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Q-Series

How will robotaxis re-shape the urban world?

Equities

Global
Automobiles

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How will the urban world be re-shaped once robotaxis become mainstream?
UBS Evidence Lab has developed a real-time simulation to model the effectiveness of a robotaxi fleet in New York City. This powerful simulation has enabled us to size the robotaxi fleet market globally at >$2trn in 2030E. Mass adoption could materially boost the revenue of several sectors, ranging from Utilities to Semis. In this report, 25 UBS analysts worked together to analyse the impact that the adoption of robotaxis will have on their industries, and identified companies set to be disrupted or favoured by this trend. Sectors benefiting the most include Internet, Utilities, Semis, Telcos and Tires.

The simulation gives us key insights on the future of transport in big cities
Our complex dispatching algorithm performs dynamic optimal route generation, connects riders with vehicles in the most efficient way possible, and quantifies a wide range of key metrics, including the running cost per km, the utilisation rate, the fleet profitability margin, and the number of charging stations needed. We have also built an interactive model, which enables investors to gauge, using their own assumptions, the size of the robotaxi fleet and the related impact for various industries. Once the inflection point is reached, we believe the growth rate for robotaxi adoption will be steep. We remain confident that the robotaxi business model works both financially and technologically, although we delay our forecast for robotaxi (L5/L4) penetration by 1-2 years, mostly to reflect higher efficiency of the fleet as shown in our simulation (i.e. fewer cars are required to cover demand).

The economics of running a robotaxi fleet are very attractive. Is it sustainable?
Our simulation shows the existing fleet of NYC taxis could be reduced by two-thirds, once vehicles become fully autonomous. The average daily utilisation rate will likely stand at c50% (peaking at 80%), implying some excess capacity will still be required. The annual revenue generated by each robotaxi could amount to $27k, with a running cost as low as $0.16 per km ($0.29 incl. depreciation) or $40/day. We estimate the fare paid by passengers for each trip could fall by more than 80% (<$3) whilst still allowing the fleet operator to make healthy margins (30-40%).

The introduction of robotaxi fleets will disrupt public transport
With a taxi fleet size similar to today's, we estimate that we can service all existing daily requests and, additionally, 15% of all public transport users within Manhattan. Eventually, passengers-sharing trips should push the cost of a ride to below $1, meaning that robotaxis would price-compete with public transport.

Figure 1: How will robotaxis re-shape the urban world?

Source: iStock

Executive summary

UBS Evidence Lab has developed a real-time simulation to model the effectiveness of a robotaxi fleet in New York City

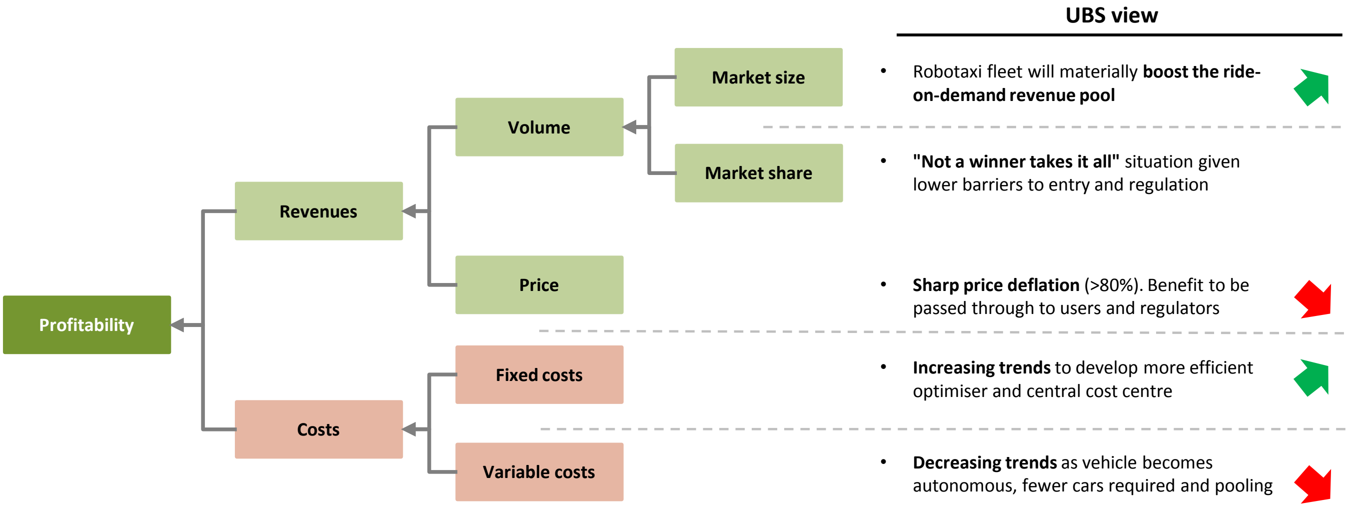
In this report, we refine our picture of what the future of mobility could look like, despite all the uncertainties around technology and regulation. UBS Evidence Lab has developed a real-time simulation to model the effectiveness of a robotaxi fleet in New York City. Our complex dispatching algorithm performs dynamic optimal route generation and connects riders with vehicles in the most efficient way possible.

This powerful simulation has enabled us to quantify a wide range of key metrics, including average wait and trip times, the number of kilometres driven by each robotaxi, the average fare, the fleet profitability margin, the excess capacity required, and the number of charging stations needed. The simulation also gives us unique insight to improve our forecasts for the potential size of the global robotaxi fleet, as well as implications across developed and emerging markets

Over the past five years, we have tried to help investors form a view on how the urban world will be reshaped by the introduction of new forms of mobility and what that could mean for various industries. Our view remains:

- The launch of robotaxi fleets will contribute materially to **growth in the ride-on-demand market**. We see the robotaxi fleet management revenue pool reaching more than $2trn by 2030E.
- **"Not a winner-takes-it-all market"**. The market share split is uncertain. While the early entrants certainly have an edge, we note that the barriers to entry in an autonomous world, once the technology is available, should drop materially.
- **Sharp price deflation.** We estimate the average trip cost will fall by at least 80% compared to the average trip today. Most of this will be passed through to the users/passengers and regulators.
- The mass adoption of robotaxis will have **far-reaching implications across many industries**, and will create **new revenue opportunities**. Sectors that should benefit the most include Internet, Utilities, Telcos and Tires.

Figure 2: Ride-on-demand profitability map



Source: UBS

What's unique about this report?

