ADAScadabra!

a framework to understand how ADAS, ride-sharing, and Autonomous driving play out

Pierre Ferragu	+1 646 681 4616	pierre@newstreetresearch.com
Rolf Bulk	+44 20 7375 9118	rolf@newstreetresearch.com
Antoine Chkaiban	+44 20 7375 9126	antoine@newstreetresearch.com
Benjamin Harwood	+44 20 7375 9160	ben@newstreetresearch.com
Derek Mogull	+1 646 681 4638	derek@newstreetresearch.com

I have had the question more and more in recent weeks: Pierre, when do we get to read your next "Tech Byte"? I therefore thought we'd start a new similar research series before Christmas. Our 'Tech Blast' will try and address controversial & speculative topics that we think are ill-addressed by the press, Wall Street, or the industry, and on which we think we can bring a differentiated framework to help investors make sense of what the future could look like. Those who have followed our tergiversations about the **'Internet of Nothing'**, **'Artificial Stupidity'** and the **'Unified Theory',** will recognize in this piece the voluntarily provocative, insolent, and frankly arrogant tone that characterized our past series. Apologies in advance: don't take the tone seriously, but do pay attention to the content, we do believe it can add tremendous value to your investment process, just by providing a completely different perspective on important matters.

Exhibit 1 – Autonomous: Pipe Dream

Honda's 'Wander' concept car

Source: Honda and NSR analysis.

Exhibit 2 – Assisted: Already Real

Tesla Autopilot Dashboard

Source: Tesla and NSR analysis.

For our first opus we thought we would address the most mis-framed topic we see debated these days: ADAS. At the time of initiation of our new coverage, we summarized our views on the matter in a single slide **(exhibits 1 & 2)**.

In short, we said ADAS has two personalities, depending on what the "A" stands for.

If it is "**Autonomous**", then ADAS is a pipe dream that will have, for investors, no other status than the one of a bubble or an option value for about another decade or two, but has interesting side implications.

If it stands for "**Assisted**", then it is a pretty cool investment theme, with names we like in the value chain and likely some impact on the premium car market.

Our objective in this note is to first sketch a framework that can help understand ADAS market dynamics today. Building on that, we will make our prediction on how we see the market evolving over the next two decades. We will conclude, as always, with implications for investors.

Key Takeaways

- **Full and ubiquitous autonomy is a pipe dream.** It won't happen before decades. In the meantime, the question is who makes money from near-autonomous driving?
- **Waymo's scale out will be too time and capital consuming:** decades and hundreds of billions of dollars. The only way forward is partnering with ride-sharing leaders.
- **Mainstream advanced autopilot is a reality.** Tesla plays it software-defined, aiming for a straight shot; other manufacturers are cursed, limited to a hardware-defined options.
- **Assets we prefer to play Autonomy:** Ride-sharing regional leaders, radars, CMOS image sensors… and of course Tesla.
- **The straight flush is…**The combination of ride-sharing and autonomous driving… Masa and the Vision Fund got this before us.

I ADAS competitive dynamics

Our Boston Consulting Group background means we love to pretend finding answers to complicated problems by putting them down into a two-by-two matrix. ADAS will be no exception. We like to think about it along two dimensions. One is the level of service, from L1 (collision warning, i.e. basic assistance) to L5 (your car picking up your kids at school by itself). The second dimension is adoption, i.e. the number of cars on the road, or the number of miles driven by the technology.

On that matrix, the Holy Grail is easy to spot. It is the top right corner, worth trillions of dollars in market capitalization… but probably out of reach for decades. The real interesting question is how one gets there. We have identified three paths conceptually sensible, and observable in the real world.

The cliff: It is the way Waymo and a long list of other pretenders are going: Getting the technology right for full autonomy first, expanding the fleet next. There is barely a tech giant without a (more or less secretive) Autonomous Vehicle project. They all claim to have autonomous cars, although still with heavy human supervision. Not so long ago Waymo cars were still requiring two operators (one checking on the car, one checking on his buddy not falling asleep…), they just decided to come down to one operator, and cars will keep being monitored remotely. All these projects are on a race towards autonomy, competing to drive up the number self-driven miles and drive down the number of human interventions per self-driven mile. **(exhibit 3)**

Exhibit 3 – The race towards Autonomy

Major players test miles and disengagement rates

Company	Test miles on public roads LTM[1]	Disengagement rate per 1000mi
Waymo	352 544	0.2
Renault-Nissan	5 007	4.8
Cruise (GM)	131 676	5.7
Baidu	1 971	24
Delphi	1 810	45
Bosch	1 454	411
Mercedes-Benz	1 088	774

[1]As of November 2017
Source: California Department of Motor Vehicles, The Economist and NSR analysis.

The creep-up: This is more what the traditional auto industry is doing[1], introducing progressively assisted-driving features. It started in 1967, with electronic cruise control (My 1978 Silver Shadow has one… pretty scary!), and the slow introduction of enhanced features: parking assistance, lane departure warning, adaptive cruise control, self-parking, auto-pilot, navigator on auto pilot, etc. **(exhibit 4)**

The creep-up is fundamentally **hardware-defined**. It progresses towards the left with the spread of hardware in the installed base, but unfortunately, new hardware

[1] In all fairness, all auto manufacturers are also working on their "cliff" projects with small fleet of autonomous vehicles being tested around the world, but the bulk of what they do is more going down the creep-up route.

supporting new functionalities pop up from zero all the time, making the top-level installed base very narrow.

