-in user on the Google platform (i.e. log into your Google account to get into the car) with default Google apps/in-car monetisation (YouTube, Google Maps, local advertising opportunities, etc.). For others, this could be in the form of partnerships with media/advertising companies.

OEMs pay a high price of not letting Waymo in their AVs

The leading established OEMs, i.e. the biggest volume carmakers and the premium OEMs including Tesla, are working on their own AV platforms. Some players are acquiring the software know-how (for example, VW-Aurora). The other carmakers, which have neither the in-house know-how nor the financial resources, will likely buy the AV 'package' from suppliers or jump on the bandwagon of existing OEM-supplier partnerships. As the smaller mass carmakers do not have to be among the AV leaders (their customers will be late adopters, also due to the high cost of the AV system), these OEMs will need an AV solution only when it is already in the process of being commoditised.

We see Aptiv as the most advanced auto supplier

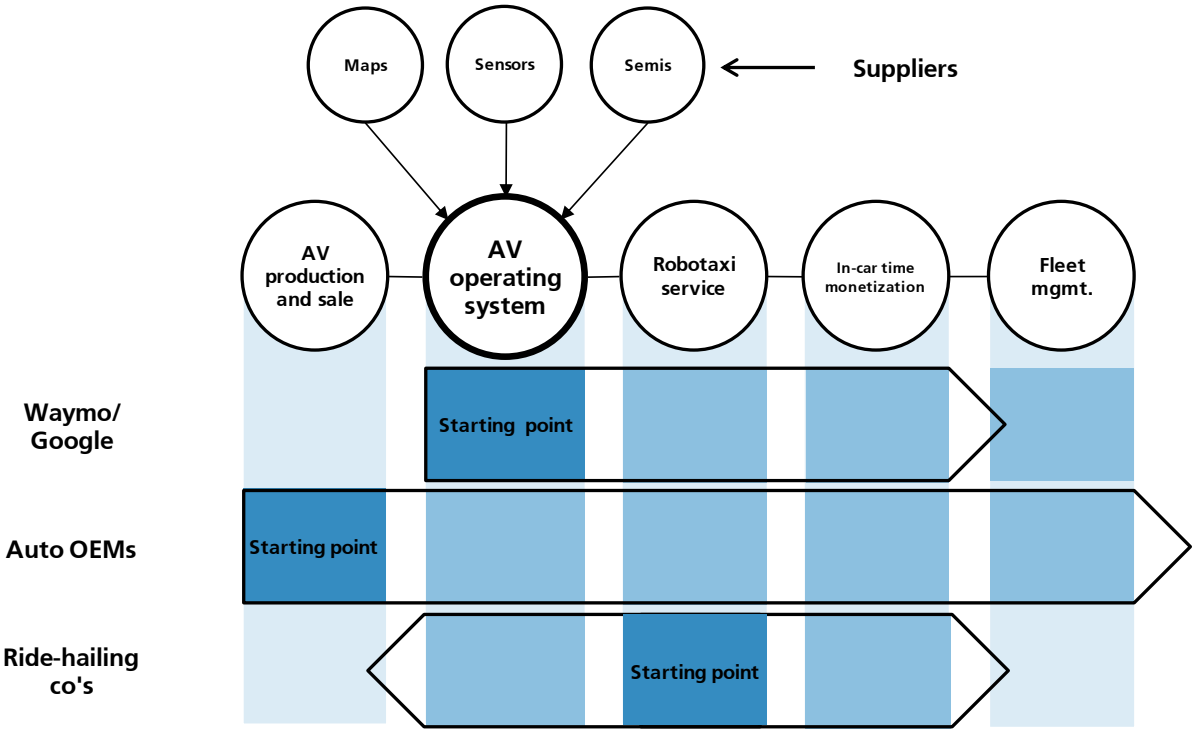
Among the tier-1 auto suppliers, Aptiv (thanks to Nutonomy) is widely seen as the most advanced by the experts we interviewed. Conti and Bosch are followers.

Uber is the only RoD player working on its AV system, but is lagging the leaders

Ride-on-demand players are also relevant in this context: Uber is working on its own AV platform, even though some of our experts think the company could pull out of the plan. This is partly because of the recent fatal accident during a test drive in Arizona, but also because Uber appears to be lagging well behind the leaders. According to the New York Times, Uber has logged 2m miles of test drives in the US nationwide. In China, Baidu's "Apollo" platform, which is licensed by several local OEMs, appears set to become the default AV operating platform solution in the country. It is an open platform, but OEMs need to get customisation from Baidu for the commercial use of Apollo. In Russia, Yandex introduced its self-driving taxi prototype in May 2017 (see details here), and since then tested autopilots in the snowy Moscow streets in November 2017 (link) and February 2018 (link). Yandex builds the software needed for its AV prototypes (tested currently on the Toyota Prius and Kia Soul platforms) using internally-developed technologies (see here for an article on Yandex's approach to AV design). The company leverages its experience in machine learning, computer vision and maps/navigation to create and integrate all the core systems necessary for AV functioning. Moreover, as part of its deal with Uber, Yandex gained access to Uber's technologies in AV design, which should help it to accelerate the implementation of its AV strategy. Although Yandex is still only testing its self-driving taxis, we believe that in the medium term the company has potential to

launch the technology commercially. If that happens, we think the Yandex.Taxi business should benefit meaningfully. Certain ride-on-demand platforms have placed greater focus on partnerships and open sourcing self-driving platforms. As such, we believe Lyft could be one of the first players to utilise the Waymo AV operating system. Alphabet recently led a $1bn financing round that brought Lyft's valuation to $11bn.

Figure 43: AV operating system – who is in the game?



Source: UBS

Being a leader in AV system integration is a differentiator for the next 10 years or so, and will determine the timeline by which an L5 car can be launched. Early movers (Waymo, Aptiv, premium OEMs) will likely have a competitive advantage, in our view. Scale will matter a lot, and only few players globally will monetise the AV platform. In fact, the monetisation will most likely happen predominantly indirectly, rather than through the licensing of the operating system. Google/Waymo is by far the best positioned to benefit, in our view. Premium OEMs are likely to require OEM partners to share development costs and gain critical mass. Meanwhile, Waymo is expanding its own robotaxi pilots: On top of the deal with FCA for the supply of the Chrysler Pacifica, the company announced a contract with Jaguar for 20,000 I-Pace all-electric SUVs to be built in the first two years of production. The first Waymo self-driving I-Pace will start tests in 2018, and become part of Waymo's driverless fleet from 2020. Further, press reports have indicated this agreement runs through 2026.

Leaders will have a true competitive advantage to expand into other attractive AV revenue pools

What can we learn from Google's strategy in the smartphone market? Google is selling its own smartphone, the Pixel, with somewhat limited commercial success. Yet Alphabet owns 85% of the smartphone operating system (OS) market through Android. Alphabet provides Android to the smartphone OEMs for free. The value-add for Alphabet is billions of logged-in users, enabling it to leverage scale to better monetise advertising. Could Alphabet/Waymo give away the OS for free? We think this is unlikely in the near term, for several reasons: (1) Waymo has a competitive edge not just in its AV algorithms but also in the hardware stack – this know-how can therefore be monetised through selling the full AV stack (including the back-end) to the auto OEMs; (2) Alphabet/Waymo could further integrate its own robotaxi service, and could capitalise on its first-mover advantage; (3) at least initially, Alphabet could charge licensing fees from OEMs, because those without their own AV know-how will ultimately need to buy a turn-key solution, and competing auto suppliers like Aptiv would also likely charge the OEMs. That said, we acknowledge there is a compelling argument to be made that Alphabet could afford to give away its technology for free as a way to gain significant share and monetise the operating system, as it did with Android.

Could Google provide the OS for free? Unlikely in the near-term, we think

Who is technologically most advanced on the road to L5?

Waymo has focused on L4/L5 from the very beginning, and is seen as most advanced by the vast majority of the experts we interviewed. The table below summarises the milestones achieved and the targets of the key players. If the leaders stick to their timelines, we should see the launch of L4 AVs from Waymo, Aptiv, GM, Tesla and Uber over the next two years.

Waymo is seen as most advanced; we should see L4 AVs from Waymo, Aptiv, GM, Tesla and Uber over the next two years

Figure 44: AV timelines at a glance

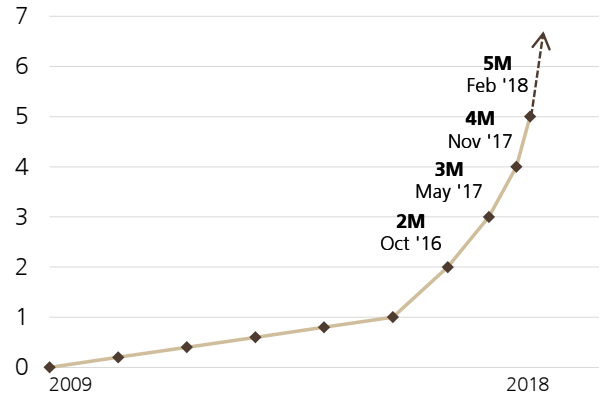
Company	2018	2019	2020	2021	≥2022
Aptiv	Level 3		Level 4		
Audi	Level 3		Level 4		Level 5
Autoliv	Level 2			Level 4*	
Baidu		Level 3		Level 4**	
BMW	Level 2			Level 3/4	Level 5
Bosch	Level 2	Level 3		Level 4	Level 5
Chang'an			Level 3		Level 4
Continental	Level 2			Level 3/4	Level 5
Daimler	Level 2	Level 3		Level 4	Level 5
Didi					Level 5
FAW Group				Level 4	
FCA				Level 3/4	
Ford	Level 2	Skip level 3 →		Level 4	
GAC		Level 3			Level 5
Geely			Level 3		Level 5
GM	Level 2	Level 4			
GWM			Level 3		Level 5
Honda	Level 2		Level 3		Level 4
Hyundai			Level 3	Level 4	
Intel				Level 4	Level 5
Jaguar	Level 2			Level 4	Level 5
Lyft				Level 4	
Nvidia	Level 3			Level 4	
PSA	Level 2		Level 3		
Renault/Nissan	Level 2		Level 3		Level 5
SAIC		Level 3			
Samsung					Level 5
Subaru	Level 2		Level 3		Level 4
Tesla	Level 2	Level 4			
Toyota	Level 2		Level 3		Level 4
Uber		Level 4			
Valeo	Level 3			Level 4	
Volvo	Level 2	Skip level 3 →	Level 4		
VW	Level 2			Level 4	Level 5
Waymo	Level 4/5				

Source: Company data, UBS
* Autoliv: Together with Geely and Zenuity; ** Baidu's Apollo programme has more than 90 partnerships.

The number of autonomous miles driven is a key indicator…

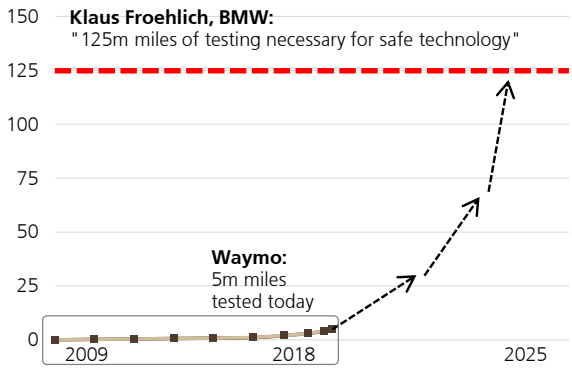
A key indicator of the progress being made is the data of the California Department of Motor Vehicles (DMV), which collects the number of autonomous miles driven by company, and also publishes the number of human interventions. On this metric, Waymo is by far the leader in terms of autonomous miles driven (5 million miles as at February 2018), and also in terms of miles without human intervention. On top of that is the number of virtual miles driven through simulation. Again, Waymo leads with more than 5bn simulated miles – 2.7bn miles in 2017 alone. This is equivalent to 25,000 cars driving 24/7. However, many more real-world miles are required: BMW's CTO Klaus Froehlich thinks that 125m miles need to be driven to achieve a safe enough AV operating system.

Figure 45: Waymo miles (m) …



Source: California DMV, UBS

Figure 46: … and what's required

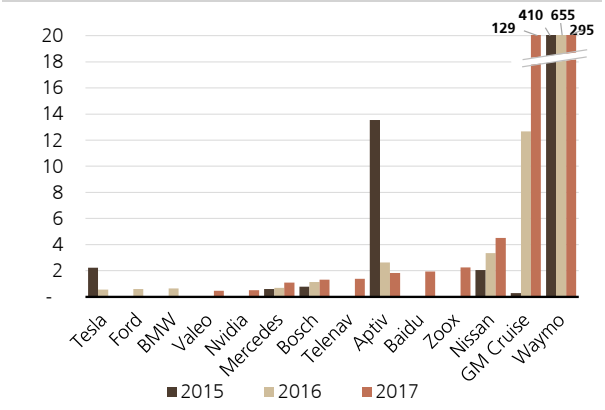


Source: BMW, UBS

However, the DMV data do not show the full picture: (1) only those players testing in California are included; (2) given the good weather most of the year, the picture in California is not representative of states with more rain, snow in winter, etc; (3) the number of human interventions is heavily dependent on the challenges that the AV needs to solve. For the time being, Waymo is driving its test miles outside the big cities in less complex traffic situations. Also, as one expert in the interviews we conducted highlighted, one needs to push the boundaries for the AV to improve the technology, which results in more human interventions during testing.