UBS Evidence Lab has developed a real-time simulation to model the effectiveness of a robotaxi fleet in NYC, leveraging a program-based mathematical model. At every 15-second frame in the simulation, the algorithm performs dynamic optimal route generation and passenger-vehicle assignment considering online vehicle capacity and rider demand. Vehicles that are not assigned in a given frame are subsequently rebalanced according to the outstanding rider demand.

UBS Evidence Lab built a complex dispatching algorithm to maximise efficiencies of the vehicle fleet

UBS Evidence Lab has built two scenarios into the simulation:

- **Scenario 1 – non-commuter,** with the goal of minimising the NYC robotaxi fleet size during weekdays and weekends;
- **Scenario 2 – commuter,** with the goal of maximising the number of commuters with a robotaxi fleet approximately equal in size to the current NYC taxi fleet, in addition to the existing demand for taxis.

UBS analysts covering a total of 11 sectors ranging from battery cell production to utilities have leveraged this unique simulation to make conclusions on the impact of the introduction of robotaxi fleets for their respective industries.

Figure 3: UBS robotaxi simulation – trip samples with key related metrics

	Scenario 1 - weekday	Scenario 1 - weekend	Scenario 2 - weekday
Trip start time	18:04	08:14	17:57
Trip end time	18:15	08:33	18:22
Fare paid (in $)	**10.07**	**14.70**	**22.97**
Profitability margin (%)	**93.30**	**92.50**	**92.32**
Trip length (in km)	3.33	5.01	11.00
Trip time (in min)	11.23	19.26	24.43
Wait time (in min)	1.25	2.06	0.86
Energy consumption (in kWh)	0.40	0.60	1.32

Source: UBS Evidence Lab

At this stage, the simulation assumes one passenger per vehicle. However, we believe the dispatching algorithm could be further improved to reflect pooling the use of the vehicle by several passengers, which should lead to even further efficiencies. For more details on the methodology, please refer to the final section of this report – 'How does the robotaxi simulation work?'

What are the key findings from the simulation?

Our analysis of the data from the simulation has enabled us to gauge some key metrics, such as the average wait and trip time, the number of km driven by each robotaxi, the average fare paid by the passengers, the profitability margin of the fleet, the excess capacity required, the electricity consumption of the fleet, and the number of charging stations required.

Figure 4 shows only a fraction of the data that we have been able to extract from the simulation.

Figure 4: Key numbers to remember

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>$2trn potential revenue could be reached from robotaxi fleets by 2030

The fleet of city taxis could be reduced by **67%** vs today

90%+ profitability margin could be generated by managing robotaxi fleets

It takes only **2 hours** for the robotaxis fleet to reach breakeven each day

The cost of a trip (for the passengers) could reduce by **80%+**

Only **9** charging stations are required to cover the daily electricity needs

With a daily running cost of **$40** daily, the market entry costs are very low

Robotaxi will price compete with public transport as cost per trip will rapidly fall <$1, assuming pooling

Source: UBS estimates

What if barriers to entry were removed?

The introduction of commercial robotaxi fleets should attract many players, given (1) the high level of profitability it could generate and (2) the fairly low market entry costs. Today, the key competitive edge of the platforms comes from the network effect – their ability to efficiently connect demand with supply. Once the human driver is removed from the equation, we think the barriers to entry could diminish materially. In other words, any OEM could decide to "inject" several thousands of vehicles into a given city with a lead time that could be very short. To this extent, we believe that (1) municipalities will grant concessions to a small number of players (hence the importance of developing strong relationships early on), and that (2) "a winner takes it all" situation is unlikely, mostly due to regulation and regional dynamics.

We see a shift from public transport to robotaxi fleets

Given the profitability potential, we think the interest from private investors could be very high. What about demand and passengers? We see the adoption rate reaching more than 20% of the urban population in developed markets by 2030. We think the amount of time spent in vehicles will increase, driven by two major forces: (1) we estimate that the trip fare has the potential to fall by more than 80%; and (2) we expect a shift from public transport to robotaxis. The simulation shows that, in a city like New York, the existing size of the taxi fleet could cover about 15% of all commuters' requests, if converted into robotaxis. The average commute time would fall from c40minutes to c15 minutes for one leg within Manhattan.

MIT recently published a study looking at the cost of running a robotaxi fleet, and concluded that the cost of using them could exceed that of personal car ownership. There is one key element where we differ: the UBS Evidence Lab simulation does not include the cost of a teleoperator, as we assume the maximum possible level of efficiency. If the cost of these workers is only $11/hour and the ratio is 50 cars per operator, it adds $0.05/ mile; a 1:1 ratio adds $2.35/mile. If we were to include teleoperators, it would add about c$35k of daily cost for the fleet, which would not materially impair the profitability metrics discussed earlier. We plan to do more detailed work on reconciling the two analyses.

What does this mean for our robotaxi/AV forecasts?

We delay our adoption forecast by a year or two

As discussed earlier, we remain very positive about the growth and profitability outlook of managing a robotaxi fleet. If anything, the simulation shows that the efficiency level reached is higher than most people would expect. However, we delay our forecast for the adoption of robotaxis by a year or two to reflect: (1) the higher efficiency of the fleet as shown by our simulation (4,500 robotaxis can service >330k trip requests on a daily basis), (2) our new forecast split between developed markets ("DM"), EM, and China; and (3) comments from industry participants that developing the technology might take longer than initially planned. We reduce our forecast for the fleet of robotaxis from 26m to 11m in 2030. Furthermore, we now assume that robotaxis will represent c5% of new car sales (from 12% before) in 2030.

We have built an interactive model, which enables investors to gauge the size of the robotaxi fleet and the impact for various industries using their own assumptions.

What are the key implications for autos?

We estimate that the penetration of robotaxi sales will be 5% in 2030 (as a percentage of new car sales). We expect the overall fleet to reach 11m vehicles by then, equivalent to 1% of the global car parc and c4% of the miles driven globally. All those metrics should expand exponentially as the adoption rate of robotaxis increases further: we currently assume 8% of the urban population globally in 2030 (including 20% in DM), rising to c37% in 2040.

5-10% negative impact on new car sales in the long run

We estimate that robotaxis could represent on average 16m units sold per year between 2016 and 2050. In the long term, we see new car sales running c5-10% lower than our current estimates. However, in the medium term, new car sales should be slightly supported until 2027 and then drop off as the adoption rate of robotaxis accelerates. Then, new car sales should recover, thanks to (1) the higher utilisation rate of robotaxis (about 10 times higher than that of a private car); and (2) the faster replacement velocity – we assume an average life of a robotaxi of about three years compared to about 10 years for a private car.