Exhibit 4 – A Brief history of ADAS

Major ADAS features introduced over time

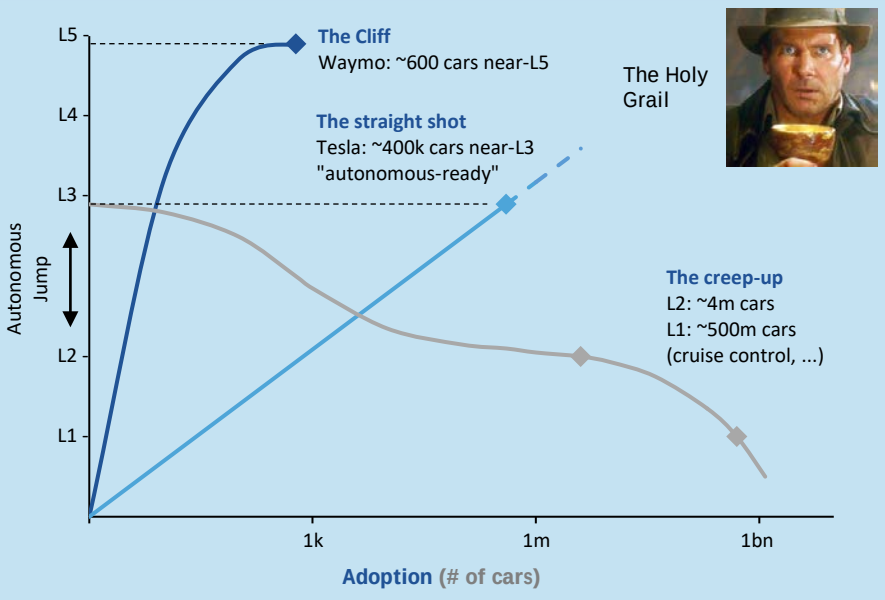
Date	Feature	Description
1967	Electronic Cruise Control	Mechanical versions even earlier than that. Maintains constant speed regardless of the slope.
1992	Adaptive Cruise Control	Cruise control that detects and adapts to the surrounding traffic automatically
2001	Lane Departure Warnings	Warns the driver if it appears the vehicle is beginning to drift out of its lane, latest versions follow lanes
2003	Parking Assistance	Estimates the size of the parking space and maneuvers the vehicle appropriately
2015	Autopilot	Combines automatic lane change (after signal is applied), adaptive cruise control, and sign recognition to regulate speed and location
2018	Autopilot with Navigator	Currently in beta, general release in coming weeks. Automatically overtake cars on the highway and take exits and interchanges
2018	GM Super Cruise	Only works on Interstates and highways that Cadillac has already mapped and forces the driver to be looking at the road (sight tracker)

Source: BCG and NSR analysis.

The straight shot: This is How we'd qualify Tesla's approach. In a very Elon Musk mindset, Tesla goes both for full autonomy *and* broad adoption, which puts the company on a unique trajectory: a straight line towards the Holy Grail. The interesting aspect of Tesla's approach is that it is equipping all cars with the ADAS hardware the company considers sufficient to reach full autonomy over time. In all fairness, Tesla and its aficionados are probably the only ones to believe that, but their completely unique positioning is worth highlighting. Whether or not they are right, it puts them in a totally unique position, while the Cliff and the Creep-up are fairly crowded spaces. The approach of Tesla is **software-defined**; improving its technology through software updates (and only partial and handy hardware updates). **(exhibit 5)**

Exhibit 5 – The different approaches to ADAS

Adoption per level of autonomy (# of cars)



Source: Waymo, Tesla, Yole, BCG and NSR estimates and analysis.

II How things play out? Who wins?

Our above framework may sound fairly obvious and not very insightful. But one could have said the same of the first BCG matrix. What is interesting is that with that chart in hands, one can start running scenarios and understand how things can play out.

II.1 What (we think) technology can and cannot do

a) No universal and scalable L5 any time soon

It is a pipe dream – on that front, everybody, including our dear protégé, Tesla, will fail. I give zero credit to Elon Musk's dream of a fleet of millions of self-driving Tesla's hanging around and paying for their lease as cabs while their owner is at the gym.

This is our prediction, and it is based on a combination of astute observations and more fundamental thinking.

Astute observations: One will notice that Waymo, the master of full autonomy, is going small. It's first service, going live as we write this, will cover only a portion of the Phoenix suburban area. It will be open to only a closed circle of existing users. Last but not least, cars will still require an on-board supervisor and remote supervision. Note this will be progress, as cars need two today, one to check on the car and one to check on the one checking on the car. I let you discover in **exhibit 6** what John Krafcik, Waymo's CEO, thinks about ubiquitous autonomous vehicles: decades away…

My observation is therefore very simple: total ubiquitous autonomy is absolutely nowhere on the radar screen of anybody but lousy journalists and analysts. Tangible plans to which serious people can attach a reasonable timeline are

only about very narrow use cases such as closed, campus, highly supervised vehicles, and long-haul trucking. Don't take me wrong: this is great and highly valuable (we don't have enough truck drivers), but it is not ubiquitous autonomy.

Exhibit 6 – Waymo's CEO on full autonomy

John Krafcik, WSJ D.Live tech conference, CA.

"At the same time right now, driverless cars are here, they're truly here, people are using them, humans are using them, I was in one on Monday in Phoenix, at the same time they're not ubiquitous, and it's going to be a really long time, I think decades, before you see this technology everywhere in the world."

Source: Wall Street Journal and NSR analysis.

More fundamental thinking: Neural networks and other machine-learning building blocks leveraged for autonomous driving all share the same central feature. ***They are stupid!*** For more on this, I invite you to source a pirate copy of the piece we wrote on the topic a couple of years ago[2]. In short, we defend Artificial Intelligence is all but intelligent, doesn't understand situations, but classifies them. On that basis, our claim is straightforward: totally autonomous driving will always require a dose of common sense and improvisation that A.I. and Machine Learning cannot deliver today. Waymo is likely at a point where it feels it has classified 99.9% of driving situations in a narrow area of Phoenix and can start letting closely supervised autonomous cars go around with clients. At some point these cars might be unleashed with only remote supervision. But they remain stupid, and for that reason, autonomous driving will never scale-up outside of extremely well-supervised environments. The underlying technology is probably cutting edge and will be deployable elsewhere but learning driving situations elsewhere will likely require heavy new specific learning. It will also require lengthy specific testing for the new area, and supervision going from super heavy (two individuals per car) down to lower supervision (remote).

And this is not about location only, it is also about situations. I have never driven in Phoenix, but I assume it is fairly uneventful compared to my hometown… **(Exhibit 7)**. How will autonomous cars deal with insertion in dense and rapid traffic in areas like the Place de l'Etoile? Isn't each single crossing of the Place a new adventure of its own, worth writing a novel?

Exhibit 7 – Many areas are not well suited for ADAS

Complex traffic at Place de l'Etoile, Paris

Source: Reddit and NSR analysis.

In summary, ***near***-autonomous driving is, based on Waymo's recent announcement, already a micro-local reality in Phoenix. The road to universal full autonomous driving at scale, though, is no slam dunk from here. We will have to speculate how we can get there, and can already tell you it will be ***time-consuming***, ***painful***, and ***capital intensive***.

It will also always be "***asymptotic***". I don't think vehicles will ever be fully autonomous. Material supervision will continue to be required forever. Bear with us, it is the topic of the next sub-section.

b) L3 ADAS is virtually on

(oops, I almost crashed as I was writing this, while my Model X was on autopilot). L3, which we simply qualify as a car driving by itself in some conditions, as long as a human operator stays in position to take over in a matter of seconds and keeps an eye on odd situations, is not widely available yet, but about nailed.