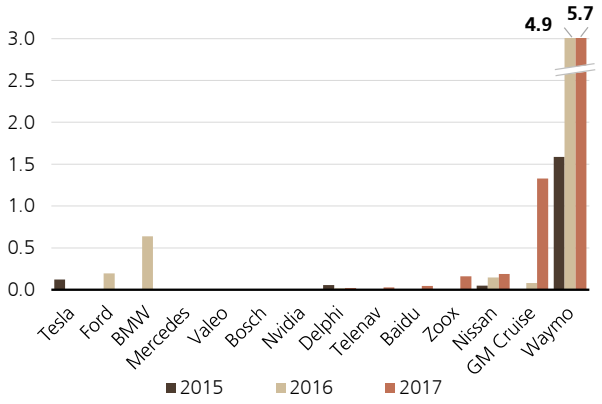
…but there are some caveats

Figure 47: Autonomous miles driven in California ('000s)



Source: California DMV, UBS

Figure 48: Autonomous miles per disengagement ('000s)



Source: California DMV, UBS

Is Tesla a leader or a laggard? In the California DMV statistics above, Tesla does not play a meaningful role. However, Tesla is far more advanced in gathering data from all the cars it has sold so far. Tesla has more than 300,000 vehicles on the road that have driven about 6bn miles on our estimates (conservatively assuming 20,000 miles per vehicle to date) – even more than Waymo's simulated miles. Out of the ~6bn total miles driven, possibly ~10% have been driven with the (semi-autonomous) autopilot function switched on. To our understanding, it makes no difference to Tesla whether the autopilot was actually engaged when it comes to data collection. It is clear that a lot of data is duplicative "waste" of simple highway cruising. Nonetheless, since all vehicles are equipped with the full range of cameras, Tesla owns the most comprehensive set of camera data globally. Because of that, Tesla would most likely be in the pole position should the camera-

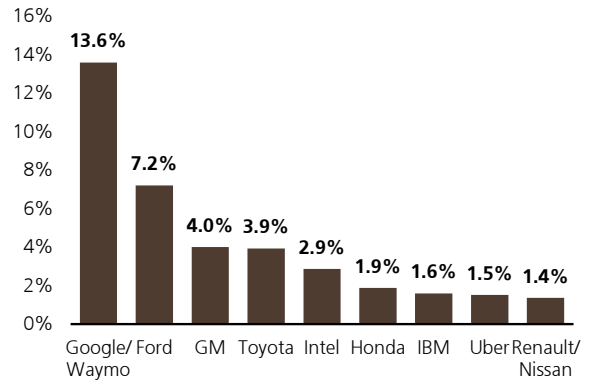
No other player has as much camera footage as Tesla, but what is it worth if regulators require lidar and HD map redundancy?

based AV system prevail. However, this is not our base case for the next 5-10 years. Other OEMs have been slow to install ADAS sensors as a standard feature in their vehicles – a strategy that could well change as the value of data collection is increasing the closer we get to the AV inflection point.

Another indication of AV technology know-how is the worldwide AV patent filings, shown below based on an analysis from the Cologne Institute for Economic Research. Additionally, UBS Evidence Lab has run an analysis of the US patent database. We would see the data only as pieces of a mosaic, because not every innovation is filed as a patent. And the possession of AV driving data as a key asset is not correlated with the number of patents filed.

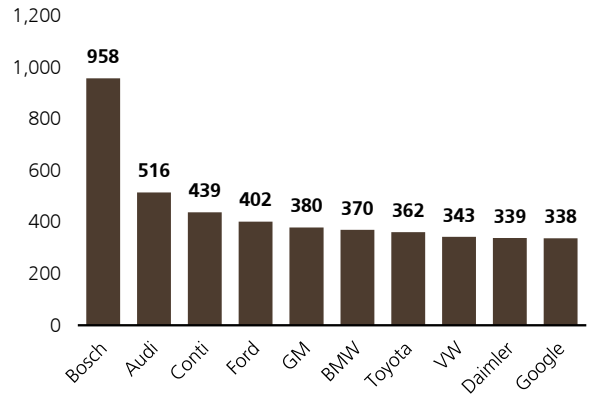
Another indication of AV technology know-how is the worldwide AV patent filings

Figure 49: Autonomous driving patents filed in the US



Source: UBS Evidence Lab
Note: Data based on patent filings with "autonomous vehicles" in the description.

Figure 50: AV worldwide patent filings (2010 – July 2017)



Source: IW Cologne, UBS

Key takeaways from our expert interviews

The vast majority of the experts we interviewed consider Waymo the most advanced player in terms of L4/L5 technology. Our panel of experts agrees that Waymo will focus on selling the AV operating system and monetise the time spent in the AV, rather than running a robotaxi service by itself. Medium term, most OEMs that are not able to develop an in-house solution are likely to be the buyers of a turnkey solution. Smaller OEMs "may have no choice but to purchase the Waymo system". Tesla is an exception, because "it is learning from data at a rate far higher than others. Tesla has the most low-definition, information whereas Waymo has the most HD information".

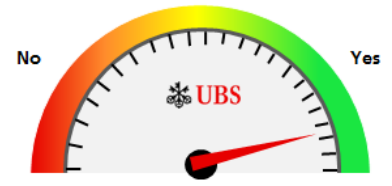
Waymo is widely seen as the leader by our experts

Among traditional auto suppliers, Aptiv was highlighted as the most advanced player with the best know-how in AV system integration, mainly thanks to the acquisition of Nutonomy. Conti, Bosch and Magna are also seen well-positioned, but behind Aptiv. Magna is seen as a potential AV producer (white label), given its in-house assembly capabilities. On the software side, Aurora is seen as a strong partner that can help OEMs to close the gap in software capabilities to the tech players (Volkswagen and Hyundai have partnered with Aurora). For OEMs, this might turn out to be a better way forward than buying the Waymo solution, because Waymo wants to own the AV "from end to end".

Several experts highlighted that L4/L5 is a "completely different thing" from the current L2/L3 systems offered by OEMs, so know-how in "L2/L3 does not provide a relevant edge for L5".

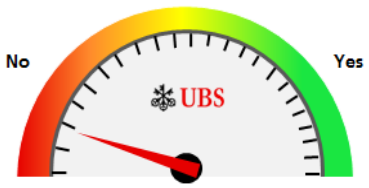
Know-how in "L2/L3 does not provide a relevant edge for L5"

Figure 51: Expert panel view: Waymo is leading in AV operating systems



Source: UBS

Figure 52: Expert panel view: Tesla is among the leaders in AV



Source: UBS

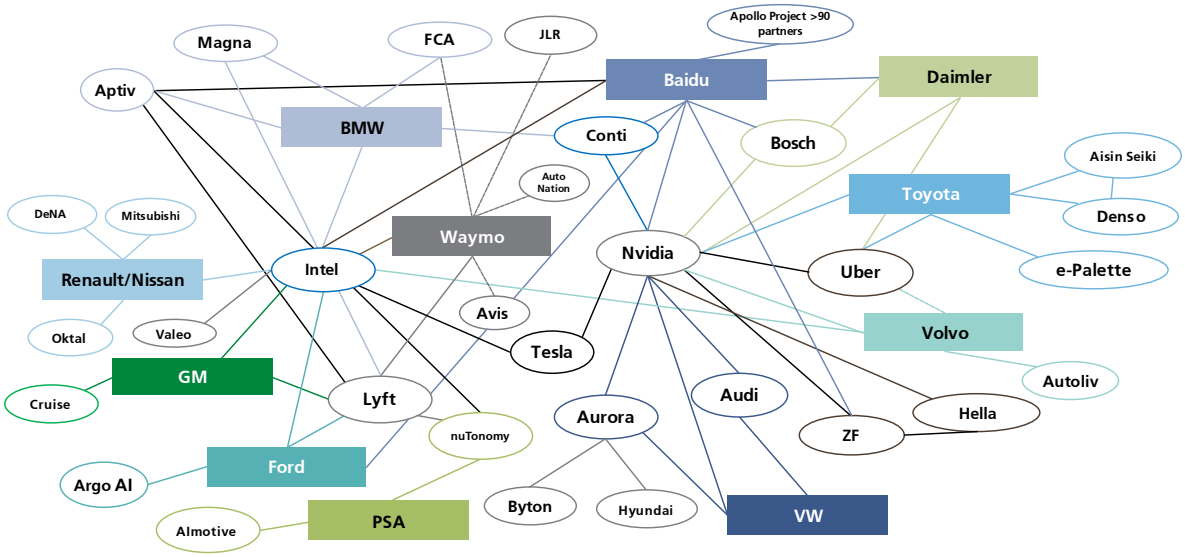
Figure 53: Expert panel view: GM is closest behind Waymo

Source: UBS

Partnerships: What's the rationale and who is working with whom?

AV partnerships range from simple supply relationships, to joint AV platform developments, minority stakes in ride-on-demand, and AV/AI start-ups by large OEMs and/or auto suppliers. The following map provides an overview of where we are. Some players like Waymo and Uber (for now) prefer to work on their AV platform on an exclusive basis, whereas others put more focus on sharing development work and economies of scale. The BMW/Intel platform is the most prominent example of the latter approach. We see the OEMs collaborating in strong partnerships as having an advantage over their competitors, because it will be near-impossible for any OEM to replicate the integrated Waymo approach – not least because of the time and financial resources it would take. From an OEM perspective, partnerships are an efficient way to reduce the cost of not letting Google/Waymo in the car, in a technology that will not be a differentiator for them in the long term. This is particularly relevant for the premium OEMs, which are about ~20% of the size of the leading volume carmakers.

Figure 54: Who has AV technology partnerships with whom in AV?



Source: Company data, UBS
Note: Dotted line indicates simple supplier relationship.

Producing and selling autonomous cars

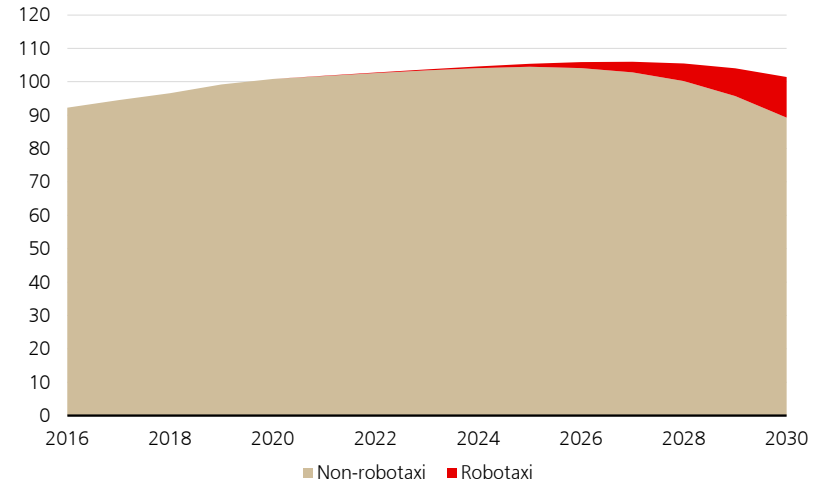
UBS VIEW:

- **A net revenue opportunity for premium OEMs and very few mass OEMs**
- **'Foxconn' business model not attractive for most auto OEMs, except for Chinese low-cost players**
- **Suppliers like Magna could become meaningful robotaxi assemblers**

AV production remains the domain of the auto OEMs

AV production remains the domain of the auto OEMs. Even Waymo stopped putting its own cars on the road, and purchased the Chrysler Pacifica and most recently the Jaguar i-Pace instead. Returns in AV production are too low for tech companies, entry barriers should not be underestimated, and the value-add for an AV happens elsewhere. Tesla's ramp-up issues have underscored that car production is not a trivial matter. Because OEMs enjoy the economies of scale and synergies with their existing business model, an AV assembly start-up would most likely not be cost-competitive.

Figure 55: Trend in global car production – new car sales to drop by ~5% due to robotaxis replacing privately owned cars in urban areas (m units)



Source: UBS

What is the value proposition for AV production and sales?

White-label robotaxi assembly is likely only attractive for a very few cost-leading (Chinese) OEMs

- **L5 'mass-transit' robotaxis – a Foxconn-type business model:** L4/L5 robotaxis are likely to be sold in large quantities to big fleet operators, implying a high bargaining power for the buyer. The robotaxi is most likely going to be a fairly basic vehicle, and the name of the producer might not even be visible for the user. We think only a very few OEMs should pursue that route, because margins are likely to be low, and only the lowest-cost mass OEMs seem well positioned to compete in this business. Naturally, we would see **Chinese OEMs or global OEMs with a low-cost EM production footprint as potential players in this business.** Some European, Japanese, Korean and Indian producers have experience in producing budget cars in EM at low cost. While volumes could be large for these players, we think the loss of brand equity (and the lost volume in privately owned cars on top) makes it a business case that will only work for less than a handful of players long-term. The absence of brand equity and growing demand for white-label robotaxis could lure

suppliers like Magna, who already today assemble niche models for OEMs. The partnership between Lyft and Magna could be a first step in this direction.

Premium OEMs look better positioned

- **L4/L5 luxury robotaxis – premium OEMs seem well positioned:** Only in the high-end robotaxi market is differentiation still possible, in our view. High-end interiors, particularly comfortable seats, and more innovative tech features could be ~5% of the total robotaxi market, similar to limousine services today. Premium OEMs will be able to capitalise on their in-house AV know-how and their brand equity, and the level of competition will likely be less intense.
- **L3/L4 cars sold to consumers.** Selling the AV to the 'traditional' car buyer, i.e. a L3/L4 highly automated car that still has a steering wheel when the owner wants to take over, is less disruptive for OEMs and an opportunity for the premium OEMs. For as long as L4 cars have not become mainstream, selling the functionality as an option package could be very profitable for OEMs.

Figure 56: Between a Foxconn-type business model and differentiated brand – how OEMs could position themselves

Ownership type		Volumes (unit sales)	
		Low	High
	Owned	Premium L4/5 AV sales (high margins) partially offset by lower volumes	Non-AV mass market vehicles Shrinking market
	Shared (Robotaxi)	Premium robotaxi service (high margins)	White-labelling for mass market robotaxi services (low margins)

Source: UBS

Why are premium OEMs in better shape than most mass OEMs?

We see premium OEMs as significantly better positioned than mass carmakers:

- The propensity to own a privately owned vehicle is likely to remain significantly higher in the premium segment, because the cost per mile argument is not that relevant for high-income households.
- Premium OEMs have more AV technological know-how than most mass OEMs, giving them an early-mover edge when it comes to launching own robotaxis.
- Selling L3/4 packages will be a profitable business for the OEMs. And the take rate of such relatively expensive features is significant: Mercedes and BMW did ~€3bn of revenues each in 2017 with ADAS options. We estimate margins on these packages to be 30-50%. This is mainly an opportunity over the next 5-10 years. Long term, as the technology becomes more commoditised, it will likely become more difficult for OEMs to monetise the features.

Key takeaways from our expert interviews

Scepticism about OEM role in a world of robotaxis

Our experts believe that AV production will not be very lucrative, and that the traditional OEM business model with the brand as the core asset is not well prepared for a robotaxi assembly business. The premium OEMs are seen in a relatively better position, because they can "better escape from being the hardware assembler for network providers".

Robotaxi service

UBS VIEW:

- **As in the online travel agency (OTA) business model, intermediaries will continue to play an important role in a world of robotaxis, despite debates around margin structure and importance relative to today**
- **Waymo and the strongest OEMs can offer vertically integrated solutions.**
- **Regional champion model most likely to crystallise, driven by regulation**
- **A horizontal aggregator model could work best for existing ride-on-demand platforms**

Not only does this business represent the largest revenue pool (moving people and goods), it also offers the opportunity to grow fast with fairly asset-light business models (assuming the fleet management is outsourced). To be among the leaders, being among the early movers is likely essential. The players below are already involved in some kind of mobility service business today.