Sharp acceleration in EV penetration

We estimate that robotaxis will represent more than 10% of global EV sales in 2030. The simulation also showed that the daily cost of running a electric robotaxi fleet is about one-third cheaper than that for an ICE (internal combustion engine) fleet. Robotaxis could also help stabilise the grid during peak electricity demand (if there is lower demand for transport).

Tire makers best positioned to benefit in Autos sector…

Tire makers should benefit from the higher number of miles driven. Despite the shrinking car parc, the number of kilometres driven is set to increase for two key reasons: (1) the time spent in vehicles should increase due to the lower fares charged to passengers (we see a price reduction of more than 80%); and (2) there should be a shift from public transport to robotaxi fleets. The simulation shows that a robotaxi should drive about 6x more than a private car today. This would lead to the number of kilometres driven per car increasing from 15,000/year to about 15,600/year. Therefore, even if we estimate that the fleet size could shrink by two-thirds with the introduction of autonomous vehicles, the kilometres driven would still increase on a like-for-like basis.

We see the revenue opportunity for tire makers related to the launch of robotaxi fleets reaching $19bn in 2030E. To put things into perspective, this would be larger than what Michelin makes today selling passenger car tires. It would also support industry volume growth, with an annual growth rate of close to 1% between today and 2030E (and most of the impact would be felt after 2025). The net revenue pool (i.e. adjusted for lower new car sales) for tires could increase by up to 50% by 2040E.

… with a potential net revenue uplift of close to 50%

How do we connect the simulation with our global forecasts?

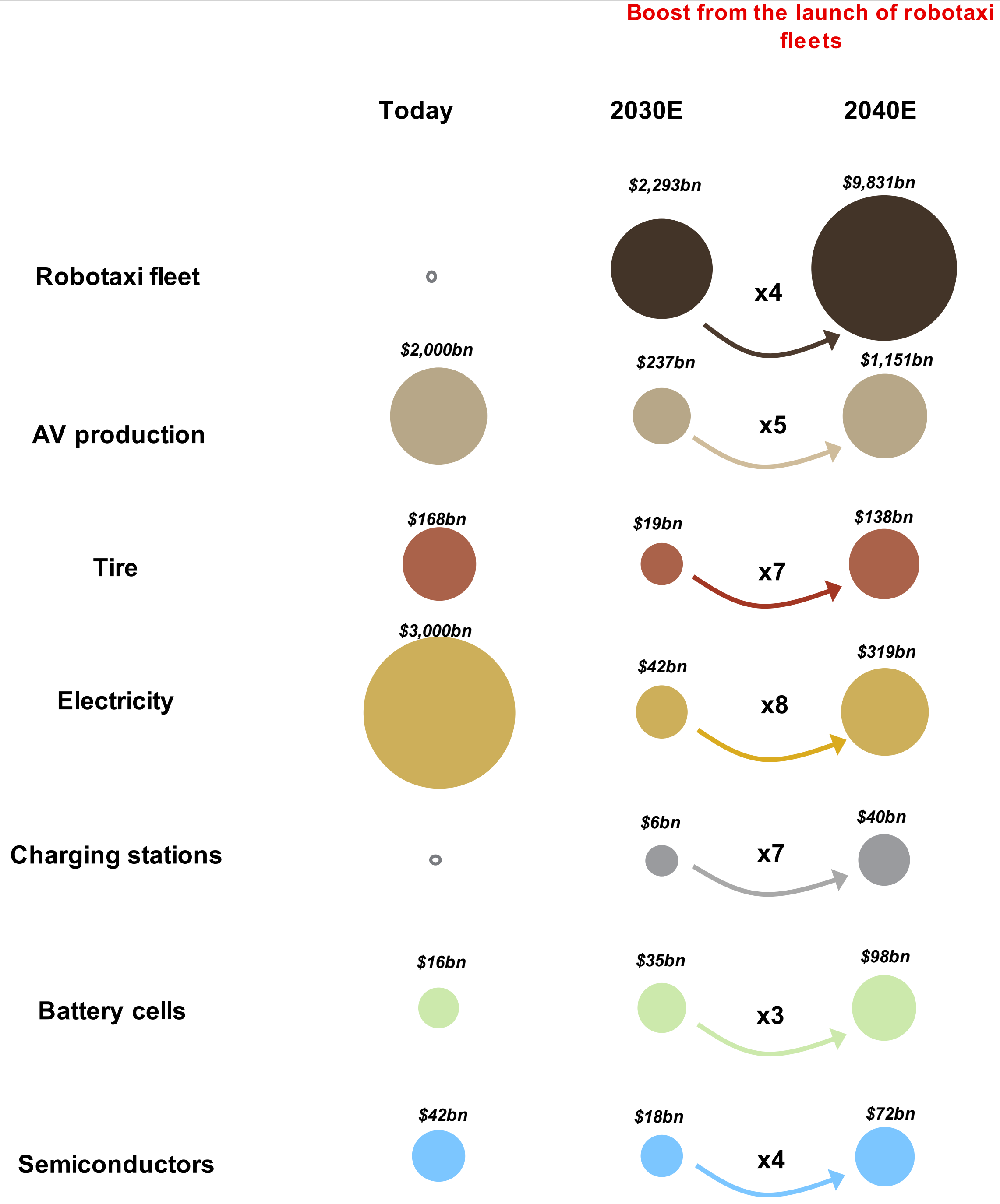
As in the past, we use the forecast for the urban population provided by the UN. We then apply the adoption curves that we described earlier. For each region (developed markets, China and emerging markets), we model different adoption curves based on income, infrastructure, cost of public transport, etc. We also assume that each robotaxi user makes two trips per day in our base case. Finally, the simulation shows that the fleet of 4,500 robotaxis can service around 330k trip requests daily. We apply this ratio to quantify how many robotaxis are required in each region.

What are the largest revenue pools that could emerge from the mass adoption of robotaxis?

The launch of robotaxi fleets should have far reaching implications across many industries. The mass adoption of robotaxis could materially boost the revenue pools of several sectors ranging from utilities to semis. We leverage this unique simulation in order to connect the dots. In this section, analysts covering 11 sectors have leveraged the robotaxi simulation, identifying the key metrics that matter the most and answering the key pivotal questions that are most relevant.