Exhibit 8 – Auto OEMs have expensive ugly prototypes

Mercedes-Benz's F015 concept car

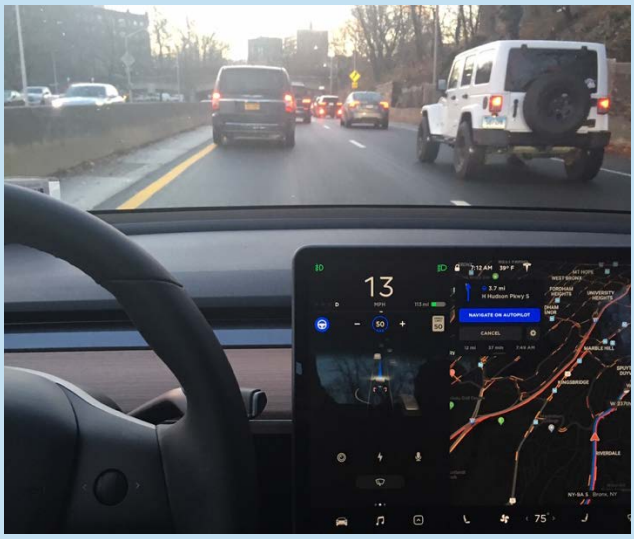
Source: TechCrunch and NSR analysis.

[2] Artificial Stupidity – published December 16th 2016, available on the Bernstein website…

Most auto manufacturers have expensive ugly prototypes at this level **(exhibit 8)**, and Tesla manufactures in high volumes cars which are not very far from that **(exhibit 9)**, and even there for some maverick drivers. 😬

Exhibit 9 – Tesla manufactures in high volume near-L3 cars

Commuting to work with navigate on autopilot in my Model 3



Source: NSR analysis.

From where we stand today, the development of L3 ADAS isn't a technological story anymore. It will really stem from two forces. ***Affordability:*** we count on auto-manufacturers to make that happen through sacrificed pricing, as always. ***Perceived safety***, which is a great example of totally performative measure[3]: L3 will be considered safe the day:

1) Public opinion decides what it doesn't know and will never know about autopilot safety is alright, and settles on what behavior is acceptable or not under autopilot[4];

2) Authorities, as always, a few years behind, bless the aforementioned public opinion by making it laws and regulations.

In other words, when it will become unfashionable to bash Tesla's autopilot at dinner parties, broad adoption will be around the corner, whatever the actual readiness and safety of the technology. Behaviors will adjust to whatever is available. It will become perceived as safe under generally accepted conditions, and regulation will follow shortly.

You see where we are coming to. Adoption of L3 ADAS is on and will be fast.

c) Is lidar required to achieve L5 ADAS?

We don't know, and we couldn't care less. We just demonstrated (some would say we only asserted, which is fair pushback) that full universal autonomous driving will always be an asymptotic pipe dream. On that basis, our view is that Lidar may – or may not, help get closer to the asymptote, which, we will see, is unlikely to matter much.

Our regular readers know we have a positive bias on Tesla, and therefore would tend, if anything, to bend towards the bear camp for Lidar. Here are the reasons why.

First, Lidars don't add much as a technology. **Exhibit 10** shows that on all dimensions, if you have cameras and radars, you are covered. Only exception would be extreme situations such as tracking object height in poor lighting conditions. As the reader now understands, our conviction is that ADAS in extreme situations will either be limited to narrow use cases that will ramp very slowly, so Lidar won't be mass-market.

Exhibit 10 – Combining cameras & radars works in most cases

Performance of sensors at different tasks & in different conditions

	Camera	Lidar	Radar
Cost	strong	weak	medium
Illumination			
Noise			
Range			
Resolution			
Weather			
Velocity Tracking			
Height Tracking			
Distance Tracking			
Classification			

Source: David Silver (Medium) and NSR analysis.

Second, we find the main argument for lidar to lack ground in our own framework. Lidar proponents argue it is required so that sensors can always provide three inputs to reduce to virtually zero the risk of misperception, i.e. of sensor input to lie about the real world. I think this is a wrong engineering mindset – ADAS safety is never going to come from any sort of functional safety (I know my sensors can't lie) but more from system safety (How does my car behave, when taking into account that sensors can sometimes lie).

Let's take a step back. Which car is designed to drive as fast in a snow storm as on a perfect summer day? None. Why wouldn't you introduce similar variability in the capabilities of an ADAS system? Near-level-5 when conditions are good, disabled in a snowstorm. Of course, it doesn't help the pipe

[3] We invented this type of measurement, in which what you measure is defined by how you decide to measure it. Amateurs of both Habermas' linguistic and quantum physics will understand where we come from.

[4] Let's be blunt and make this first Tech Blast a provocative one (but only in the footnotes). The key question is whether sexual intercourse under autopilot is a major risk factor.

dream of Waymo cars driving by themselves year-round in New York, but for you and me, it is great value proposition.

These elucubrations may sound vain and trivial at this point in the story. They are not. All our framework rests on them.

II.2 THE CLIFF: remember Google Fiber?

Those going after 'the cliff' will be doing just that for a very long time: climbing up a cliff. It means a slow progression, discovering the path step by step. It also means high risk of fatal accidents as the path gets discovered and reveals unanticipated pitfalls, and obviously maximum focus on safety as a result, which implies slow and costly progress.

Waymo is the lead climber here, obviously, and sets the path. Here is what we know of the Waymo way:

a) Years of preparation to get to impressive statistics before going live (look back at **exhibit 3**: 1 human intervention every 5,000 miles is pretty amazing).

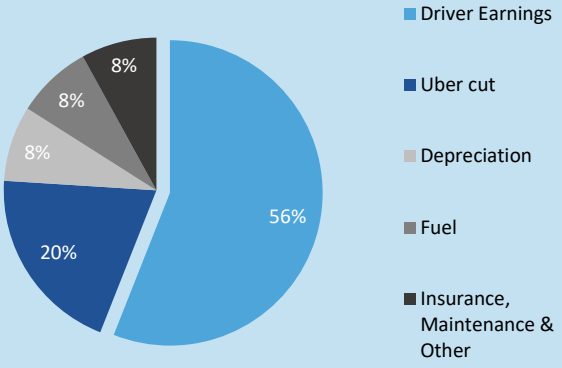
b) Start small and slow: Waymo only started commercial operations this month, in a narrow suburban area of Phoenix, with a closed group of selected users.

c) "belt & suspender" in terms of safety set up, with an operator in each car for now. (Poor guys… boring job, right? More fun to be a taxi driver.)