Robotaxis: the largest revenue pool, and the opportunity to grow fast with fairly asset-light business models

Figure 57: Mobility service providers – Daimler is the most active OEM so far

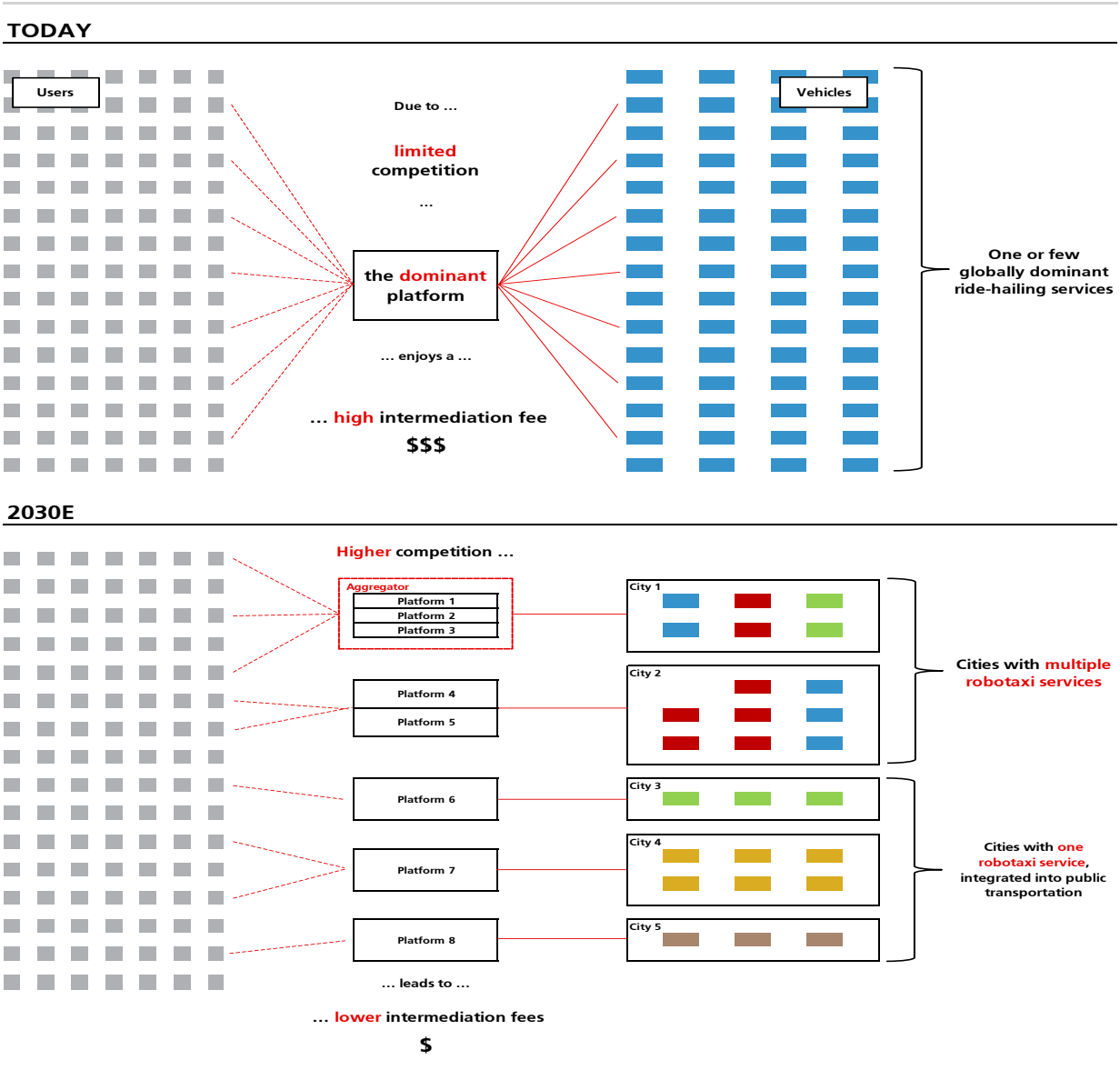
AV player	Buy/lease	Subscription	P2P ride-sharing	Ride-sharing	Ride-hailing	Multi-modal mobility
Daimler	X	*tba*	Turo, Croove, Flinc	Car2go	mytaxi, chauffeur privee, Careem, Via, Blacklane	Moovel
Lyft	Lyft Express Drive	All-Access Plan	Lyft Line		Lyft	-
Uber	Uber Marketplace	Uber Plus	Uber Pool		Uber	transit
Ford	X	Canvas	"Peer-2-Peer"	Zoomcar	Chariot, Lyft	
GM	X	Book by Cadillac		Maven, Maven Gig	Lyft, SideCar	
BMW	X	Access by BMW	Scoop	Drive Now	ReachNow, Scoop, bus.com, may mobility	Ridecell
Volvo	X	Care by Volvo		Sunfleet		
Toyota	X		Getaround		Uber, Japan Taxi	
Renault/ Nissan	X			ZITY	Easy Ride	
Audi	X			Audi on demand, Unite		
Honda	X			Reachda, Grab		
Hyundai	X			IONIQ, WaiveCar	Grab	
Porsche	X	Porsche Passport				
VW	X			ZipCar	MOIA, Gett	
FCA	X				Kango	
PSA	X		KooliCar, TravelCar	Communauto, emov, Bollore		Free2Move
Tesla	X					
Waymo					Waymo	

Source: Company data, UBS

Longer term, however, the service provider business model could evolve. Leading ride-on-demand 1.0 providers currently organise and 'own' the supply by acquiring drivers on their platform. In a robotaxi world, the supply of cars will likely be regionally concentrated in the hands of fewer big fleet operators. Uber, Lyft etc. could become 'consolidator' apps that match the supply from various fleet owners into one app. However, this job could also be done by Google Maps, for example. Integrated players owning the AV technology can exercise their negotiating power on ride-sharing platforms by threatening to establish their own competing app (i.e. similar to the direct booking initiatives by chain hotels). They could use external apps as a means to optimise the asset utilisation, while generating the 'baseload' through an owned app.

Platforms are likely to face lower intermediation fees due to concentration of supply

Figure 58: Increased transparency and competition – why debates around forward margin structure and two-sided marketplace/platform importance relative to today could persist



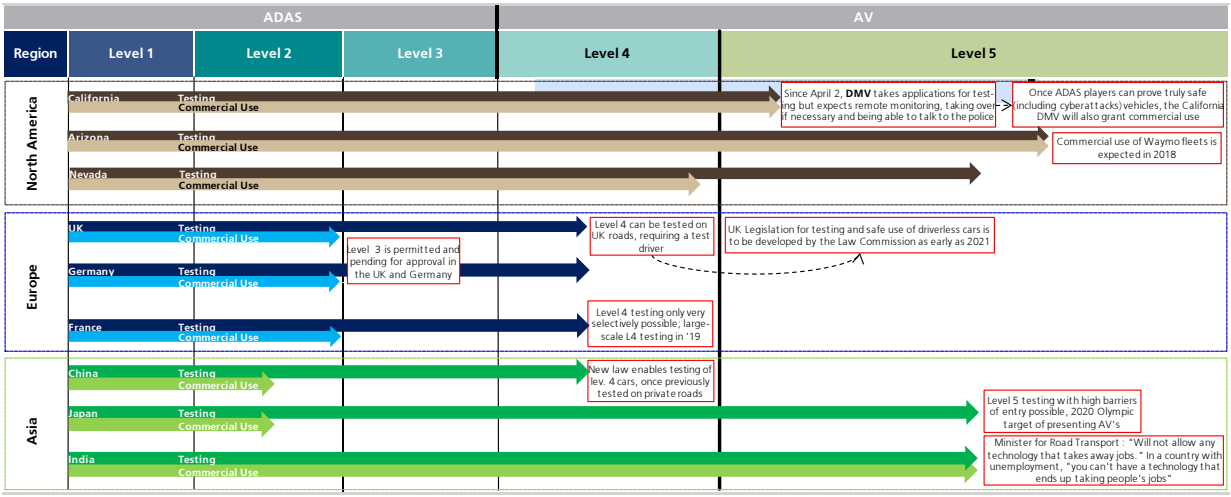
Source: UBS

Ride-on-demand apps will likely try to move to subscription services to increase consumer loyalty and reduce competitive pressure. In any case, the risk to the 20-30% effective take-rates that ride-on-demand apps currently enjoy is likely to the downside in the world of robotaxis.

Regional champions are the most likely outcome

Owing to regulation, we think it is highly unlikely to be a global 'winner-takes-it-all' business. It is more likely to become an industry that is led by **regional champions**. For example, it is highly likely that **China** remains a 'closed shop' with local players (such as Didi) in the lead. In **Europe**, there is a significant likelihood in our view that governments and municipalities will regulate robotaxis tightly. Robotaxis are likely to become seamlessly integrated into public transport systems, and could be run on a concession basis. It might well be that, once a concession is granted, only one firm is allowed to operate robotaxis in a specific city. Such a model might turn out to be the most profitable one, but will likely require a high degree of vertical integration of the provider. In **North America**, regulation is likely less relevant, not least because there is less cannibalisation of (less-developed) public transport networks. Nonetheless, experts we interviewed believe that any given metro area can only handle 3-4 players before unit economics become too difficult to manage for long-term profitability. In **emerging markets**, the business case for robotaxis is most likely further out, given relatively low costs for the human driver and the complexity of traffic. Potentially large markets like India will not be meaningful in size for at least another 15-20 years, most likely.

Figure 59: Regulation is highly diverse, and likely to lead to the formation of regional champions



Source: UBS

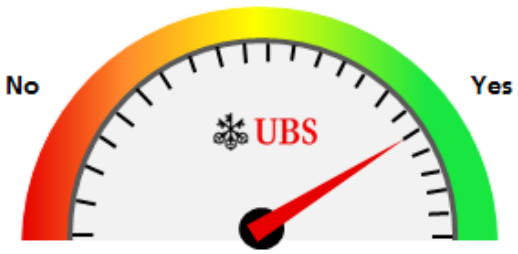
Key takeaways from our expert interviews

Regulation seen as a key driver of industry structure

"There won't be that one winner who takes it all", is just one of the comments that go in the same direction. Most of our experts consider a landscape with regional champions most likely. Regional specifics in regulation are a key driver behind this view. Ride-hailing regulations and standards will be defined "city by city". Cities are likely to regulate the activity, and consider it a "public transport service" (example: Singapore), so that differentiation on the app side would only be possible in areas like service and ease of use. In the early days, companies "will try to be in as many layers of the ecosystem as possible before the real industry structure shakes out." "Whoever owns the customer relationship will drive a lot of the infrastructure and economics". "The AV platform operator and not the ride-

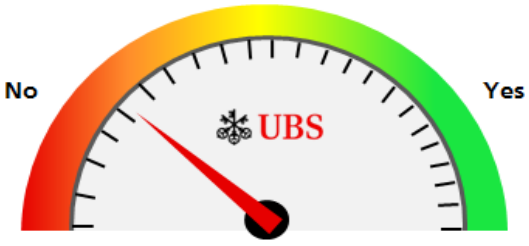
hailing app will be the centre of gravity – take Google Android as an example." OEMs *"will do their best to run a ride-hailing service and manufacture the hardware, with maintenance on top of that". One expert makes the point that the customer side could also be fairly concentrated, because the business partner of the robotaxi provider might not be the individual passenger but rather a public transport operator or a municipality.*

Figure 60: Will there be regional champions over time? – expert panel view



Source: UBS

Figure 61: Will Waymo enter the robotaxi market with an own fleet? – expert panel view



Source: UBS

What can we learn from comparing ride-on-demand platforms with online travel agencies?

How powerful will the platform be?

As the evolution of Rideshare 1.0 continues and mass adoption of autonomous vehicles eventually comes to fruition, we believe the ride-sharing industry could shift to look more like the online travel agency (OTA) business model. This analogy is one that experts cited many times in our discussions with them, and one that we believe makes logical sense over the long term as companies like Uber expand offerings to modes of transportation other than cars (i.e. bikes, scooters, public transportation, food delivery, etc.). We would call this *horizontal aggregation* of mobility services.

"Just like Amazon started in marketing just proprietary product, they then went into a marketplace business. And I see us moving more into a transportation and mobility marketplace as well... I see us extending both in terms of the type of transportation that we offer and in terms of opening up our platform to third-parties to become more and more relevant to consumers on a global basis."

– Dara Khosrowshahi, Uber CEO, March 2018

Specifically, in a similar way to how the OTAs act as an intermediary between the demand-side (individual consumers) and the supply-side (airlines, hotels, etc.), we think this two-sided platform model makes sense as autonomous ride-sharing increases in adoption over the next 10-20+ years. As we pointed out above, one way in which this industry could evolve includes fleet operators (potentially the likes of OEMs, Waymo, or even privately owned fleets) 'plugging in' to the ride-sharing platforms (Uber/Lyft) as the supply side of the equation, in a similar way to how airlines and hotels use Expedia and Booking.com as distribution channels.

Demand side

Existing leaders in ride-on-demand are by no means the 'natural winners' in robotaxis. That said, working in favour of those companies will be:

- **Existing brand awareness and adoption among consumers:** As such, the OTA model appears like the path of least resistance for other players in the ecosystem without having to invest heavily in their own brand marketing to drive consumer interest and adoption in their own services.
- **Data:** We believe current ridesharing companies have a competitive advantage via the amount of data they have collected to date related to route optimisation/utilisation and consumer transportation habits, which will be increasingly important in a world of AV ridesharing.

Price transparency is a key driver of platform profitability

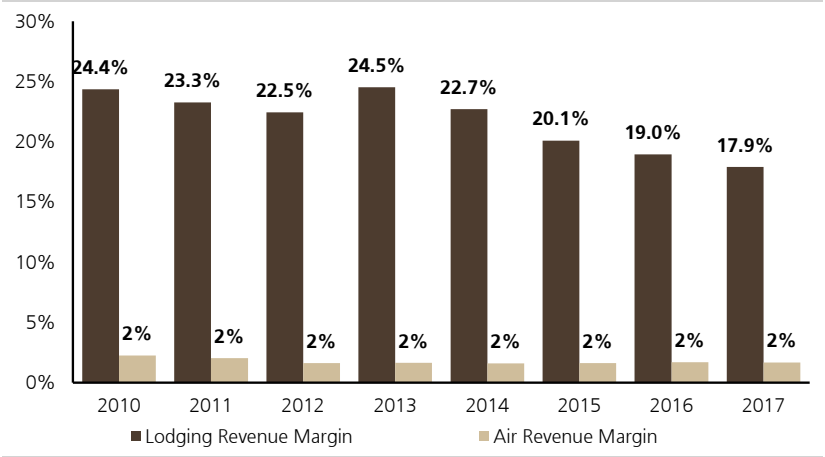
One 'wildcard' will be how transparent the end-demand marketplace is likely to become – for example, there has been a bear case around online travel agencies for the better part of 10 years, based on Google as a search engine at the top of the funnel and the OTAs as merely 'matchmakers' between consumers and hotel rooms. However, brand awareness, customer trust and scaled EBIT that can be redeployed to drive traffic and improve conversion will likely be the normative world order. We do not believe it is by accident that Uber's new CEO/COO have a demonstrated track record in the world of OTAs. In our view, the pure 'matchmaking' component of those businesses (and their respective apps) could become less valuable should other platforms and providers scale and choose to invest behind their own consumer-facing service.