Figure 5 shows the potential revenue boost the launch of robotaxi fleets could have on various industries. Our interactive model discussed later enables investors to change the key assumptions.

Figure 5: The launch of robotaxi fleets could have a material impact on the revenue potential of various industries (https://neo.ubs.com/shared/d218tKFglY)



Source: UBS estimates

Note: For Utilities, we compare power prices "at the pump" with a wholesale level utility revenue pool, which is why the actual revenue upside will likely be moderately below 10%

Figure 6: What does the robotaxi simulation mean for various industries?

Sector	The robotaxi simulation shows ….	Our key conclusions are …
OEMs	Daily revenue of the robotaxi fleet is $3.3m (4,500 vehicles)	Given profitability and lower cyclicality of revenues, OEMs should consider entering the field
	Running cost of a EV robotaxi is a third cheaper than an ICE taxi	Further acceleration of EV penetration
	Long-term new car sales could be 5-10% lower due to robotaxi adoption	
Suppliers	Robotaxi fleet profitability margin is >90%	Once the vehicle becomes autonomous, barriers to entry become materially lower
	Running cost of robotaxi is $40 daily	Robotaxi sales will represent >10% of BEV sales in 2030
Tires	Robotaxi drives on average c250km daily (or 90k km p.a.)	Tire consumption of robotaxis is 6x higher than that of private cars
	Size of taxi fleet could be reduced by two-thirds	Revenue boost could reach $19bn in 2030 and $138bn in 2040
	Number of km driven will increase (up to 20x per hour)	Net revenue uplift could be 50% of today's industry sales
	Running cost of EV robotaxi is one third cheaper than for an ICE taxi	Mix impact (larger tires) should be positive
Internet	Daily revenue of robotaxi fleet is $3.3m (4,500 vehicles)	Technology & platform companies have ample flexibility/optionality in potential business models
	Robotaxi fleet profitability margin is >90%	Despite near-term investments, AV deployment has the potential to improve profitability of
	Takes up to 2 hours for fleet to reach profitability breakeven each day	operating the network
	Trip fare could be reduced by >80%	
	Daily running cost of a robotaxi is $40	
Utilities	Daily electricity consumption is 65,000kwh (for 4,500 robotaxis)	Revenue could reach $42bn in '30 and >$300bn in '40, or ~6% of global electricity consumption
	Running cost of an EV robotaxi is a third cheaper than for an ICE taxi	Charging and grid upgrades only represent 10% of total capex over next 10 years
	Only 9 charging stations required to cover daily electricity needs of fleet	
	Electricity represents c14% of robotaxi's daily cost	
Telco	The average daily utilization rate of the fleet is c50%	The revenue pool could reach US$100-120bn by 2030 translating into revenue per car of US$10k per annum
	The average fare is $10 and the average trip length is 10min	It is not clear how much "incremental" capex will be required
	Each robotaxi drives c250km daily	The latency requirements for robotaxis could be higher, demanding a higher degree of reliability
Batteries	Running cost of an EV robotaxi is a third cheaper than for an ICE taxi	Revenue boost could reach $35bn in 2030 and $98bn in 2040, 6x higher vs today's market size
	Robotaxi will drive c90k km per year	Robotaxi sales will represent >10% of BEV sales in 2030
	We assume life-cycle of robotaxi will be ~3 years	
	Each robotaxi will have to (fully) recharge every two days	
Semis	Running cost of a EV robotaxi is a third cheaper than an ICE taxi	Revenue boost could reach $18bn in '30 and $72bn in '40, almost 2x today's market size
	Long-term new car sales could be 5-10% lower due to robotaxi adoption	Robotaxi could be helpful accelerant of the semiconductor content per car
	By 2030E L5 penetration could be 5% of new car sales	Shift to EV adds $550 per car to the average of c$450 per car today)
		L4/L5 could carry as much as $2,000 per car
Insurance	Insurance costs represent 18% of robotaxi operating costs	Insurance could be reduced, but liability is likely to increase, leading to stable insurance costs overall
	Size of taxi fleet could be reduced by two-thirds	
Car rental	Daily revenue of robotaxi fleet is $3.3m (4,500 vehicles)	Rental companies appear like natural partners for platforms
	Robotaxi fleet profitability margin is >90%	Rental companies already have years' worth of data on customer
	Takes only two hours for fleet to reach profitability breakeven	
	We estimate that cleaning represents 5% of daily operating cost of fleet	
Real Estate	Network in the simulation has 770 kilometres of road	Launch of fleets could reduce on-street parking, freeing up land for alternatives
		Location desirability may change if commute time can be spent more efficiently
		In long run, we see limited threat to central business district
CapGoods	Only 9 charging stations (6 chargers each) required to cover daily electricity	Reduction in new car sales could have material impact since auto capex forms c10% of sector sales
	Running cost of an EV robotaxi is a third cheaper than for an ICE taxi	Shift towards EV could create incremental demand for automation players
ESG	Running cost of an EV robotaxi is a third cheaper than for an ICE taxi	Transition technologies for low-carbon mobility are developing rapidly
	Trip fare could be reduced by >80%	If jobs were put at risk, or if access to affordable (public) transport became a "postcode lottery",
		regulators would have reason to impose conditions of operation
	Size of taxi fleet could shrink by two-thirds	Either structure (concentrated ownership or distributed ownership of robotaxis) could bring benefit

Source: UBS estimates
Note: For Utilities, we compare power prices "at the pump" with a wholesale level utility revenue pool, which is why the actual revenue upside will likely be moderately below 10%

Figure 7: Impact of the mass introduction of robotaxis

Robotaxi impact	Sales growth	EBIT margin	ROIC	Valuation	Overall	Comment
Auto OEMs						Mindset needs to shift from "selling a car" to "selling a min"
Auto suppliers						Strong sensor volume growth ahead but steep price deflation
Tire makers						Benefit through higher number of kilometers driven and better mix
Batteries						EV penetration boosted due to cost advantage vs ICE
Car rental						Rental companies appear natural partners for the platforms
Internet						Platforms have ample flexibility/optionality in potential business models
Semis						Robotaxis could sharply boost the semi content (EV + AV)
Utilities						Electricity consumption boosted; investments requirement manageable
Telecom						Sharp increase in data consumption
Chemicals						Further challenges for chemical companies with ICE exposure
Capital Goods						EV will have fewer moving parts and less bearings vs ICE
Insurance						Manageable impact, as traditional motor fleet premium size is limited
Real-Estate						Shift in location desirability and change-of-use could bring opportunities
Real-Estate Brokers						Market-wide impact on real estate values would be de minimis