Motivation is high. Current economics of ride-sharing and taxi services say the driver is just over half of the cost and represents ~$25k per year for 40h per week drive. This is the sort of value autonomous driving can unlock. **(exhibit 11)**

Exhibit 11 – The driver accounts for ~56% an Uber ride's cost

Uber ride cost breakdown (%)

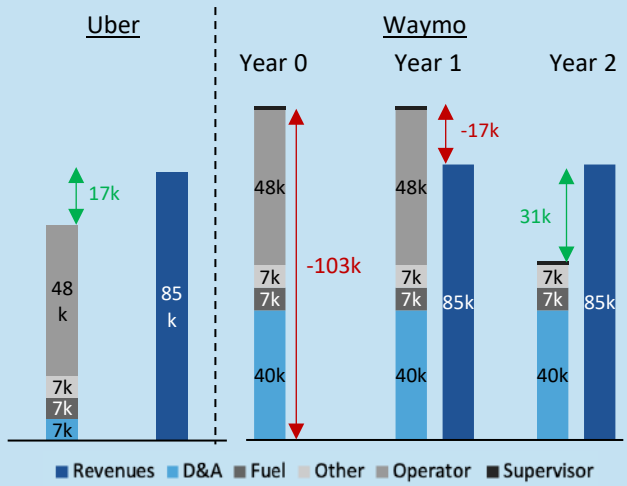


Source: Uber, Ridester, Therideshareguy and NSR estimates and analysis.

That is a typical "moonshot" perspective. Let's look at the growth path for a Waymo. In our understanding of what the technology can and cannot do, Waymo will be able, in a few months or a few years from now, to offer in a small area of Phoenix real self-driven cabs. On the way there, the service, with an operator in every car, won't be profitable at all, and actually likely lose as much money as Uber would make on a similar area, with crap cars and cheap drivers. **(exhibit 12)**

Exhibit 12 – Waymo's path to profitability takes years

Profit contribution of 2 Uber cars vs 1 Waymo car (US$k)

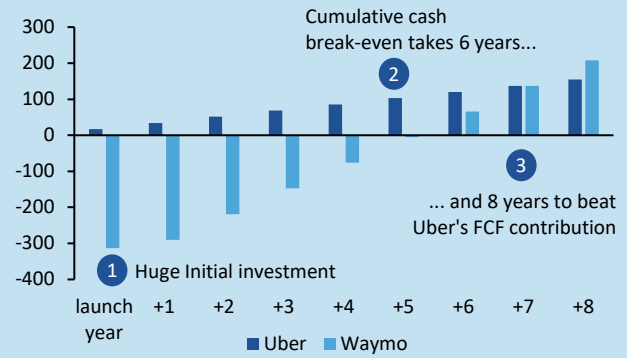


[1]Two Ubers each driven 40h/week, vs. a single Waymo driven 80h/week
Source: Uber, Waymo, Ridester, Therideshareguy and NSR estimates and analysis.

And this is what it will cost Waymo to grow. Once the first area of Phoenix becomes sustainable (supervision cost decrease below ride-sharing benefits), expansion can start. For every area, Waymo needs to invest in an additional fleet, have it drive without clients for enough time to get the local learning to a point where getting clients onboard with an operator becomes acceptable, and eventually replace the operator by a remote supervisor. That is a monster cash profile: huge initial investment and years to recoup it. **Exhibit 13** gives you a rough idea of how it can look on a per-car basis: peak cash burn of over 300$k in year one, six years to recoup the initial cash out, eight to break even with the base ride-sharing model.

Exhibit 13 – The Waymo model requires a lot of capital

FCF contribution of 2 Uber cars vs 1 Waymo car[1] (US$k)



[1]Two Ubers each driven 40h/week, vs. a single Waymo utilized 80h/week
Source: Uber, Waymo, Ridester, Therideshareguy and NSR estimates and analysis.

Don't get me wrong. I don't say it is a bad business model, it is a decent one, with a contribution cash return on invested capital above 20%, but it is an extremely capital intensive one. In these days where capital seems to flow from everywhere, it might not be an issue…

… But there is another catch. This business model assumes no competition. Will Waymo develop commercially without triggering a price war with ride-sharing companies? Isn't there another monster cost to expect in taking down established ride-sharing players?

This whole thing reminds me of Google Fiber. They were very serious about it. The clear moonshot: if you have fiber all around the place you can make $50 cash profit per month per user, an order of magnitude more than what search is, and getting fiber to pass a home is only a $1000-4000 investment. That's a no brainer.

There is one catch, though. In this business case you know well how much you spend, less so how much you will recoup. With 125m households in the U.S., a nationwide Google Fiber investment was a >$200bn capex. Then, you know you can eventually make $50 per month per home in contribution profit, but you don't know how long it will take you to get there, and how costly it will be to win all this business, that you will have to snatch away from well entrenched pre-web-era companies.

That's occasionally the problem with moonshots. It looks good on paper for a smart guy not used to competition (read a Google executive), but in the real world, it sometimes meets tough real-world frictions.

We all know how it all ended. Google Fiber was dumped. In October 2016, after initial rollouts proved more expensive and time consuming than anticipated, all expansion plans were put on hold[5].

In summary, Waymo growing by itself will burn cash for decades. The end game will always look amazing, but always a decade or two down the line. Look first at how much it costs to take an Uber off the ground. Tens of billions of dollars. And that was on green field, with no competition. Commercially, for Waymo to take business from established ride-sharing companies will by itself cost hundreds of billions. That will add to the bill of engulfing $280k by launched car… that is $300bn to replace Uber drivers in operation today, assuming one Waymo replaces two of them!

At this point our conclusion is pessimistic: The cliff is too high, the climb is too slow and too expensive. But we wouldn't want Waymo to shut down operations! There is one way the cliffhangers can jump up the Sylvester Stallone way. **(exhibit 14)**

Exhibit 14 – The cliffhangers can jump up

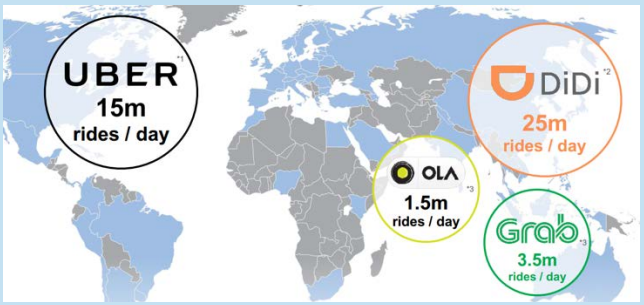
Sylvester Stallone in Cliffhanger

Source: GeekTyrant and NSR analysis.

This is partnering with established ride-sharing operations. It is not just us thinking it this way, obviously. All serious ride-sharing players have understood two things. The first one is that autonomous driving can massively improve their economics, and, concurrently, the second one, is that an autonomous driving competitor would kill them. That's the reason why they all have very serious autonomous driving plans. That's also the rationale we understand behind the participations of SoftBank's Vision Fund in key ride-sharing and autonomous driving assets. **(exhibit 15)**

Exhibit 15 – Softbank has a global Ride-sharing portfolio

Softbank's Ride-sharing portfolio



Source: Softbank and NSR analysis.