Supply side

Robotaxi supply likely to be relatively concentrated, more than in hotel business

In a world where the supply side of the platform could consolidate from thousands of drivers in a given region to 8-12 fleets of AVs, the next logical question is "what does that do to take rates and profitability?" According to press reports, Uber and Lyft currently have take rates (the share of the total ride fare) in the 25-35% range. This compares to Expedia and Booking.com, which enjoy a consolidated net revenue margin of 10-15%. Breaking this down further, air take rates (ie, the commission charged by the travel agency) have historically been in the range of 2-3% and lodging in the range of 15-25%.

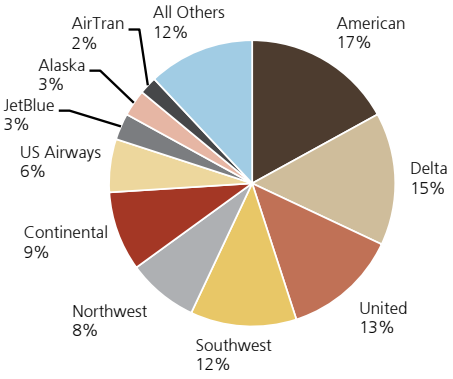
Figure 62: Expedia lodging and air take rates



Source: Company data, UBS estimates

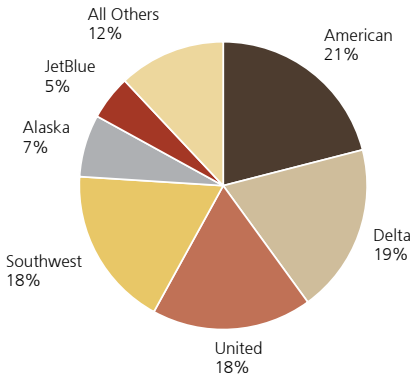
This difference is largely a function of the degree in which the supply side of the OTA platform is fragmented versus consolidated. For example, the air industry is fairly consolidated in North America, with four major airlines (American, Southwest, Delta and United).

Figure 63: US domestic capacity share, 2005



Source: Diio, UBS estimates

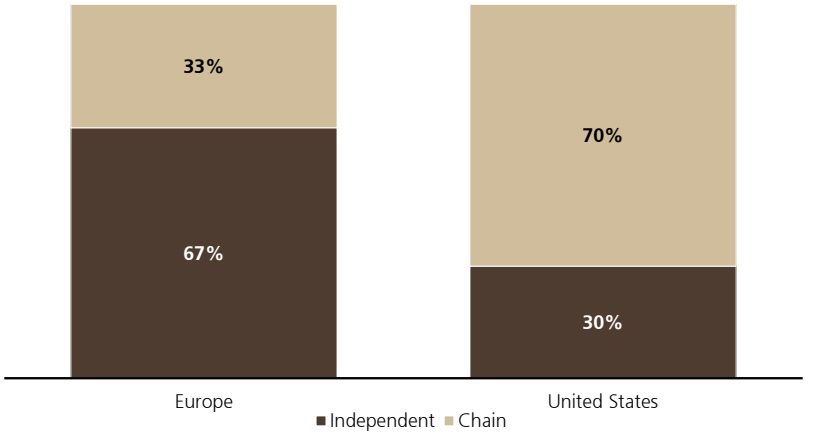
Figure 64: US domestic capacity share, 2017



Source: Diio, UBS estimates

The hotel industry is more fragmented, with a handful of major chains (though there is a recent trend of consolidation) coupled with a handful of smaller chains and a long tail of independent/boutique hotels (which rely heavily on the OTAs for distribution). Not surprisingly, the larger chain hotels benefit from their scale and are charged commissions in the 10-15% range, whereas the independent hotels are typically charged 15-25%, or more in some cases.

Figure 65: Share of rooms – independent versus chain hotels

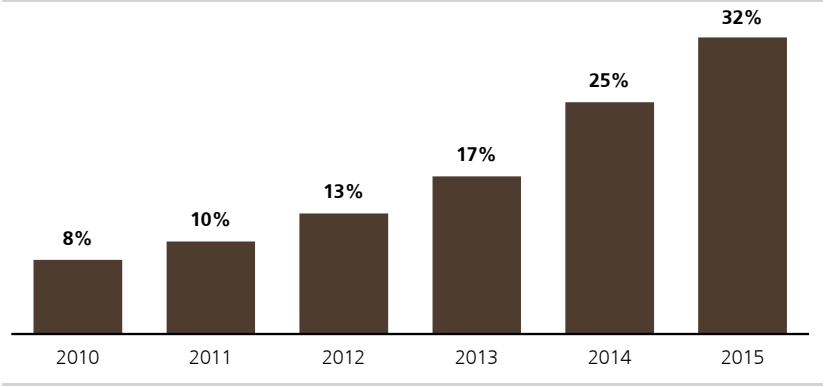


Source: Phocuswright, *Independent Lodging Market: Marketing, Distribution and Technology Strategies for Non-Branded Properties* (October 2015)
Note: To be categorised as independent, hotels had to be unbranded, although they could form part of a common ownership group of up to five properties as long as they operated independently.

In our view, the future robotaxi industry is more likely to look like the hotel industry (and its method of distribution) than the airline industry today. A further component of this view is the potential for individuals to eventually become AV fleet operators (similar to shared accommodations and professional property managers) as the cost of AV ownership becomes more affordable. In theory, individuals could eventually achieve this via buying multiple AVs (i.e. Jaguar's i-Pace integrated with Waymo's AV technology and operating system), forming a fleet

and plugging in to ridesharing platforms such as Uber and Lyft. This could act as a long tail of supply potentially coming on the platform, similar to that of independent/boutique hotels and shared accommodation for global OTAs today. While we recognise there are hurdles to overcome before this becomes reality, we would point out that the idea of renting out a room in your home seemed unrealistic 15-20 years ago for some of the very same reasons an individual could cite today (i.e. trust, regulation, etc.).

Figure 66: Percentage of US travellers who used private accommodation

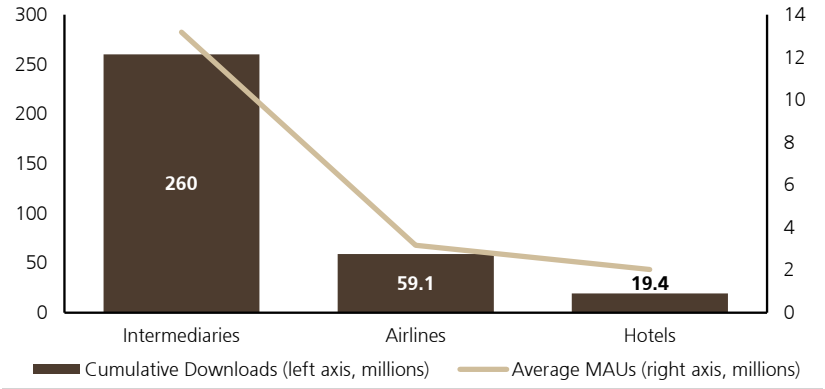


Source: Phocuswright

What about a supplier-direct-to-consumer model?

While it is possible that some OEMs and Waymo could be successful in driving direct bookings on their own robotaxi services (i.e. Waymo is testing this concept in Phoenix), historically, suppliers have also leaned heavily on intermediaries as a distribution tool and mechanism to reach end-users. We note that apps from travel intermediaries have significantly more cumulative downloads and average monthly active users than travel suppliers. As we have pointed out, this largely results from intermediaries' ability to offer a superior mobile experience, data and analytics capabilities, and greater marketing resources.

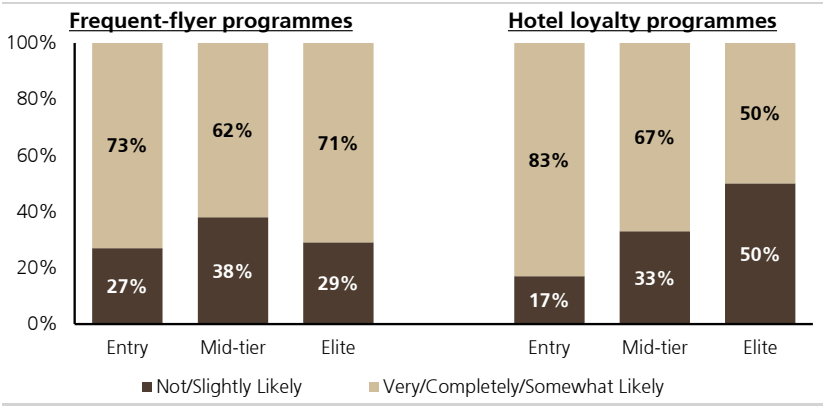
Figure 67: When available, intermediaries typically are welcomed by consumers



Source: Phocuswright

Further, despite efforts by travel suppliers to push for direct bookings, overall consumers have historically been disloyal (even if they have signed up for a specific loyalty/reward programme).

Figure 68: Loyalty programme member likelihood to book outside a loyalty programme



Source: Phocuswright

While there are many debates to be had around regulation, potential business models and the forward margin structure of Rideshare 1.0 companies in a world of AV ridesharing, we believe the potential to leverage their existing competitive positioning, in addition to expanding into other forms of transportation that may carry higher take rates (i.e. bikes, scooters, etc.), gives us some comfort in the OTA analogy.

Figure 69: Robotaxi service ecosystem – a number of questions remain unanswered

Source: UBS

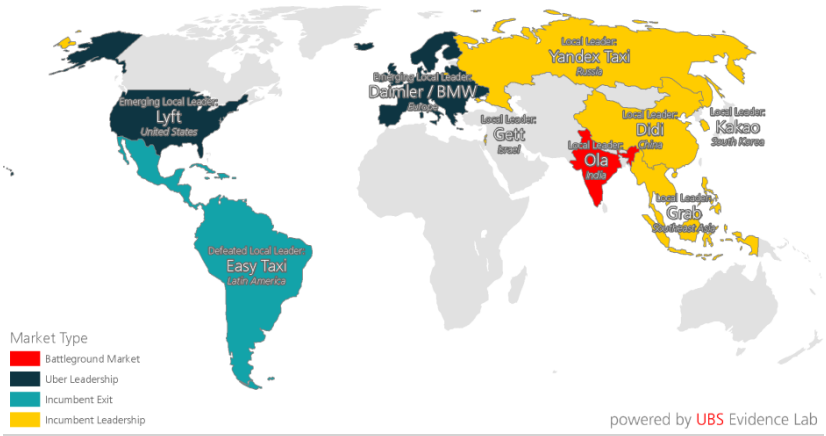
Who is in the lead?

Three groups of companies appear best positioned to lead in this space: Ride-on-demand players, a few leading OEMs (GM, Daimler) and Waymo. In today's ride-on-demand business with a human driver, Uber has the number one position outside China, while Didi is the undisputed leader in China. Among OEMs, Daimler is the biggest player in the ride-on-demand market today, an asset that will be shared with BMW in a new JV structure. Removing the driver from the vehicle establishes a completely new business case. As discussed, it will be a challenge for today's leaders in the ride-on-demand business to carry their leading position over into a robotaxi world to the same degree as they are not seen as leaders in AV technology by our expert panel. As some carmakers will likely focus on AV fleet management, it will likely also make sense for them to offer the AV as a service, in order to have a better handle on asset utilisation. On the other hand, having opportunity to expand horizontally into other AV-related services (deliveries etc.) is an advantage for the existing ride-on-demand platforms.

Ride-on-demand players versus OEMs, and maybe Waymo?

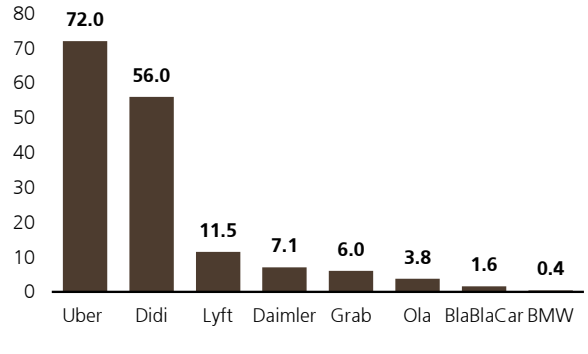
The figures below illustrate the competitive situation in the ride-on-demand market today. Note that revenue and valuation figures are based on various press reports, and may not line up exactly with actual company financials.

Figure 70: Ride-on-demand 1.0 market split today



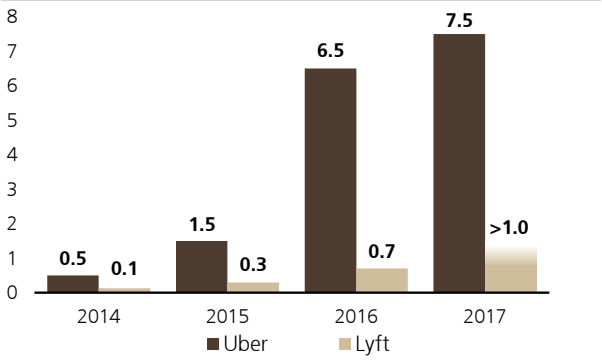
Source: UBS Evidence Lab

Figure 71: Ride-hailing valuations in comparison ($bn)



Source: Various media reports, company data, UBS

Figure 72: Ride-hailing net revenues ($bn) in comparison



Source: Various media reports, company data, UBS

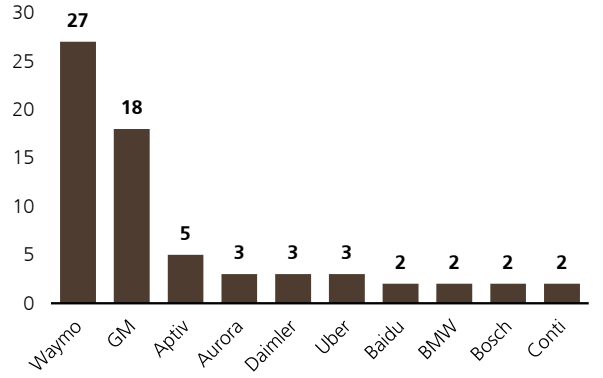
Players who have already declared their plans to enter the robotaxi service world include OEMs such as GM and Daimler. Waymo also started its own robotaxi offering in the suburbs of Phoenix, Arizona. We expect Waymo to extend its pilots to other cities over the next few years, even though we expect its main strategic focus to be on the in-vehicle AV system rather than in running the service.