Source: UBS estimates

Figure 8: Stocks positively and negatively impacted by the theme

Impacted...	Positively	Negatively
Sector	**Stock**	**Stock**
Auto OEMs	GM VW	PSA FCA
Auto suppliers	Hella Valeo Aptiv	Veoneer Leoni
Tire makers	Michelin Pirelli	
Batteries	LG Chem Samsung SDI	
Car rental	Sixt pref.	
Internet	Baidu Alphabet Lyft Yandex	
Semiconductors	Infineon NVIDIA TSMC	Melexis
Utilities	Enel E.ON Iberdrola	
Telecom	AT&T Verizon China Mobile AMT	
Chemicals	Umicore LG Chemicals Asahi Kasei Toray Sika Albemarle	Johnson Matthey EMS-Chemie BASF
Capital Goods	Siemens	SKF Sandvik
Insurance	Zurich AXA	Hastings
Real Estate Brokers	CWK	
Real Estate	Retail* Residential*	Industrial*

Source: UBS estimates; Note: *Real Estate subsectors provided, given the breadth and fragmentation of the market (over 2000 listed real estate companies globally)

What are key players saying about the launch of robotaxi commercial fleets?

Lyft (LYFT Initiation) is taking a dual-pronged approach to AV development: both first party (1P) through its Level 5 Engineering Center and third party (3P) through its opensourced platform and partnerships with Aptiv, Waymo and others. Lyft has deployed a fleet of robotaxis (with a safety driver) in Las Vegas since January 2018, and has performed over 35,000 trips since then in Aptiv autonomous vehicles. Further, Lyft & Waymo recently announced that Waymo will deploy 10 Waymo vehicles on the Lyft platform over the next few months in the Metro Phoenix area. In terms of timeline, Lyft believes it is well positioned to help facilitate the gradual introduction of AVs on selected, defined routes to complement human drivers on the platform. Lyft's goal is deploy an AV network capable of delivering a portion of rides on its platform within the next five years. Within a 10-year timeframe, Lyft has a goal of having the capability to deliver a majority of rides on the Lyft platform through a scaled, low-cost AV network.

Uber's Advanced Technologies Group ("ATG") is focused on developing autonomous vehicle technologies. Established in 2015, it has built over 250 autonomous vehicles, collected data from millions of AV testing miles, and completed tens of thousands of passenger trips. The company has signed partnerships with the following OEMs: Toyota in 2018, Volvo in 2016 and Daimler in 2017. The company recently announced that Toyota, DENSO and SoftBank

Vision Fund will invest $1bn in ATG, valuing the new Uber ATG entity at $7.25bn on a post-money basis, according to the company.

Where does the NYC simulation stand vs Tesla?

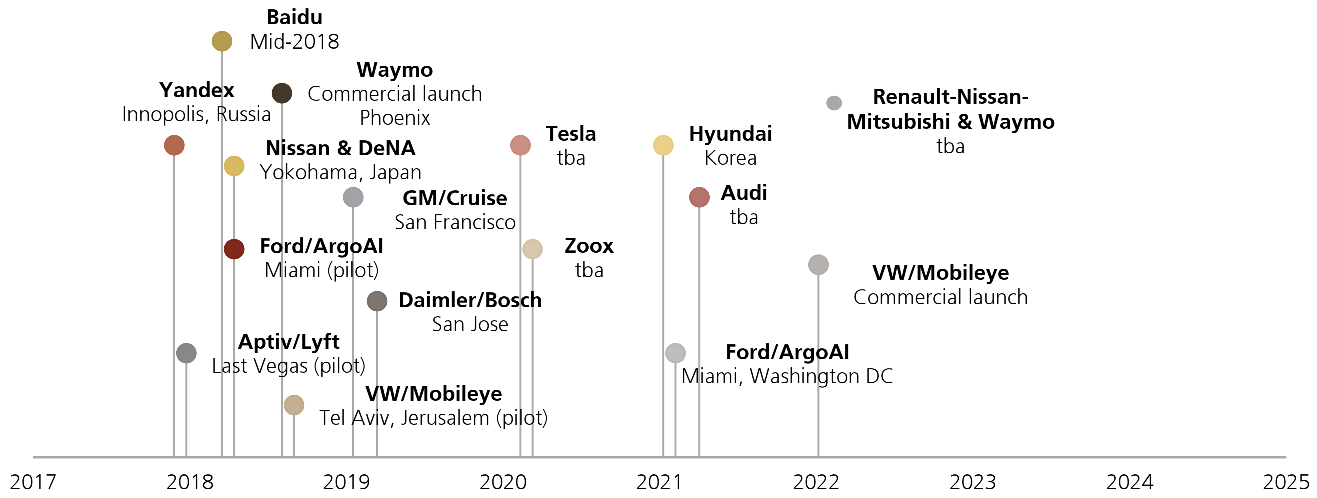
At its Autonomy Day, **Tesla** CEO Elon Musk targeted the deployment of "feature complete self-driving" capabilities (defined in Q&A as Level 5) this year and the launch of its robotaxi in 2020. Tesla estimates the cost to operate a robotaxi right now is less than $0.18/mile, and that each vehicle, could, "conservatively", earn $30k in revenue/year at a 50% utilisation rate. Musk said the "entire expense structure" is currently dedicated to AV development. The simulation of robotaxi fleet in NYC shows revenues per year of c$27k with a running cost of $0.16/km and an average utilisation rate of 48%.

GM's Cruise division is considered by most AV experts as lagging only Waymo on AVs (see Q-Series: Who will win the race to autonomous cars?). The company continues to target a launch in the second half of 2019. Cruise is not only focused on robotaxis, as it also has partners in delivery. Once it manages to get autonomous vehicles deployed, the company sees itself as one of the leaders, as it has the required investment in capital to be able to operate the network. It believes that working in a fleet gives it the scale to get to private AVs as well. It has highlighted that it will focus on the best structure to ensure that it is able to monetise the robotaxi business. GM acquired Cruise in 2016. Softbank invested in Cruise at an $11.5bn valuation (see Cruising to a higher multiple) and Honda's Cruise investment in October 2018 valued Cruise at $14.6bn.