To me, ride-sharing is a very straight forward business to understand: Natural duopoly. It reminds me of the good old yellow page business. The two initial market leaders gather momentum, dry out the market opportunity for followers, and in the end-state, the economics of the scale leader are

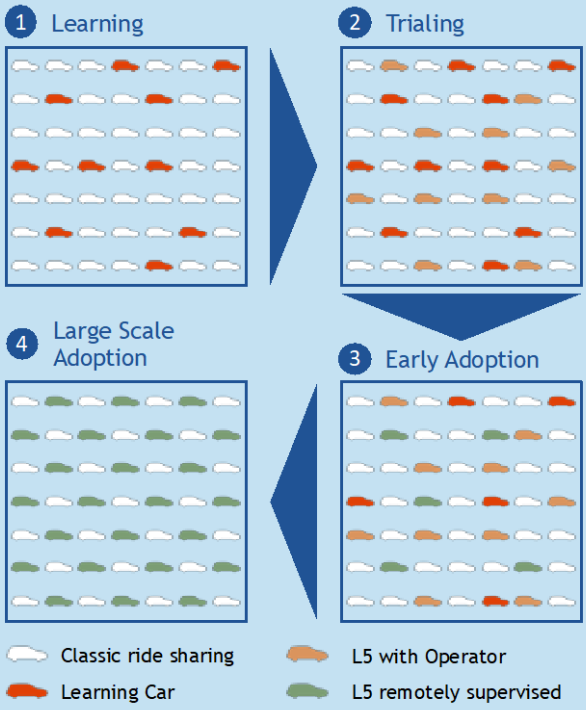
[5] Our esteemed colleague Blair Levin developed an interesting perspective in the Harvard Business Review on the matter, actually calling Google Fiber a success for the way it fostered investments at incumbent service providers, supporting the development of its own content business. An excellent perspective we recommend reading, and that could apply (in an extremely speculative way) to Waymo: Google will eventually put Waymo on hold, the day autonomous driving becomes so ubiquitous that it frees up more eyeballs for Google's core advertising business! https://hbr.org/2018/09/why-google-fiber-is-high-speed-internets-most-successful-failure

outsized, while the challenger survives under the pricing umbrella of the former. (A simple way to remember that: Long Uber, Short Lyft – check our next section for more details).

On that basis, only the ride-sharing market leader will have a go at deploying autonomous driving. Here is what it will look like: In every location, it will deploy a limited number of cars with full learning capabilities, and a larger number of cars with data gathering capabilities. With that initial limited investment, the operator will climb the "local learning" cliff rapidly with minimal expense. Once there, the company will introduce a commercial service at a limited extra-cost, even including on-board operators, and will be able to insert fully autonomous cars in its service very rapidly, directing them to its easiest and safest rides. Eventually, maybe 10 or 20 years down the line, a large portion of cars will be self-driving, but the fleet will remain largely manned as well, in a **sustainable hybrid model**. **(exhibit 16)**

Exhibit 16 – Ride-sharing leaders are best positioned for ADAS

Market share of light vehicle transportation offers at different steps



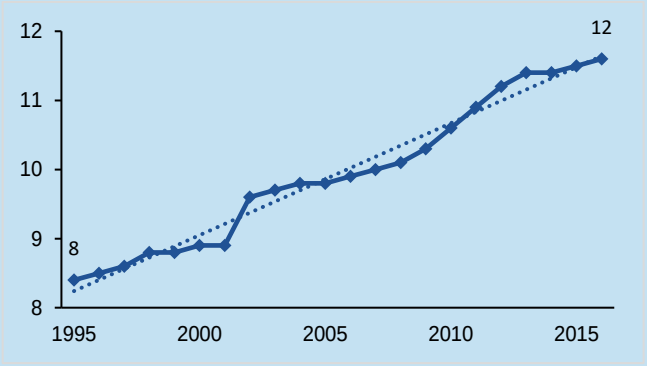
Source: NSR estimates and analysis.

II.3 The creep-up: paced by refresh cycles and affordability

A curse: replacement rates. The creep-up has a real issue: replacement rates in the car industry. They are terrible and only getting worse. According to the data we could find, they stood at eight years in the US in 1995, creep up all the time, and are likely in the 12-year region today. **(exhibit 17)**

Exhibit 17 – Cars last 50% longer than they did 20 years ago

Average car life in the US (years)

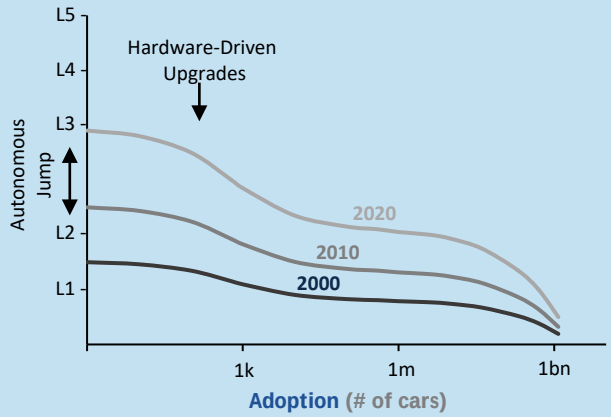


Source: Bureau of Transportation, Zero Hedge and NSR analysis.

That means the current creep-up curve will evolve like a snake eating an elephant. It will keep progressing on its right end, crawling along the L1 level, as L1 becomes ubiquitous on all cars. In the meantime, manufacturers are slowly introducing L2 today, and will get to L3 only over time, in the higher end of their product range, i.e. very slowly. **Exhibit 18** shows how we expect the creep up curve to evolve over time.

Exhibit 18 – Creep-up is cursed by hardware defined upgrades

Adoption per level of autonomy over time (# of cars)



Source: Yole, BCG and NSR estimates and analysis.

A tragedy: hardware-defined. ADAS is hardware-defined for the up-creeper. They cannot shoot for the moon because they must deploy the next generation of hardware spread in their installed base before they can move up. And obviously this takes time, as hardware can be added in scale only as unit costs decline, which comes with scale. A real tragedy, and as in any good tragedy, there is a vicious circle at play, making things only worse.

As long as hardware is not in the installed base, the ADAS system of the up-creepers cannot learn much, and as long as the ADAS system is not great, thanks to what it has learnt, it

is challenging to get drivers to pay for hardware. Moreover, the economics of Auto manufacturing are too tight to finance it. Assuming a proper ADAS hardware costs $2,500 (which might be a tad generous), it represents two thirds of the gross profit of a $35,000 sedan.