Key takeaways from our expert interviews

Waymo and GM seen as leaders

The experts' views range from "OEMs by nature cannot do mobility services" to "they will want to be the network operators". Among traditional carmakers, GM is seen as a fast follower to Waymo, "with a two-year lag". Toyota, Daimler and BMW are also mentioned as being among the leading OEMs. GM's robotaxi pilot is seen as technically more challenging than Waymo's because the company has chosen complex San Francisco traffic with a more compelling business case rather than a less complex suburban environment with no business case behind. Waymo's pilot in the Phoenix, Arizona, suburbs "will not prove the business concept of a robotaxi". Possibly "Lyft could be the first user" of Waymo's technology. One expert highlighted that Waymo would still need "thousands of people" to develop dispatch algorithms to run a robotaxi service. Also, "absolute failure rates are still far away from a human driver, which means it is not ready for large-scale release". Uber responded to the threat of new entrants by working on its own AV system, whereas all other ride-on-demand players decided to stay out of AV tech investments. Some of the experts we interviewed supposed that Uber is so much behind with its own AV tech that it might have to stop its activities and look for a partner instead.

Figure 73: Who is best positioned – expert panel view: 3 points for first place, 2 points for second place, 1 point all others



Source: UBS expert interviews

Figure 74: Robotaxi pilots – who has announced?

Company	# cars	OEM	Model	Delivery
GM	~2,500 p.a.	GM	Chevrolet Bolt	2019
Aptiv/ Lyft	30	BMW	5-Series	2018
Uber	24,000	Volvo	XC90	2019-21
	20,000	Jaguar	i-Pace	2020
Waymo	600	FCA	Chrysler Pacifica	2016/17
	1,000	FCA	Chrysler Pacifica	>2018

Source: Company data, UBS

Robotaxi fleet management

UBS VIEW:

- **Owning and managing the AV fleets will likely be an attractive business model…**
- **…but asset utilisation risk needs to be well managed**
- **The fincos of the large OEMs appear well positioned**

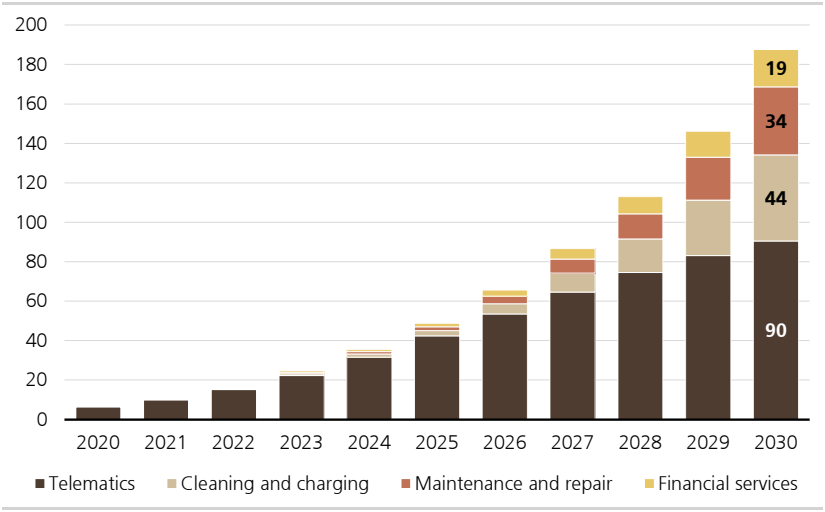
Large OEMs with own finco arms could own this business, but there are also opportunities for dealerships and rental car players

A robotaxi fleet will require: (1) financial services including the asset ownership and/or alternative financing models behind it; (2) cleaning and charging; (3) maintenance and repair. OEMs and their financing arms, in collaboration with the existing dealership network, appear a 'natural fit' for this type of business. It appears unlikely to us that tech players would want to get involved. Some parts of the fleet management could also be done by rental car companies, in particular cleaning, charging and basic maintenance tasks. For example, Waymo has signed contracts with Avis and AutoNation for the maintenance and repair of its growing robotaxi fleet. Also, VW and Didi are in talks about a JV for managing Didi's ridesharing fleet, with the long-term aim to run a robotaxi fleet.

Asset utilisation is the key risk

The flipside of being the AV fleet owner and manager is to assume the asset utilisation risk. The app provider has an incentive to have more (underutilised) robotaxis on the road, in order to fully cover peak demand hours. We discussed the importance of asset utilisation in detail in our Robotaxi Q-Series.

Figure 75: AV fleet ownership and management – a $188bn revenue pool by 2030E



Source: UBS estimates

Key takeaways from our expert interviews

Is owning the fleet a "moat"?

"Owning the fleet is a moat". While it can offer good returns, the fleet owner would predominantly bear the utilisation risk while the platform owner would even have an interest to have underutilised assets in order to cover peak demand at all times. Our experts see OEMs with big balance sheets and the know-how from their financing arms as a strategic asset.

Monetising the time in the AV

UBS VIEW:

- **Google appears best positioned, given its ability to leverage AV OS advantage, plus consumer-facing platforms (i.e. Google Maps/Waze, YouTube, Google Search)**
- **Current social media, streaming media, internet search businesses should benefit via incremental time spent on mobile and tablet devices**
- **OEMs with own AV operating system could own a relatively small part of the pie**

In our view, monetisation within this layer of the ecosystem should be thought of in two ways: (1) monetisation of the physical space inside of the AV, including any interfaces or voice-assistant options; and (2) incremental time spent on mobile devices and/or tablets. On average, vehicle owners today spend one hour per day in a car performing "unproductive" driving tasks most of the time. In an AV, either owned or in a robotaxi service, users can spend this hour productively (i.e. consuming media/entertainment, use social media, work, etc.).

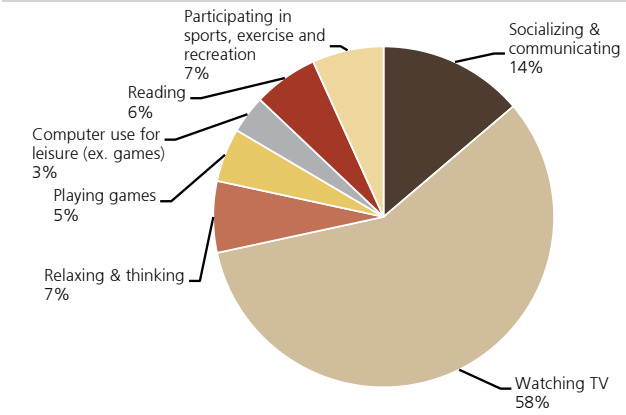
Google is in pole position…

In our view, the first aspect lends itself to partnerships and agreements with global internet and media platforms. Specifically, we expect in-car monetisation to primarily come from sponsored ads on a map interface (similar to what Waze is doing today), voice assistants (Google Home, Alexa, etc.) or even engaging with streaming media using a screen or interface provided (i.e. Netflix, Spotify, YouTube, etc.). We believe Google is likely to have an advantage over most competitors here by linking the AV operating system (a layer in which it will likely have a significant role) with the passenger interface. This could play out in a number of scenarios for Waymo, including: (1) operating its own fleet and/or ridesharing service; (2) license the AV OS and integrate capabilities to monetise time spent; and/or (3) give away the AV OS for free (similar to Android) to fleet operators who agree to give Google control over the in-car monetisation features. That said, as competition within this layer increases (as the revenue pool grows) with additional opportunities being opened up to other internet and media companies, Waymo will likely lose a degree of share to some of these companies.

…but social media likely to benefit as well

Related to the second aspect, regardless of who owns the fleet, AV OS or ability to monetise the inside of an AV, there will likely still be a large percentage of users who choose to spend this time on their personal mobile devices or tablets. In this case, if autonomous vehicles open up an extra hour per day where people do not have to pay attention to driving, this is likely to be spent in the same manner that they spend their sedentary leisure time today. Key beneficiaries are likely to include current social media, streaming media and internet search businesses.

Figure 76: Percentage of time spent per day in selected leisure and sports activities (2016)

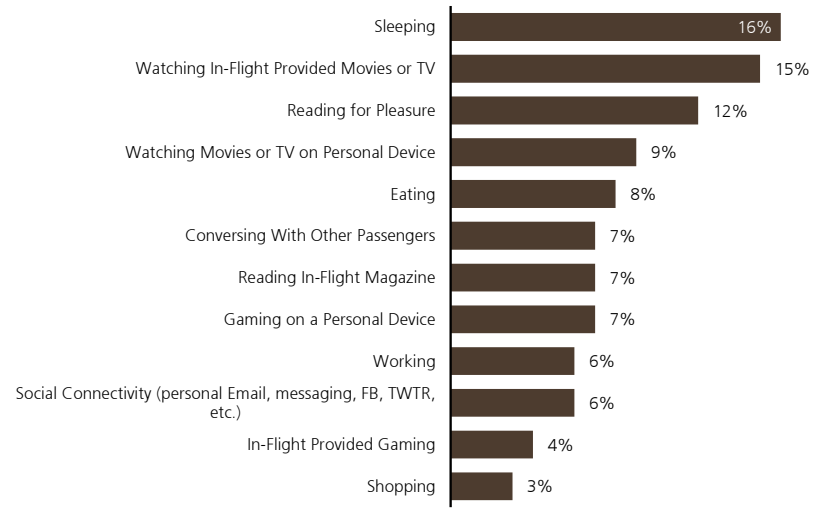


Source: Bureau of Labor Statistics

Free Wi-Fi is the key difference between robotaxis and flights

It is likely that time spent in an autonomous vehicle will not be dramatically different from how airline passengers spend their time. Specifically, when excluding activities such as sleeping, eating and reading, passengers appear to spend some 50% of their time on personal devices and the other 50% utilising the airplane's interface for activities such as watching in-flight provided movies or TV, in-flight provided gaming, or reading the in-flight magazine.

Figure 77: How do airline passengers spend their time?



Source: Airline Passenger Experience Association, *The Global State of the Air Passenger Experience (2014)*

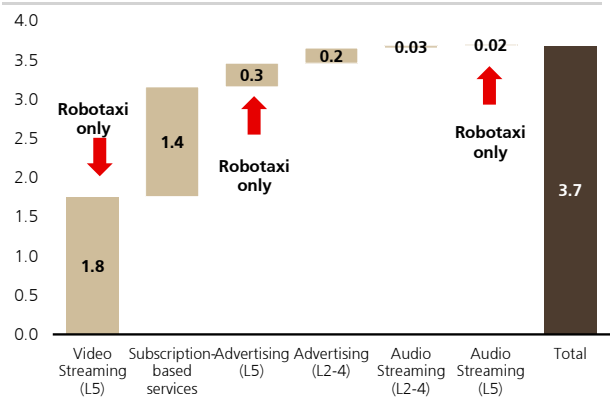
That said, one key difference could occur between time spent in-flight versus time spent in an autonomous vehicle. Passengers in an AV will likely have greater access to Wi-Fi or the internet via mobile devices or tablets relative to airline passengers (where in-flight Wi-Fi access is typically hit or miss, though improving). Thus, AV passengers could potentially end up relying less on in-car interfaces/experiences relative to airline passengers. According to the International Air Transport Association (IATA), the top three on-board Wi-Fi usage preferences are: (1) browse the internet (73%); (2) send/receive emails (62%); and (3) instant messaging

(62%). All three of these preferences benefit global-scaled internet companies (Google Search, Gmail, Facebook Messenger, WhatsApp, etc.).

OEMs with their own AV platform could, to a lesser extent, also generate additional revenues by targeted advertising on their AV operating system, offer services such as autonomous parking, or receiving a small fee from third-party apps for being on their AV platform, similar to the App Store model. Ride-on-demand providers will likely also fight for their fair share. Their revenue model could shift away from selling the mile to in-car time monetisation. But they might have to rely on Google Maps.

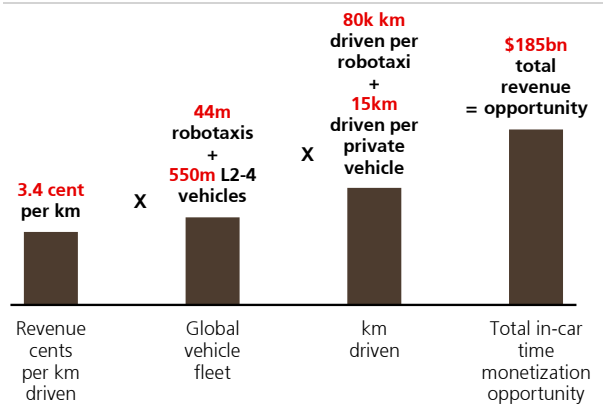
OEMs with their own AV operating system are also likely to get a certain (relatively small) share

Figure 78: Monetising the time in the car – just 3.4 cents per mile…



Source: UBS estimates

Figure 79: …create a $185bn revenue opportunity



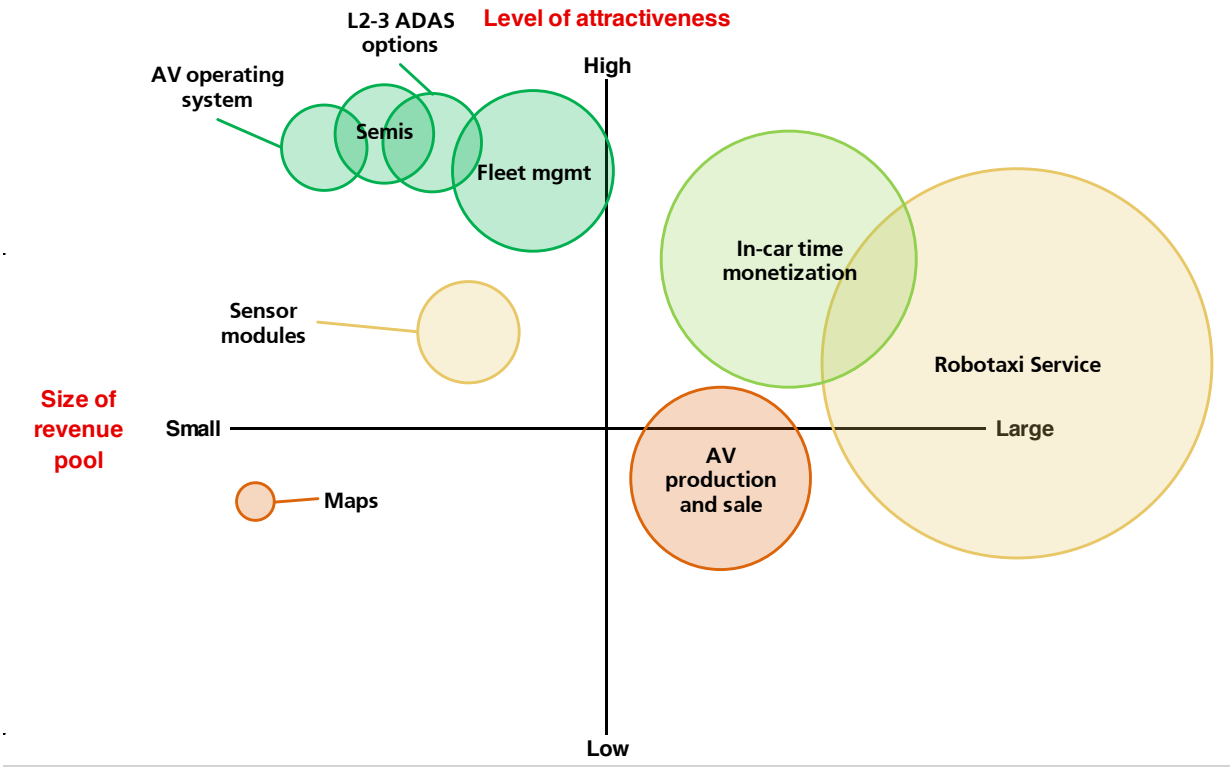
Source: UBS estimates

Putting it all together: Who will win?