Ford acquired a majority stake in its autonomous unit, Argo, in 2017. Argo has been testing vehicles in Pittsburg, Detroit, Miami and Washington DC. We were impressed by our AV test drive at Ford's event in November (see The Autonomous Race Has Only Just Started). Ford believes that consumers will continue to want to own cars even as ride-sharing and AVs take off. It also sees itself as having a greater opportunity in this world, with a larger value proposition. It believes it has lots of work ahead but that it will be able to capitalise on the trends. To that end, Ford has recently launched a shared mobility app called Office Ride.

As of October 2018, **Waymo** had driven over 10m autonomous miles on public roads. In December 2018, Waymo previously announced it has launched a commercial self-driving service in the Metro Phoenix area (Link). Further, Waymo has made a number of additional announcements over the past few months, including: 1) opening an 85,000 square foot technical service center in Mesa, AZ, more than doubling its capacity to service, maintain and grow its fleet of Waymo One cars; 2) partnering with American Axle & Manufacturing to repurpose a facility in Michigan and open the world's first factory 100% dedicated to the mass production of L4 AVs; 3) Waymo's ride-hailing app is now available on Google Play; & 4) making their internally developed Laser Bear Honeycomb 3D lidar sensor available to select partners outside of self-driving (beginning with robotics, security, agricultural technology, and more). As we have previously written in our Waymo Deep Dive, we believe Waymo has flexibility in the business models it could likely approach within the autonomous ride-on-demand industry. With little known today by the investing community about the future monetization (and even business model iterations) for Waymo, we have explored multiple scenarios that could materialize for Waymo in the coming years, including: 1) operator of an AV ridesharing service; 2) software/tech is used to operate an AV fleet (ridesharing platforms are distribution channel); 3) licensing software/technology (possible in-car time monetization); and 4) a hybrid of all three above approaches.

Figure 9: What are key players saying?



Argo Graphics (JP7595)Source: Company announcements, media reports, UBS estimates

Could the simulation be applied to emerging markets?

It is difficult to apply the same economics of the robotaxi simulation built for NYC to EM. While megacities in EM could represent an attractive opportunity for robotaxi fleets given the high level of population density, we believe the penetration there is likely to significantly lag that in developed markets ("DM"), given (1) lower income, (2) lower pricing, and (3) cheaper infrastructure and other challenges such as traffic conditions and heavy use of two-wheelers. As a consequence, we model only a 2% penetration of the urban population in EM excluding China in 2030 (vs 20% in DM).

As mitigating factors, we note the following. (1) Nine of the top 10 countries for ride-on-demand app downloads were emerging markets. It is therefore clear that there is a high level of interest in these new forms of mobility in EM despite the lower level of penetration of cars, lower incomes, lack of infrastructure, etc. (2) We see scope for taxi fares to fall by more than 80%. If the trip is shared by at least five people, robotaxis will be able to price-compete with the cost of the metro in Delhi, for instance. (3) The market entry costs are extremely low: daily running costs (excluding depreciation) should be only $40 per vehicle.

As regards China, we think adoption should follow a similar pattern to that in DM – and we do not rule out that the possibility that China might eventually have a higher robotaxi penetration than DM.

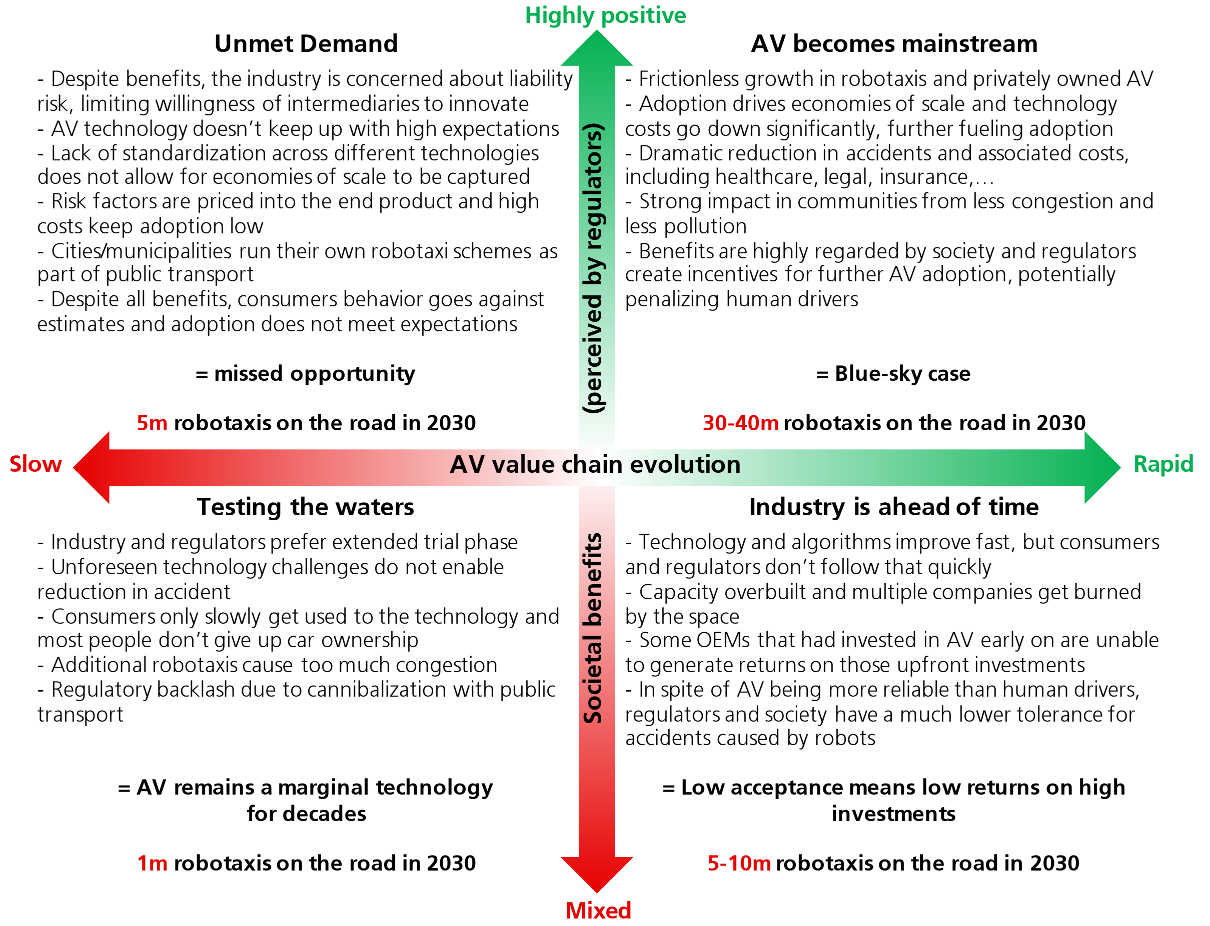
Impediments to making robotaxis a reality

There are a number of impediments and challenges to overcome before robotaxis become a reality. These include: (1) customer attitudes to being driven without a driver; (2) regulation, which is currently not appropriate for such a reality; and (3) design, security and technological challenges. 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, so 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 AVs, liability legislation, organizing the marketplace, etc.