When I think of the fate of the traditional auto industry in this whole story, it makes me cry.😢 They simply cannot win, and that is a problem to add on top of the electrification curse they are already under. We don't cover auto manufacturers, but we can tell you that being a premium one is not going to be fun in the next ten years.

II.4 The straight shot: Best near-term momentum

All in, all the time. Tesla is the Navy Seal of auto manufacturing. Elon Musk is a maverick and a marketing genius[6], and only such combination could go down that route: The only way to make ADAS a reality is to put the ultimate hardware in all cars on day one, release a basic version of the product immediately, get people excited about it, pay for it, using it, learn from it, and progress from there. That is Tesla's autopilot virtuous cycle. **(exhibit 19)**

Exhibit 19 - Tesla's autopilot drives a virtuous cycle

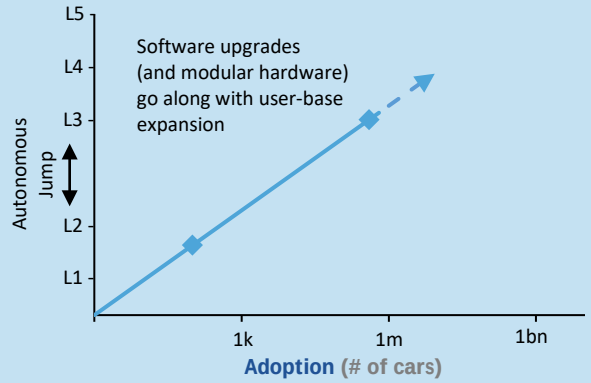
Tesla's ADAS virtuous cycle

Source: NSR analysis.

That means a lot. That means Tesla's approach is **software-defined**, and it isn't a tragedy anymore, on the contrary. Tesla's autopilot escapes the curse of the creep-up and reaches escape velocity. With over 100,000 cars delivered per quarter by the end of next year, the installed base is growing fast and Tesla can improve rapidly its autopilot reaching an asymptotic Level 3 **(exhibit 20)**

Exhibit 20 – The straight shot goes

Adoption per level of autonomy over time (# of cars)



Source: Tesla and NSR estimates and analysis.

We are all beta testers. The beauty of Tesla's model is that all drivers contribute. Data is gathered in shadow mode on all cars, potentially all the time, while actual autopilot miles are clicking up rapidly. Tesla recently announced over 1.2bn miles driven on autopilot and could communicate questionable[7], but powerful statistics from a marketing standpoint: one incident per 3.34 million miles when Autopilot is engaged.

Anyone $5,000 in will call it autonomous driving. Many will call us cynics on this one, but human nature is what it is. The most beautiful aspect of Tesla's approach is that it lets the definition of what an autopilot experience should be calibrate itself to the best-effort experience it can offer. Tesla owners who throw $5,000 at a crap so-called autopilot that nearly kills you several times a day and manages a lane change at best once a day, are not going to complain about the former, but will stay in awe and admiration of the latter. (True story… completely useless but so fun to play with. Definitely worth the $5,000!) In the meantime, engineers in Germany, at leading premium car manufacturers, argue about what an Autopilot should or shouldn't be able to do.

Could Tesla's Hardware choices prove wrong over time? Not really. Tesla let the definition of what an autopilot experience should be form as its drivers experience what its hardware platform can deliver. Questioning whether the hardware is right would be equivalent to question whether x86 is the right architecture for a PC or a server. You will find a lot of people explaining you it is the most terrible one, but the market share of x86 in PCs and Servers remains north of 95%...

[6] The latter in reality means only a man with a high dose of common sense and a good anthropological understanding of the homo-modernicus we are.

[7] Autopilot statistics are unfair, as it is mostly used on highways. But who cares, it is all about perception.

III Implications for investors

Now that we made our call on how we think the ADAS landscape will play out over the next couple of decades, we feel comfortable giving some directions about where to invest. We have three rock solid convictions: long ride-sharing market leaders, long some of the ADAS hardware… and, guess what? Long Tesla!

III.1 Long ride-sharing

How amazing! Isn't this, again, a great illustration of our research philosophy: no limits. We started digging really deep into ADAS, and we come with the conclusion that the most interesting opportunity is in ride-sharing[8].

What we learnt from yellow pages: the natural duopoly game.

I started my career doing strategy for yellow page players. It was the opportunity for me to learn very important competitive dynamics that I called at the time the natural duopoly. Or the "database game". It helped me call fool when Nokia acquired Navteq, at the time the worse acquisition in tech ever, and it helps me call today ride-sharing leaders.

My framework is pretty simple. If a market follows the following three characteristics, it will end in a duopoly, with the market leader benefiting from outsized margins.

Characteristic #1: immaterial incremental cost per user. As with a database service, adding a client costs nothing to your core business. It is the case for yellow pages, and more or less the case for ride-sharing. We will develop that in future research, as it is a bit more complicated, but trust us. In the ride-sharing business adding users is such a blessing that all players burn billions doing it as fast as possible.

Characteristic #2: Scorched earth. Assets are building with a scorched earth dynamic. Any addition to your asset base is an opportunity gone for your competitor. Works very well for yellow pages, advertisers pay for one for sure, maybe two, but definitely not three. There is nevertheless no strict exclusivity in terms of contributors to the assets (advertisers for yellow pages, drivers for ride-sharing) and in terms of users.

Characteristic #3: value of scale: scale gives your service a strong competitive advantage. It usually relates to a networking effect. Obvious in the yellow page and the ride-sharing business.

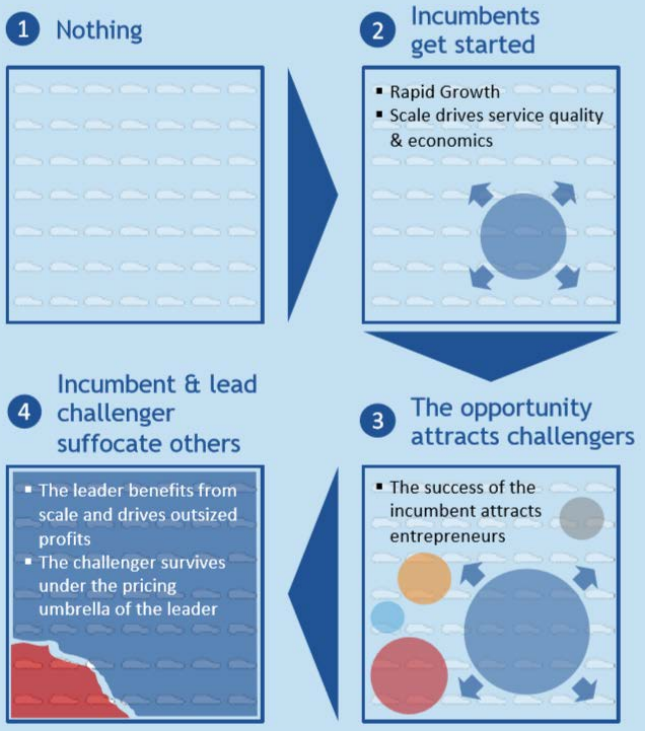
If such characteristics are in place, the two market leaders gather momentum, dry out the market opportunity for followers. The largest player benefits from outsized return, facing no material competition and provides a pricing umbrella for the challenger.