Ranking the attractiveness of the AV business models

Which businesses look most and least promising from a return perspective? We are using Porter's five forces to determine the attractiveness of the different parts of the AV value chain. The chart below summarises our thinking, based on the detailed analysis provided in the section above.

Figure 80: Porter's five forces screening



Source: UBS

Our key conclusions:

- **Semis (+):** The leading AI processor players are likely to enjoy a strong and profitable market position for a long time. The compute and sensor subsegments appear most attractive to us.
- **Sensor modules (=):** Since AV system integration will likely happen elsewhere, in our view, we consider sensors an area of high growth, but with a high degree of rivalry. Several auto suppliers are now committing a large part of their invested capital base to AV, hinting to relatively low returns. Long term, the number of sensors required in an AV is likely to decrease and prices will likely come under pressure. Lidar could be an area of differentiation and therefore lower risk of commoditisation.
- **Maps (-):** Maps are not a differentiator in the long term. While HD maps are a prerequisite for autonomous driving, the ROI might be low on high

investments. Waymo, which might end up being the leading AV operating system used by OEMs, uses its own map solution.

- **Operating systems (+):** Owning the AV "brain" will be highly lucrative, in particular in combination with the monetisation of the time in the car. The OS could end up being the enabler to make money in other areas of the AV ecosystem, rather than a revenue pool by itself. Without other sources of income, it would only be an area of high investments but limited return, which we see mainly as a concern for OEMs.

- **Robotaxi services (=):** Running a robotaxi platform has an average attractiveness, due to the limited scope for differentiation in a highly competitive environment. As consumers are highly sensitive to the price per mile in a very competitive and fully transparent marketplace, loyalty could be low. Some markets will have a highly concentrated customer base, because the robotaxis will be centrally organised by a public transport operator. In an integrated business model together with other value-added services (AV operating system, monetising time in the robotaxi, fleet services), providing the platform can add more value, we believe. There will be a market for premium mobility on demand, and existing premium OEMs could capture a significant share of this market, provided that their technology does not fall behind the leaders.

- **AV production and sales (=):** White-label AV production can be a business model for only very few mass-market players with best-in-class cost structures. For premium brands that will be able to safeguard their brand equity in a premium mobility world, AV production will likely remain value-accretive. One important question related to the attractiveness of this business is the liability risk. For robotaxis assembled for big fleet operators, it is likely the service provider taking the liability risk, whereas OEM-branded AV will likely be the liability of the carmaker. For OEMs, the AV opportunity has to be seen net of the loss in volumes in the traditional business.

- **In-car time monetisation (+):** The AV platform owners, either big data or (to a lesser degree) auto OEMs and robotaxi apps will be the gatekeeper for the content that the passenger has access to while in the AV. We consider this a very lucrative business in a fairly well ring-fenced environment.

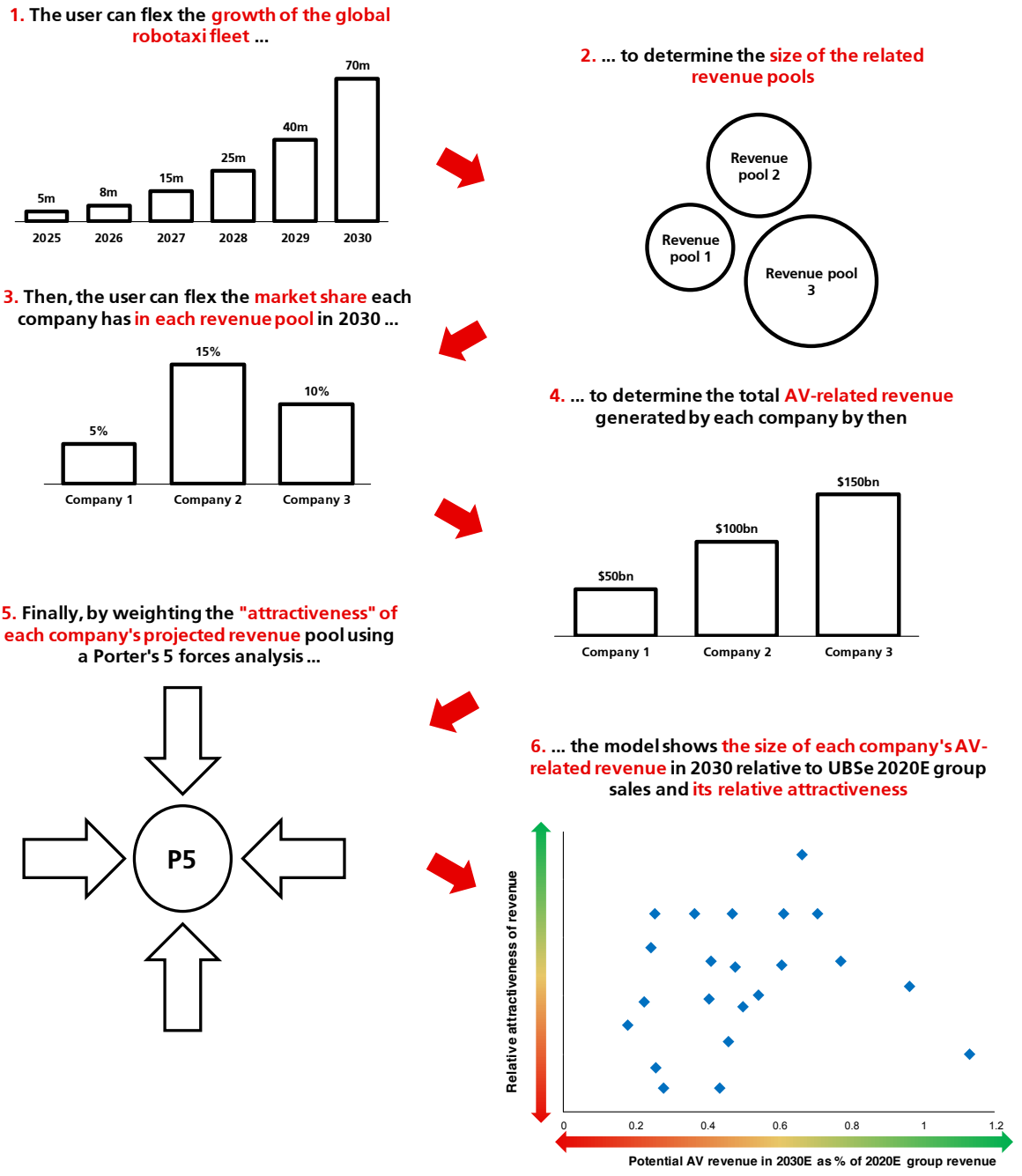
- **L2-3 ADAS options (+):** A very profitable business for auto OEMs and suppliers alike, with affluent auto buyers ready to spend extra dollars for additional ADAS functionality.

Who are the biggest AV beneficiaries in our coverage universe?

UBS interactive model to assess AV revenue opportunity company by company

We have built an interactive model that connects the size and attractiveness of the respective AV revenue pools with the expected market shares of the key players in our coverage. The output is: (1) the size of the total revenue opportunity on a company-by-company basis; and (2) the size of the AV revenue opportunity with a 2030 view as a percentage of estimated 2020 revenues. We take into account the *external* revenue pool only, ie, a player that develops an AV operating system, but only sells the finished AV, will not have any revenues for its in-house AV operating system.

Figure 81: How does our interactive model work?



Source: UBS

The table below summarises our base-case 2030 expected market shares of all companies in our tech and autos coverage. This input can be changed in the interactive model.

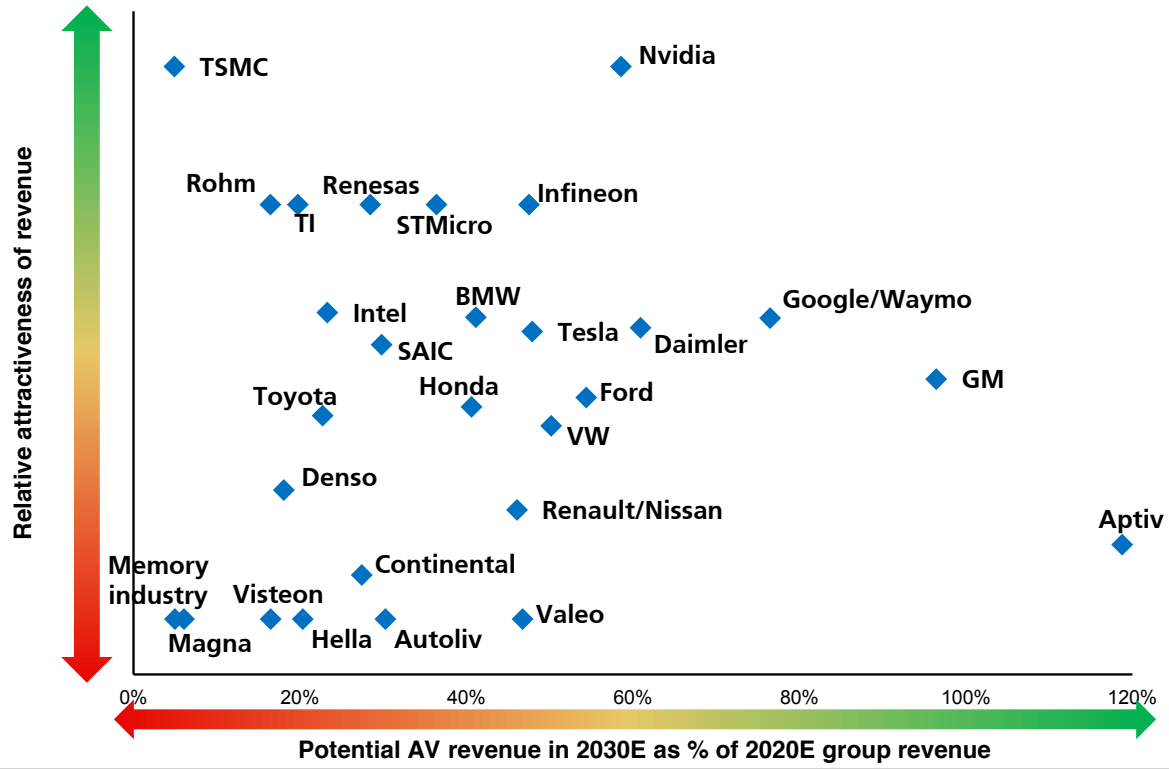
Figure 82: Market share assumptions (base case) – can be flexed in interactive model

		Semis: sensors	Semis: compute	Semis: memory	Sensor modules	Maps	AV operating system	Robotaxi service	Fleet mgmt.	In-car time moneti-zation
Content per unit ($)	L2	114	126	-	405	-	-			
	L4/5	615	1,000	290	2,538	360	2,907			
Annual revenue per unit ($)	L2							-	-	165
	L4/5							44,005	3,685	1,636
Tech	Google/Waymo	0%	0%	0%	0%	50%	60%	3%	0%	35%
	Infineon	20%	0%	0%	0%	0%	0%	0%	0%	0%
	Intel	0%	33%	0%	10%	0%	0%	0%	0%	0%
	Nvidia	0%	33%	0%	0%	0%	0%	0%	0%	0%
	Memory industry	0%	0%	100%	0%	0%	0%	0%	0%	0%
	Renesas	10%	0%	0%	0%	0%	0%	0%	0%	0%
	Rohm	3%	0%	0%	0%	0%	0%	0%	0%	0%
	STMicro	15%	0%	0%	0%	0%	0%	0%	0%	0%
	Texas Instruments	15%	0%	0%	0%	0%	0%	0%	0%	0%
	TSMC	0%	8%	0%	0%	0%	0%	0%	0%	0%
Auto OEMs	BMW	0%	0%	0%	0%	5%	3%	1%	3%	1%
	Daimler	0%	0%	0%	0%	5%	0%	6%	6%	1%
	Ford	0%	0%	0%	0%	0%	0%	5%	5%	1%
	GM	0%	0%	0%	0%	0%	0%	9%	9%	1%
	Honda	0%	0%	0%	0%	0%	0%	3%	4%	1%
	Renault/Nissan	0%	0%	0%	0%	0%	0%	3%	5%	1%
	SAIC	0%	0%	0%	0%	0%	0%	3%	5%	1%
	Tesla	0%	0%	0%	0%	0%	0%	0%	0%	1%
	Toyota	0%	0%	0%	0%	0%	4%	0%	15%	1%
	VW	0%	0%	0%	0%	5%	0%	8%	10%	1%
Auto suppliers	Aptiv	0%	0%	0%	20%	0%	7%	0%	0%	0%
	Autoliv	0%	0%	0%	5%	0%	0%	0%	0%	0%
	Continental	0%	0%	0%	20%	2%	4%	0%	0%	0%
	Denso	7%	0%	0%	10%	0%	4%	0%	0%	0%
	Hella	0%	0%	0%	3%	0%	0%	0%	0%	0%
	Magna	0%	0%	0%	5%	0%	0%	0%	0%	0%
	Valeo	0%	0%	0%	18%	0%	0%	0%	0%	0%
	Visteon	0%	0%	0%	1%	0%	0%	0%	0%	0%

Source: UBS estimates

Revenue pool times market share equals the total US dollar revenue opportunity by company. The numbers are net of the lost volume of privately owned vehicles sold. Our matrix below depicts the revenue opportunity as a percentage of the 2020 estimated group revenues, indicating to what extent the AV opportunity will move the needle for the company's long-term investment case. We put this in relation to our attractiveness ranking based on Porter's five forces. For companies in the top-right corner, AV is a highly relevant and lucrative driver of the investment case.