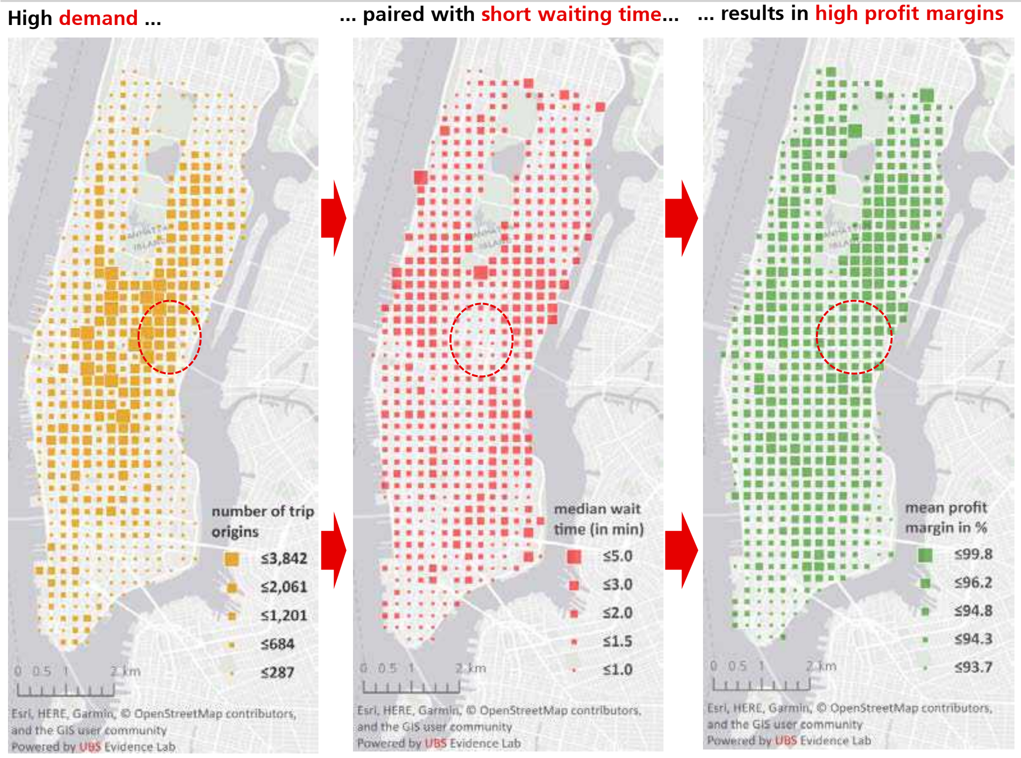
Figure 10: Axes of uncertainty – AV adoption



Source: UBS estimates

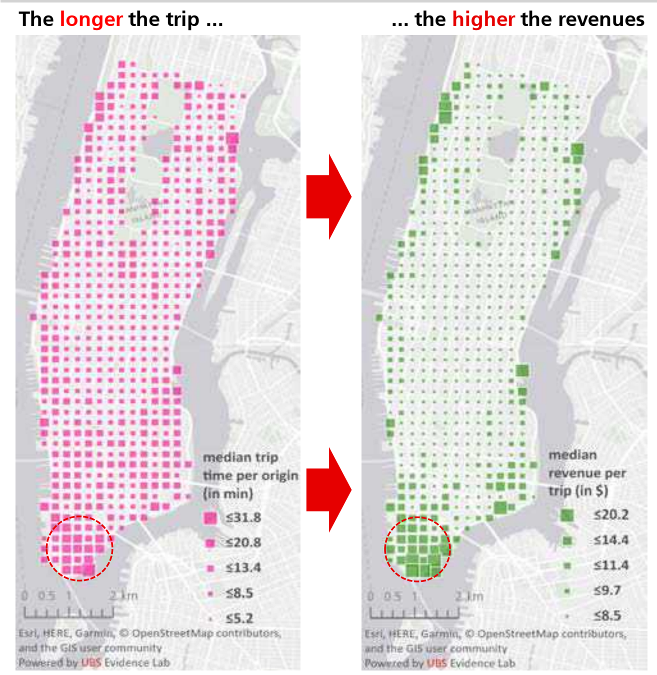
The robotaxi simulation in a few charts

Figure 11: Converting our data into profit margins



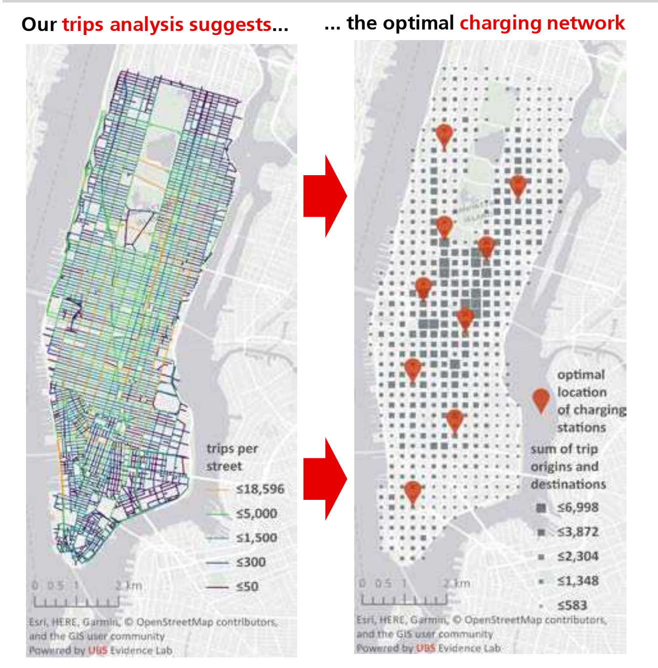
Source: Esri Basemap, UBS Evidence Lab

Figure 12: Trip time (in min) vs. revenue (in $)