The model behind our conclusion is very simple: At t=0, all competitors grab as many clients as possible, offering their service for nearly nothing and investing as much as they can in growing scale. Very rapidly, all subscale players run out of cash or give up, seeing (rightfully) no path to profitability.

Only two remain. The leader inflates its profitability until a living-dead competitor survives under its pricing umbrella and takes share. This is where pricing stabilize, the leader leaves just the breathing space for the challenger to survive, thereof maximizing its profitability. The duopoly gets set in stone: no new entrant can hope to gather the scale required to build a profitable operation on the scorched earth the two players left behind them. **(exhibit 21)**

Exhibit 21 – Ride-sharing is meant to be a duopoly

Market share of ride-sharing offerings at different steps



Source: NSR analysis.

If you don't believe my framework holds for ride-sharing, look at the Lyft-Uber dynamics and acknowledge it is playing so far exactly according to plan.

[8] We published yesterday a 2018 recap with updated thoughts on our research principles. Worth a read: Apple, Tesla, AMD, AMAT, Nvidia: A year in review and our Manifesto for 2019

Can ride-sharing end the way Yellow Pages ended? Yellow page sort of disappeared, though. Absolutely fair point, they are still around, but it isn't the business it used to be, they got displaced by the fundamental technological shift Google and the Internet represented. The next question is therefore: "what could displace in the long run ride-sharing?"

It is obviously autonomous driving. The real threat to ride-sharing is autonomous driving, that's pretty obvious. **But this is exactly the call we are making: We do not believe autonomous can take over ridesharing without the ride-sharing leaders!** This means to us the threat doesn't exist. Uber will eventually be the autonomous driving leader. Implications for Waymo? That's not really my problem, but if I were them, I would shop myself around as soon as I feel I have a material technology edge. A frontal fight between Waymo and Uber is one Waymo will lose.

At this point, a rigorous thinker following my thread will ask: But why preferring the ride-sharing leader to the Autonomous leader, if both are required for success?

Excellent question. It simply is because there is no natural monopoly, not even duopoly building in autonomous. In a couple of years, when ride-sharing is ripe for broad-based adoption of autonomy, there will be a plethora of technology platforms available out there, which can support the "**asymptotic autonomy**" we have described above. In that context, the value of an autonomous driving pure-play will be very uncertain. Oversupply is never good for prices.

Quod Erat Demonstrandum!

The asset to own is the ride-sharing leader, not the autonomy leader. If your brokers call you about hot IPOs early next year, don't ignore them. And if you want the best research on the topic, stay in touch…

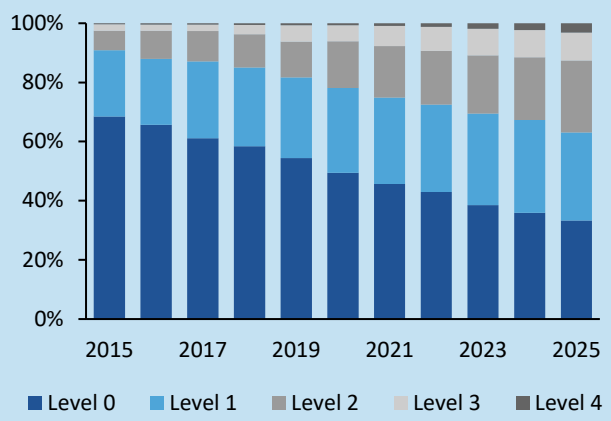
III.2 Long ADAS Radars and CMOS image sensors

Playing the ADAS value chain is not new, but we do not pretend to only come up with new ideas. We do like the ADAS value chain.

As in any good classic tragedy, the beauty of the plot holds in the fact that characters have no choice but follow their fate[9]. The whole auto industry will have to deliver ADAS, even if it loses this war. As ADAS technology improves and gets accepted, it will have unquestionable impact on safety and simply become compulsory. We are therefore bullish on ADAS penetration, and we find existing forecasts on that front too cautious. **(exhibit 22)**

Exhibit 22 – Yole ADAS penetration conservative forecast

ADAS Penetration by level (%)



Source: Yole and NSR analysis.

Exhibit 23, below, summarizes a fairly conventional view of what an L3 ADAS system requires in terms of hardware. That is today about $2.6k per car, and I suspect that bill will come down rapidly as adoption broadens, driving experience and volumes. Our best guess of how this bill of material evolves over time is described in **exhibit 24**.

Exhibit 23 – ADAS hardware today costs around ~$2.6k

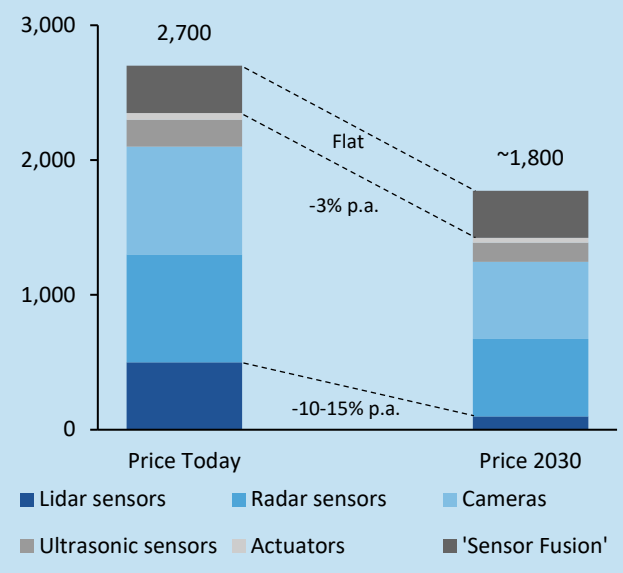
L3 ADAS Build – Hardware Costs (US$)

	Quantity	Price	Total Price
Radar Sensors	8	100	800
Cameras	8	100	800
Ultrasonic Sensors	10	20	200
Actuators	na	50	50
'Sensor Fusion' unit	1	350	350
Lidar Sensors	1	500	500
			2,700

Source: NSR estimates and analysis.

[9] This makes me sound like I like classic tragedy. Not true, though. Note the nuance, I understand it, but I hate it. Boring.