Figure 83: AV opportunity matrix, company by company



Source: UBS

- **Internet: Waymo/Alphabet** stands out as the key winner, with an AV opportunity in 2030E representing some 80% of 2020E Alphabet group revenues. We see it dominating in the AV operating system, and a substantial share in in-car time monetisation.
- **Auto OEMs: GM** is ahead of OEM competition in terms of AV technology and among the leaders in rolling out a robotaxi service. **Daimler** screens as best positioned among premium OEMs, with a leading position in mobility services today. **Tesla**, while undoubtedly among the OEMs with the best AV software know-how, could be challenged in its decision not to use lidar technology.
- **Semiconductors:** In our global semis coverage, **Nvidia** and **Infineon** are among the players most impacted by AV. However, we think **Intel's** AV opportunity (while smaller relative to group revenues than Nvidia's) is not fully reflected in the current share price.
- **Auto suppliers: Aptiv** is by a wide margin the best positioned AV play in our global coverage. On aggregate, suppliers rank below the leading OEMs in our analysis because a significant part of the sensor market is likely to face intense competition; lidar stands out positively.

We highlight that this summary focuses on the net winners from the AV revolution. Several mass carmakers and auto suppliers will likely be net losers, because while they are unlikely to benefit from the upside from rising AV sales, they stand to suffer from the AV-induced decline in new car sales. The more basic the content provided by the suppliers, the more negatively they are likely to be affected by a structurally declining car ownership rate in the decades ahead.

At a glance: Sector Thesis Maps

Global auto OEMs

AV impact on sector … **Growth:**  **Margins:**  **ROIC:**  **Valuation:** 

Exposure to …

Semis/ software	Sensors	Maps	AV op. system	Robotaxi service	Fleet manage-ment	In-car time moneti-sation	AV production and sales	L2-3 ADAS options	Loss of volume
☐	☐	☐	X	X	X	X	X	X	X

KEY FINDINGS

Q: What were the most relevant findings from the expert interviews for our sector?

Tech-oriented experts generally have a cautious view on OEMs in a world of robotaxis. However, GM is widely seen as one of the fast followers to Waymo. Also, premium OEMs are seen as better positioned to sustain the brand equity in an AV world.

FINANCIAL IMPACT

Q: What will be the impact on the industry?

Mixed. OEMs that are not either a premium player or a cost-leading volume carmaker will suffer from a net loss in revenues and a dilution of brand equity.

REVENUE POOL

Today ($bn)	2030E ($bn)	2020-30E growth
~2,000	~3,000	50%

ATTRACTIVE-NESS

Q: How attractive will the revenue pool be?

Running an integrated AV production and robotaxi business model could be financially attractive, whereas a white-label AV assembly will likely be unattractive for most of the OEMs.

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from AVs?

Mixed, with a positive trend. GM and Daimler stand out as leaders in terms of AV technology and mobility services, whereas BMW has built the most relevant technology partnership platform.

SECTOR VALUATION

Q: Could the trend to AVs lead to a change in sector valuation multiples?

The topic is a drag on OEM valuations already today, which is missing the point that some OEMs are likely to be net beneficiaries of AV, in our view.

STOCK IMPACT

Q: What stocks will be impacted most positively and negatively?

Positively: Premium OEMs, GM. Negatively: Mass car makers lacking financial resources and cost structures to compete in an AV world[1].

1. Note: Valuation multiples on the following pages based on stock prices as of 7 May 2018

MOST FAVOURED	Stock	UBS rating	2018E PE	Potential revenue impact 2030E	Comment
	GM	Buy	6x	>50%	GM's acquisition of Cruise put it in a leading position for AVs. Moreover, its testing in the complex environment of San Francisco should result in a faster AV learning curve. Trading at <6x earnings, the market is not giving GM credit for this long-term opportunity.
	Daimler	Buy	7x	>50%	Daimler is Europe's leading OEM in mobility services. It owns Europe's largest taxi app and runs a multi-modal mobility platform, among other activities. In partnership with Bosch, Daimler is likely to be among the leading OEMs in AV technology.
	Volkswagen	Buy	6x	~50%	VW, while not being among the first movers, has significantly accelerated its AV strategy. It has partnered with Aurora to create the AV "brain" and has formed a separate brand for group-wide mobility services called MOIA. As the leading volume brand in Europe and China, we see VW well positioned in these two key AV/robotaxi markets.

LEAST FAVOURED	Stock	UBS rating	2018E PE	Potential revenue impact 2030E	Comment
	PSA	Neutral	11x	NA	PSA for now is not among the leaders in AV technology, and it lacks scale compared with the largest mass-market OEMs.
	FCA	Neutral	6x	NA	FCA is a supplier to Waymo and has joined the BMW/Intel open platform. However, we think FCA has limited in-house know-how and has invested less than peers in the space. While the luxury brands, Jeep and RAM appear better protected than average from shrinking car ownership rates, the Fiat brand in Europe is likely more at risk.
	Tesla	Sell	NA	25-50%	Tesla is the OEM with the biggest collection of camera footage from its vehicles all around the world. However, we believe regulators will likely ask for additional layers of redundancy in the AV system, ie, lidar. Tesla's system is based on camera and radar only.

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Global auto suppliers

AV impact on sector … **Growth:**  **Margins:**  **ROIC:**  **Valuation:** 

Exposure to …

Semis/ software	Sensors	Maps	AV op. system	Robotaxi service	Fleet manage-ment	In-car time moneti-sation	AV production and sales	L2-3 ADAS options	Loss of volume
X	X	X	X						

KEY FINDINGS

Q: What were the most relevant findings from the expert interviews for our sector?

Competition will be intense and auto suppliers do not screen as best positioned to bring the highest added value. For the next 5-10 years, a lidar-based system (as opposed to camera-based) will likely win, and duplication and redundancy will be required by the regulator. This will drive strong content growth, but price deflation will be extremely high (we see the AV system cost reaching $10,000, compared with $100,000 today). In the long run, AI could reduce the number of sensors required. Lidar is an area of differentiation and potentially better returns.

FINANCIAL IMPACT

Q: What will be the impact on the industry?

The strong growth will continue in the medium term, but it is unclear whether any players will be able to make attractive enough margins. In the long run, some suppliers might have to write down some assets as the technology they have invested in becomes irrelevant.

REVENUE POOL

Today ($bn)	2030E ($bn)	2020-30E growth
~5 (ADAS)	~100 (ADAS)	20x

ATTRACTIVE-NESS

Q: How attractive will the revenue pool be?

Mixed. Auto suppliers will mostly capture the sensor/hardware revenue pool, which is most at risk of being commoditised in the long run. We doubt traditional auto suppliers can compete with tech companies when it comes to the AV operating system, and they have limited interest in managing the fleet of robotaxis.

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from AVs?

Yes, the industry has already committed a high level of R&D over the past few years.

SECTOR VALUATION

Q: Could the trend to AVs lead to a change in sector valuation multiples?

Unlikely in the near term.

STOCK IMPACT

Q: What stocks will be impacted most positively and negatively?

We prefer auto suppliers that are not committing too much capital to solutions that might become irrelevant in the long run. We also favour auto suppliers that are developing partnerships (as opposed to seeking the highest level of vertical integration and doing everything in-house)

MOST FAVOURED

Stock	UBS rating	2018E PE	Potential revenue impact 2030E	Comment
Conti	Buy	13x	25-50%	Most advanced European ADAS supplier.
Valeo	Buy	16x	25-50%	ADAS one growth driver, but company also strong in electrification/hybridisation.
Aptiv	Neutral	17x	>100%	By far most advanced in AV among our global supplier coverage, thanks to Nutonomy acquisition.

LEAST FAVOURED	Stock	UBS rating	2018E PE	Potential revenue impact 2030E	Comment
	Schaeffler	Sell	8x	Negative	Not positively exposed to AV. Loss of volume is a long-term threat as car ownership decreases.
	Autoliv	Sell	20x	25-50%	Relatively small AV business, underperforming in growth versus peers.

Q: What else should investors know? / The sector impact in more detail

Traditional tier 1 suppliers will face other challenges: (1) break up the silos and review the group structure; (2) increase the focus on sensor fusion, and (3) digitalise some assets and shift into new services (vehicle diagnostics). Some might even consider making cars in the long run.

Tyre makers are set to benefit from the increased number of kilometers driven. We estimate that the annual cost for tyres will be 5-6x higher than in a private car today. However, the higher weight of fleet buyers should put pressure on pricing, but this could be offset by improving product mix (i.e. more durable tyres).

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Global internet

AV impact on sector … **Growth:**  **Margins:**  **ROIC:**  **Valuation:** 

Exposure to …

Semis/ software	Sensors	Maps	AV op. system	Robotaxi service	Fleet manage-ment	In-car time moneti-sation	AV production and sales	L2-3 ADAS options	Loss of volume
☐	☐	X	X	X	☐	X	☐	☐	☐

KEY FINDINGS

Q: What were the most relevant findings from the expert interviews for our sector?

There are still many unknowns related to how this industry/ecosystem will play out. For example, it has yet to be determined which layer of the ecosystem global internet companies, such as Alphabet's Waymo, will ultimately be most exposed to (i.e. license AV technology, in-car monetisation, operate fleet and/or ridesharing service). That said, it has become clearer to us that Waymo is the leader in autonomous driving technology and it appears it will be first to market with a fully autonomous ridesharing service in Phoenix in 2018. In Russia, Yandex introduced its self-driving taxi prototype in May 2017 and since then has tested autopilots in the snowy Moscow streets in November 2017 and February 2018. The company extensively leverages its experience in machine learning, computer vision and maps/navigation to create and integrate all the core systems necessary for AV functioning. Moreover, as part of its deal with Uber, Yandex gained access to Uber's technologies in AV design, which should help it to accelerate its AV strategy implementation.

FINANCIAL IMPACT

Q: What will be the impact on the industry?

Ultimately, this will be dependent on the primary business model adopted by global internet companies within the autonomous ridesharing ecosystem. In our view, global internet companies are well positioned to benefit from this opportunity, given the optionality they have in determining which layer of the ecosystem is best as the evolution of this industry and technology progresses.

REVENUE POOL

2017E ($bn)	2030E ($bn)	2020-30E growth
~15	~1,412	~100x

ATTRACTIVE-NESS

Q: How attractive will the revenue pool be?

Given the optionality for global internet companies, we believe the aggregate revenue pool is attractive, though with varying margin profiles, depending on how the unit economics of each layer ultimately play out. Specifically, we believe the robotaxi service revenue pool is significantly larger than in-car monetisation and the AV OS, but likely comes with lower margins, given the competitive landscape and levels of marketing investments needed.

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from AVs?

Yes. Companies such as Waymo, Baidu, Uber, Lyft, Yandex and Didi are all preparing for a world of autonomous ridesharing. While some are further along than others, we believe the optionality relative to other non-internet companies places global internet companies in an advantageous position.

SECTOR VALUATION

Q: Could the trend to AVs lead to a change in sector valuation multiples?

Yes. We do not believe global internet stocks are currently pricing in these call options, which could result in long-term value creation for shareholders. For example, applying current market multiples to Alphabet's 'core' (desktop and mobile search and YouTube) FY 19E EBITDA and EBIT, we would argue that investors are currently ascribing little-to-no-value to the company's cash balance, emerging businesses (cloud and hardware) or long-term call options (including Waymo and life sciences efforts).

STOCK IMPACT

Q: What stocks will be impacted most positively and negatively?

We believe Alphabet and Yandex will be most positively impacted.

MOST FAVOURED

Stock	UBS rating	2018E PE	Potential revenue impact 2030E	Comment
Alphabet	Buy	31x	>50%	We believe Waymo presents upside to investor's long-term expectations for Alphabet, given little-to-no value is being ascribed to this initiative at this point.
Yandex	Buy	29x	NA	Although Yandex still only tests its self-driving taxis, we believe that, in the medium term, the company has potential to launch the technology commercially. If that happens, we think the Yandex.Taxi business should benefit meaningfully.

Q: What else should investors know? / The sector impact in more detail

As discussed within this report, we believe that much of the revenue opportunity/value within the autonomous ridesharing value chain will be enjoyed by those closest to the end user (i.e. the ridesharing platforms, in-car monetisation and/or controlling the OS). As such, we believe the inertia within the industry is driving most companies involved to move as fast as possible in the direction of this value. Specifically, the companies not currently operating a ridesharing platform at scale today (i.e. Waymo and OEMs) are developing their own technology to either roll out their own ridesharing platforms (even if just in select geographies) and/or to plug in fleets to current ridesharing platforms (while controlling the software/tech and in-car experience). On the other hand, current ridesharing platforms (i.e. Uber and Lyft) are developing their own technology in order not to get left behind should a large quantity of the autonomous vehicle supply choose to partner with the 'other' platform. The common theme at this point in the industry lifecycle is that, whichever direction they are coming from, companies recognise the importance of trying to control their own destiny and having optionality along the way.

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Global semiconductors

AV impact on sector … **Growth:**  **Margins:**  **ROIC:**  **Valuation:** 

Exposure to …

Semis/ software	Sensors	Maps	AV op. system	Robotaxi service	Fleet manage-ment	In-car time moneti-sation	AV production and sales	L2-3 ADAS options	Loss of volume
X	X							X	

KEY FINDINGS

Q: What were the most relevant findings from the expert interviews for our sector?

The two most relevant findings from the survey work are: (1) a broad consensus that there will be a need to all three sensor modalities – driving a need for significant sensor content in a L4/L5 autonomous vehicle; and (2) the compute capacity required will also be significant. In short, the interviews reinforced our view of the content opportunity that autonomous vehicles will bring to the semiconductor industry.

FINANCIAL IMPACT

Q: What will be the impact on the industry?

The trend towards rising autonomous vehicle penetration will accelerate the growth potential in the industry. We believe that the opportunity can accelerate the growth in the autos semiconductor sector and will drive up the weight of the automotive industry within the mix for overall semis.

REVENUE POOL

Today ($bn)	2030E ($bn)	2020-30E growth
~35	~104	3x

ATTRACTIVE-NESS

Q: How attractive will the revenue pool be?

Given general consolidation of supply in recent years within semis, we see this as a highly attractive opportunity and limited competition challenges (at least compared with other sectors).

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from AVs?

Further R&D and cost reduction is required to drive volume up, but this is a well-trodden path for which – more than other sectors – the semis industry is very well prepared and experienced with (given Moore's Law).

SECTOR VALUATION

Q: Could the trend to AVs lead to a change in sector valuation multiples?

Yes – as we progress towards the inflection point in AV demand, this could inflate the sector multiple.

STOCK IMPACT

Q: What stocks will be impacted most positively and negatively?

For any companies with exposure to autos, the trend should be generally positive (content growth opportunity). Our preferred names in the sector are Infineon, Intel and TSMC, for exposure to the theme.

MOST FAVOURED

Stock	UBS rating	2018E PE	Potential revenue impact 2030E	Comment
Infineon	Buy	23x	>50%	Key beneficiary of sensor content increase.
Intel	Buy	14x	>20%	Provider of compute capacity and has many engagements across industry, but little priced in.
TSMC	Buy	15x	NA	Leading-edge manufacturing capacity key L4/L5.

LEAST FAVOURED

Stock	UBS rating	2018E PE	Potential revenue impact 2030E	Comment
STMicro	Sell	19x	25-50%	Solid exposure to sensors, but risks elsewhere.

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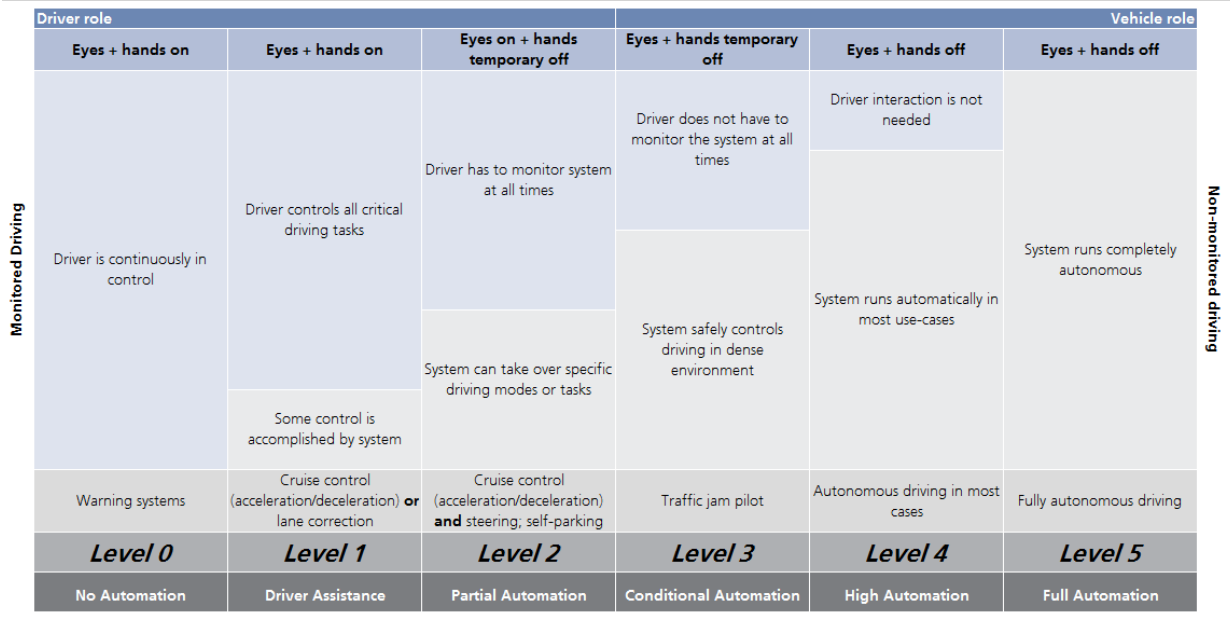
Appendix

Figure 84: Definition of autonomous driving levels



Source: SAE, UBS

Figure 85: UBS AV expert interview questionnaire

Sensor/computing suite

1. Which sensors are required for level 5 autonomous cars? How many of each?
2. At which level do you see the costs of the sensor and computing suite for a level-5 car in 2020 and 2025? Where is it today in your view?
3. Is there any system architecture you have come across that appears most/least promising to you?
4. Which suppliers do you consider most advanced in lidar technology? Does know-how in radar or camera provide an advantage also for lidar? Long range versus short range plus benefits from solid state? What is your view on the cost curve?
5. How relevant is V2V or V2X communication to enable faster adoption? Does it reduce the investments required in 5G?

Maps/positioning

6. Are HD maps a prerequisite for a scalable, profitable robotaxi business model?
7. Will HD maps replace the extensive testing that is currently necessary before putting robotaxis on the road in a specific city?
8. Who is the best automotive map provider, and who is most advanced in HD map coverage?
9. Will there be one dominant map provider that becomes "standard" for everyone?
10. Will the German OEMs and Conti have an edge through their ownership of HERE?
11. Can maps be a competitive advantage for OEMs/AV providers at all?
12. Is a 5G network essential for a level-5 AV?

Strategy

13. From an OEM's perspective, how important is a R&D partnership with a chip manufacturer (Intel, NVIDIA)?
14. Is it better for OEMs to rely on AV solutions from suppliers or to invest in their own AV system? Will they prefer to pick the best suppliers on a sensor-by-sensor basis, or do they want to buy at a "one-stop-shop"?
15. Should OEMs enter the mobility as a service/robotaxi space, or focus on the hardware (the vehicle) only?
16. Will the ride-hailing apps have a competitive edge over carmakers in a world of robotaxis, or will they lose relevance to OEMs or others?

17 Will the role of traditional auto suppliers in AV technology be stronger or weaker, compared with their OEM relationships today? Will providers of individual sensors or subsystems be at a disadvantage to full system suppliers?

18 Will there be a competitive edge for early movers in AV, or will commoditisation happen that quickly that any investment to lead the pack will not pay off?

19 How important is it to recruit software engineers in Silicon Valley or Israel? Are other locations at a structural disadvantage?

Waymo

20 How will Waymo enter the market? Will it run its own commercial robotaxi fleets, or will it only do pilots to validate the technology?

21 Which type of OEMs/ride-hailing apps/other fleet operators will buy the Waymo solution? What is the risk that no major OEM wants to buy its technology ("selling the soul"), and how would Waymo likely respond if that is the case?

22 What do you think is the key competitive edge of Waymo over the other players? Where is it at a disadvantage?

Tesla

23 Do you think Tesla can be among the leaders in AV in the current strategic setup? Can it close the gap in vision after the end of the Mobileye partnership?

24 Is it an advantage or disadvantage that it relies on camera, ie, does not add lidar to the system? Will regulators approve systems without lidar redundancy?

Who is leading (population: OEMs, OE suppliers, tech companies, fleet operators)?
Give us the three players (by relevance) you think are most advanced on/best positioned for…

25 AV sensor suite/hardware know-how
26 Software/algorithms
27 Real-life testing of AV
28 Monetising ADAS (level 2, 3) in a traditional vehicle ownership model
29 Mobility services that can be used as a platform for running a robotaxi fleet
30 System integration: AV solution provider to OEMs

Can you share your other views/comments (if any) on the competitive positioning of:

31 Daimler
32 Volkswagen
33 BMW
34 General Motors
35 Ford
36 FCA
37 Delphi/Aptiv
38 Continental
39 Hella
40 Bosch
41 Uber
42 Apple

Ecosystem

43 How will the robotaxi landscape play out? Winner takes it all, or several regional champions, or even more fragmented?
44 How important will collaboration with cities be? Will robotaxis be part of a public transport system, and if so, which players are best positioned to win partnerships/concessions?
45 Will cities/municipalities limit the number of robotaxis or robotaxi providers through regulation (concessions or similar)?
46 Regulation and liability risk: Which regions/countries are most/least advanced? Which markets will be attractive for robotaxi fleets in the 2020-25 timeframe, and which are "no-go" areas from a regulatory/legal viewpoint?

Source: UBS

***UBS Evidence Lab** provides our research analysts with rigorous primary research. The team conducts representative surveys of key sector decision-makers, mines the Internet, systematically collects observable data, and pulls information from other innovative sources. They apply a variety of advanced analytic techniques to derive insights from the data collected. This valuable resource supplies UBS analysts with differentiated information to support their forecasts and recommendations—in turn enhancing our ability to serve the needs of our clients.*

For this report, we partnered with UBS Evidence Lab to analyse millions of patent records filed in the US Patent and Trademark Office.

Valuation Method and Risk Statement

Risks in the global automotive sector include, but are not limited to: The global economic cycle, currency exchange rate moves, interest rate moves, raw materials prices, and the global credit cycle. Further, the industry currently undergoes a phase of disruption from the shift to electric and autonomous cars, and the emergence of mobility as a service, which could gradually replace car ownership.

Required Disclosures

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12-Month Rating	Definition	Coverage[1]	IB Services[2]
Buy	FSR is > 6% above the MRA.	46%	25%
Neutral	FSR is between -6% and 6% of the MRA.	39%	23%
Sell	FSR is > 6% below the MRA.	15%	12%
Short-Term Rating	**Definition**	**Coverage[3]**	**IB Services[4]**
Buy	Stock price expected to rise within three months from the time the rating was assigned because of a specific catalyst or event.	<1%	<1%
Sell	Stock price expected to fall within three months from the time the rating was assigned because of a specific catalyst or event.	<1%	<1%

Source: UBS. Rating allocations are as of 31 March 2018.
1:Percentage of companies under coverage globally within the 12-month rating category.
2:Percentage of companies within the 12-month rating category for which investment banking (IB) services were provided within the past 12 months.
3:Percentage of companies under coverage globally within the Short-Term rating category.
4:Percentage of companies within the Short-Term rating category for which investment banking (IB) services were provided within the past 12 months.

KEY DEFINITIONS:Forecast Stock Return (FSR) is defined as expected percentage price appreciation plus gross dividend yield over the next 12 months. In some cases, this yield may be based on accrued dividends. **Market Return Assumption (MRA)** is defined as the one-year local market interest rate plus 5% (a proxy for, and not a forecast of, the equity risk premium). **Under Review (UR)** Stocks may be flagged as UR by the analyst, indicating that the stock's price target and/or rating are subject to possible change in the near term, usually in response to an event that may affect the investment case or valuation. **Short-Term Ratings** reflect the expected near-term (up to three months) performance of the stock and do not reflect any change in the fundamental view or investment case. **Equity Price Targets** have an investment horizon of 12 months.

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Company Disclosures

Company Name	Reuters	12-month rating	Short-term rating	Price	Price date
Alphabet Inc.[6b, 6c, 7, 16b, 22, 26b]	GOOG.O	Buy	N/A	US$1,054.79	07 May 2018
Amazon.com[16b, 22]	AMZN.O	Buy	N/A	US$1,600.14	07 May 2018
Apple Inc.[7, 16b]	AAPL.O	Buy	N/A	US$185.16	07 May 2018
Aptiv PLC[16b]	APTV.N	Neutral	N/A	US$93.28	07 May 2018
Autoliv[16b]	ALV.N	Sell	N/A	US$139.71	07 May 2018
Baidu, Inc.[4, 5, 6a, 16b, 22]	BIDU.O	Suspended	N/A	US$258.24	08 May 2018
BMW[7]	BMWG.DE	Neutral	N/A	€91.56	07 May 2018
Continental[7]	CONG.DE	Buy	N/A	€228.20	07 May 2018
Daimler[7]	DAIGn.DE	Buy	N/A	€66.83	07 May 2018
Denso[7]	6902.T	Neutral	N/A	¥5,597	08 May 2018
FCA[7, 16b, 22]	FCHA.MI	Neutral	N/A	€19.23	07 May 2018
Ford Motor Co.[4, 6a, 7, 16b]	F.N	Buy	N/A	US$11.34	07 May 2018
Geely Automobile[2, 4, 16a]	0175.HK	Neutral	N/A	HK$22.95	08 May 2018
General Motors Company[6b, 7, 16b]	GM.N	Buy	N/A	US$36.34	07 May 2018
Great Wall Motor[13, 16a]	2333.HK	Buy	N/A	HK$8.10	08 May 2018
Hella	HLE.DE	Buy	N/A	€53.60	07 May 2018
Honda Motor[16b]	7267.T	Buy	N/A	¥3,630	08 May 2018
Infineon Technologies AG	IFXGn.DE	Buy	N/A	€23.52	07 May 2018
Intel Corp.[6b, 6c, 7, 16b, 26c]	INTC.O	Buy	N/A	US$53.33	07 May 2018
Magna International[16b]	MGA.N	Neutral	N/A	US$60.81	07 May 2018
Micron Technology Inc[16b]	MU.O	Sell	N/A	US$48.48	07 May 2018
Nissan Motor	7201.T	Sell	N/A	¥1,113.0	08 May 2018
NVIDIA Corp[16b]	NVDA.O	Neutral	N/A	US$248.68	07 May 2018
Porsche	PSHG_p.DE	Buy	N/A	€71.60	07 May 2018
PSA Group	PEUP.PA	Neutral	N/A	€20.09	07 May 2018
Renault[7]	RENA.PA	Buy	N/A	€89.75	07 May 2018
Renesas Electronics	6723.T	Neutral	N/A	¥1,071	08 May 2018
Rohm	6963.T	Neutral	N/A	¥10,440	08 May 2018
SAIC Motor	600104.SS	Neutral	N/A	Rmb34.06	08 May 2018
Samsung Electronics[22]	005930.KS	Buy	N/A	Won52,600	08 May 2018
Schaeffler	SHA_p.DE	Sell	N/A	€13.09	07 May 2018
SK Hynix	000660.KS	Neutral	N/A	Won83,500	08 May 2018
STMicroelectronics[5, 7, 16b]	STM.PA	Sell	N/A	€19.92	07 May 2018
Taiwan Semiconductor Manufacturing[16b]	2330.TW	Buy	N/A	NT$228.00	08 May 2018
Tesla, Inc.[16b, 22]	TSLA.O	Sell	N/A	US$302.77	07 May 2018
Texas Instruments Inc[16b, 26d]	TXN.O	Sell	N/A	US$104.51	07 May 2018
TomTom	TOM2.AS	Buy	N/A	€8.29	07 May 2018
Toshiba[2, 4]	6502.T	Buy	N/A	¥294	08 May 2018
Toyota Motor[7, 16b]	7203.T	Neutral	N/A	¥7,155	08 May 2018
Valeo	VLOF.PA	Buy	N/A	€57.56	07 May 2018
Visteon Corp.[4, 6a, 6b, 7, 16b]	VC.O	Neutral	N/A	US$124.62	07 May 2018

Company Name	Reuters	12-month rating	Short-term rating	Price	Price date
Volkswagen[7, 13]	VOWG_p.DE	Buy	N/A	€176.22	07 May 2018
Western Digital Corp[16b, 26a]	WDC.O	Neutral	N/A	US$78.52	07 May 2018
Yandex N.V.[16b]	YNDX.O	Buy	N/A	US$34.08	07 May 2018

Source: UBS. All prices as of local market close.
Ratings in this table are the most current published ratings prior to this report. They may be more recent than the stock pricing date

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26b. A U.S.-based global equity strategist, a member of his team, or one of their household members has a position in Alphabet Inc.
26c. A U.S.-based global equity strategist, a member of his team, or one of their household members has a position in Intel Corp.
26d. A U.S.-based global equity strategist, a member of his team, or one of their household members has a position in Texas Instruments Inc.

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