Exhibit 24 – ADAS BoM will decrease materially over time



Source: NSR estimates and analysis.

In all these ADAS components, we want to be selective, though. We want to separate them into three categories:

Uncertain: these components are on the list, but we are unsure they will eventually be needed. Lidar sensors are the key item on this list: today's costs remain prohibitive for large scale adoption, while its eventual necessity is questionable (see section II.1.c above).

Commoditizing: we are unsure these components will benefit from restrained supply and defend good pricing power. Cameras: suffering from a highly competitive market and a risk of a race to the bottom in terms of pricing. Ultrasonic sensors: mature feature, already heavily adopted in vehicles today for e.g. for park-assist.

Jury still out: we know these components are required, but we don't think technology and its adoption is mature enough to make the call. The item that comes to mind here is the number cruncher in the car, i.e. the chip where the "thinking" happens. Nvidia and Intel/Mobileye are market leaders, but Tesla is opting for its own purpose-built chip. Makes it difficult to call a winner, even more so to make it an investment thesis.

What is left we like. The **long-range radar market** is concentrated, and radar is an unequivocal necessity for ADAS, supplementing camera input (see exhibit 10). **CMOS image sensors** (embedded in cameras) is a highly concentrated market, which will continue to grow as camera content increases.

Implications for our coverage: here comes what really matters in the end. How to play the hardware value chain. In our coverage we prefer **Infineon**, who have taken an early lead in long-range radar modules, with **NXP** (not covered) and **STM** (not covered) as strong secondary players in the market. Infineon also has exposure to Actuators, and 32-bit secure MCUs (Aurix product line), the MCUs of choice in 8/10 ADAS computing platforms. In CMOS image sensors for ADAS, **ON Semiconductors** (not covered) claims 70% market share.

III.3 Tesla wins

We think Tesla will keep winning in the auto industry for years and years. Today, Tesla is mostly about electric, in five years from now it will be mostly about autopilot.

Tesla will gain 10-15% share of the premium market, reaching the scale of BMW by 2025. As electrification boosts market demand, Tesla significantly expand production capacity and meets no serious competition (Model 3 & Model Y). We already have evidence of Tesla's potential – they have captured ~20% of the premium US market in the past four months.

At the scale of BMW by 2025, Tesla will deliver 3m vehicles annually, generating $14-25bn in EBIT. In this scenario, Tesla's share price could reach $1,200-2,000, assuming a 15x EBIT multiple, in line with mature good growers in HW tech (**exhibit 25-26**).

Exhibit 25 – Tesla in 2025 will look like BMW on steroids

	Tesla Today	BMW Today	Tesla 2025+	Rationale
Units	~100k	~2.5m	~2-3m	Dealership expansion, pace of EV adoption
ASP	~$100k	~$45k	$40-45k	>$35k market, cost competitive
Dealers	330	~5,000	~4,000	~25-40% p.a. growth
Unit/Dealer	~300	~500	~500-750	Grows with lower ASP
>$100k	*~300*	*~150*	*~200-250*	
Share >$60k	~5%	~15%	~10-15%	Grows with dealer expansion
Share >$35k	~1%	~10%	~10-15%	Model 3 & Model Y

Source: Corporate reports and NSR estimates and analysis.

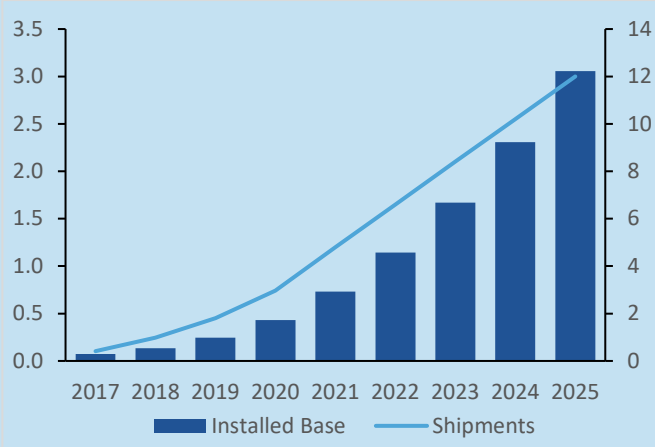
Exhibit 26 – Tesla's valuation in 2025 – not a car manufacturer as we know them today

	Expected range	Rationale
Revenue	~$100-150bn	Autos: $80-120bn Energy, Storage, Used cars: ~$20-30bn
GM (%)	>25%	Premium brand, tech leader Manufacturing: 3-5pts margin advantage Distribution: 3-5pts margin advantage
OM (%)	>15%	Operating leverage similar to BMW
EBIT	$14-25bn	Operating leverage similar to BMW
EV	~200-350bn	15x EBIT. Assumes: Inline with mature good growers in HW tech
Share Price	~$1,200-2,000	Assumes flat share count and no debt/cash

Source: Corporate reports and NSR estimates and analysis.

In five years from now, Tesla's edge will move away from EV to ADAS. Electric powertrains will slowly become a commodity, as competitors successfully transition to EVs. Tesla will therefore lose its uniqueness and edge on the powertrain. However, Tesla will maintain their premium and their lead in ADAS, owning the only monster installed base of near-L3 cars: 12m units on the road, with a superior autopilot experience (**exhibit 27**). ADAS is a software game, benefitting from scale, experience, and installed base. As the only company opting for the "straight shot" approach today, Tesla will own the L3 landscape, the same way they have owned the EV landscape, and it will be difficult for competitors to catch-up.

Exhibit 27 – By 2025, Tesla will have a monster installed base of 12m near-L3 cars



Source: Corporate reports and NSR estimates and analysis.

IV Conclusion.

ADAS: bull or bear? Well, the question is ill-formed. ADAS is a very diverse market. We say actual autonomous driving is a very long shot, and it won't create much tangible value by itself. It will need ride-sharing leaders to thrive and this is where the opportunity is for investors. Watch out for the IPO of **Uber** next year. As for lower ADAS level, **Tesla** is the only winner we see amongst car manufacturers, and in the value chain, for now, quality bets are radars (**Infineon**) and CMOS sensors (**ON semi**, not covered).

Disclosures

12 month historical recommendation changes are available on request

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Sales:

Charlie Gaynor
+44 20 7375 9121
charlie@newstreetresearch.com

Zach Monsma
+1 212-921-7729
zach.monsma@newstreetresearch.com

Ethan Lacy
+1 212-921-4925
ethan.lacy@newstreetresearch.com

Steven Perez
+44 20 7375 9112
steven.perez@newstreetresearch.com

Michael Chambers
+65 6730 9268
michael@newstreetresearch.com

Joshua Evans
+44 20 7375 9115
joshua@newstreetresearch.com