Source: Esri Basemap, UBS Evidence Lab

Figure 13: Location of optimal charging stations



Source: Esri Basemap, UBS Evidence Lab

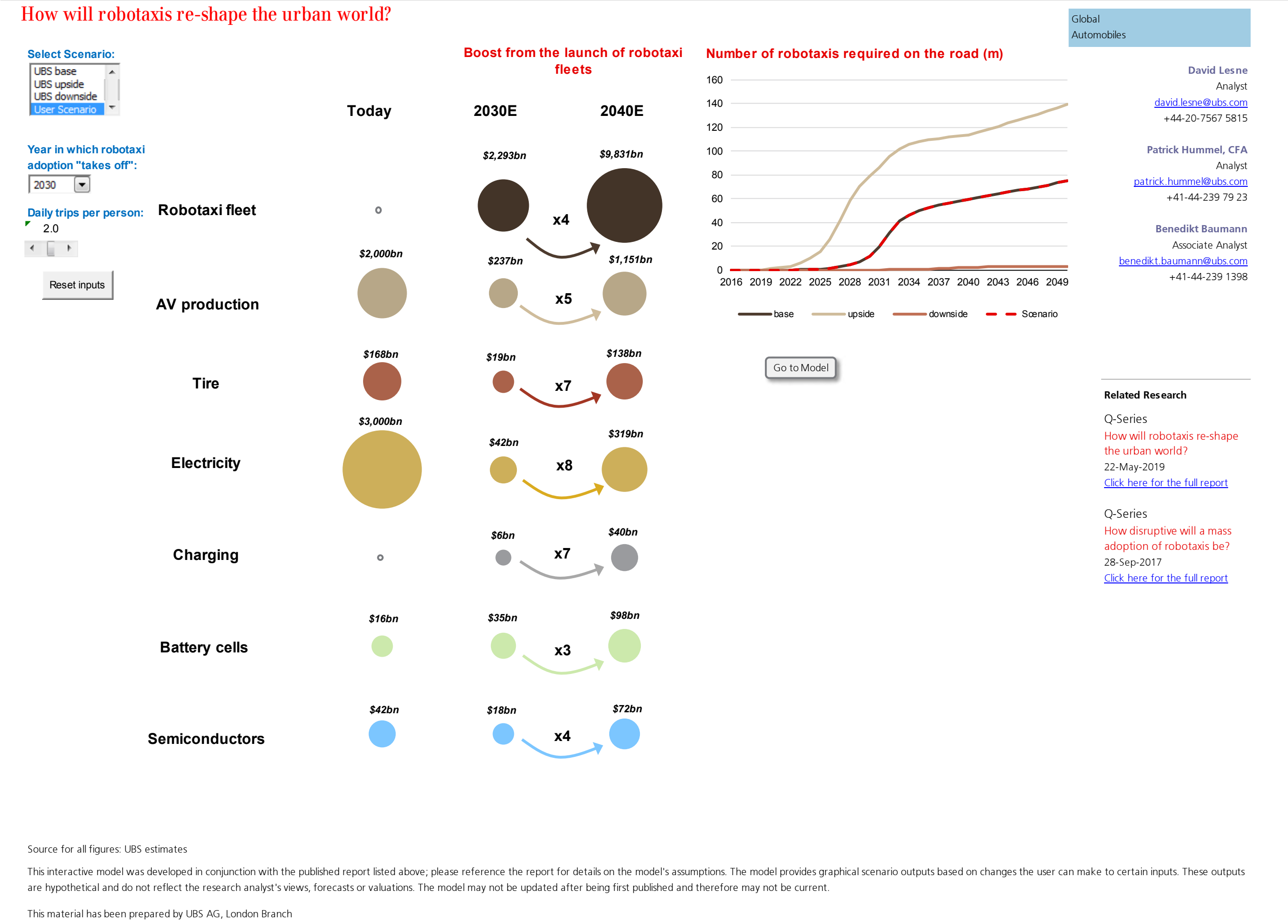
Near and mid-term signposts

We will be tracking the following data and events to gauge whether our thesis is playing out in the upcoming months and quarters:

DATA RELEASE / EVENT DATE		WHAT WE EXPECT
from today	**Ongoing newsflow on the establishment of new ride-on-demand (ROD) services, the expansion of existing services, and the growth of user numbers and revenues**	**More services, more cities, more users** Though occasional setbacks in the growth of ride-on-demand services seem inevitable (mostly driven by regulation), we expect the industry to continue growing. The largest players (Uber, Lyft, Didi, etc.) will report user numbers and revenue on a quarterly basis, and we expect these datapoints to go only in one direction. Tesla recently announced it plans a launch before the end of the year.
Mid-2019	**Launch of GM/Cruise and Daimler robotaxi (pilot) services in San Francisco**	**Successful launches involving at least several dozen vehicles** Both GM/Cruise and Daimler have long since announced the launch of the first commercial robotaxi fleets in San Francisco, albeit with safety drivers on board. Key points to watch will be how wide-spread these services are (throughout the city, or just in small, geo-fenced areas), how well the technology performs, and how the public perceives the services.
From 2019	**Google/Waymo expands its robotaxi fleet and orders more vehicles**	**Jaguar delivers several thousand i-Pace electric cars to Waymo for use in its fleet service, and Waymo orders new cars, exclusively electric** Aside from Google/Waymo's ongoing expansion of its robotaxi service in Pheonix, Arizona, and into other cities, we expect most or all future bulk vehicle orders for the service to be for electric cars. This would confirm our thesis that electric cars are a natural fit for ride-on-demand services (autonomous or not), given lower fuel and maintenance costs, expanding charging infrastructure and shrinking charging times.
From 2020	**More established OEMs launch robotaxi (pilot) services in various cities**	**VW, Renault/Nissan, Volvo, Hyundai, Chinese OEMs and others launch pilot services in various cities** Google/Waymo will have been the first player to launch a relatively large-scale robotaxi service, followed by GM/Cruise and Daimler. From 2020, we expect a large number of OEMs (and potentially also some suppliers like Aptiv or Baidu) to follow their lead.
Semi-annually /annually	**UBS Evidence Lab app downloads/UberX pricing trends and ROD consumer survey**	**We plan to continue to update investors with analysis of UBS Evidence Lab's unique data** We have some unique time series of data emerging, since we started to write about shared mobility in 2014.

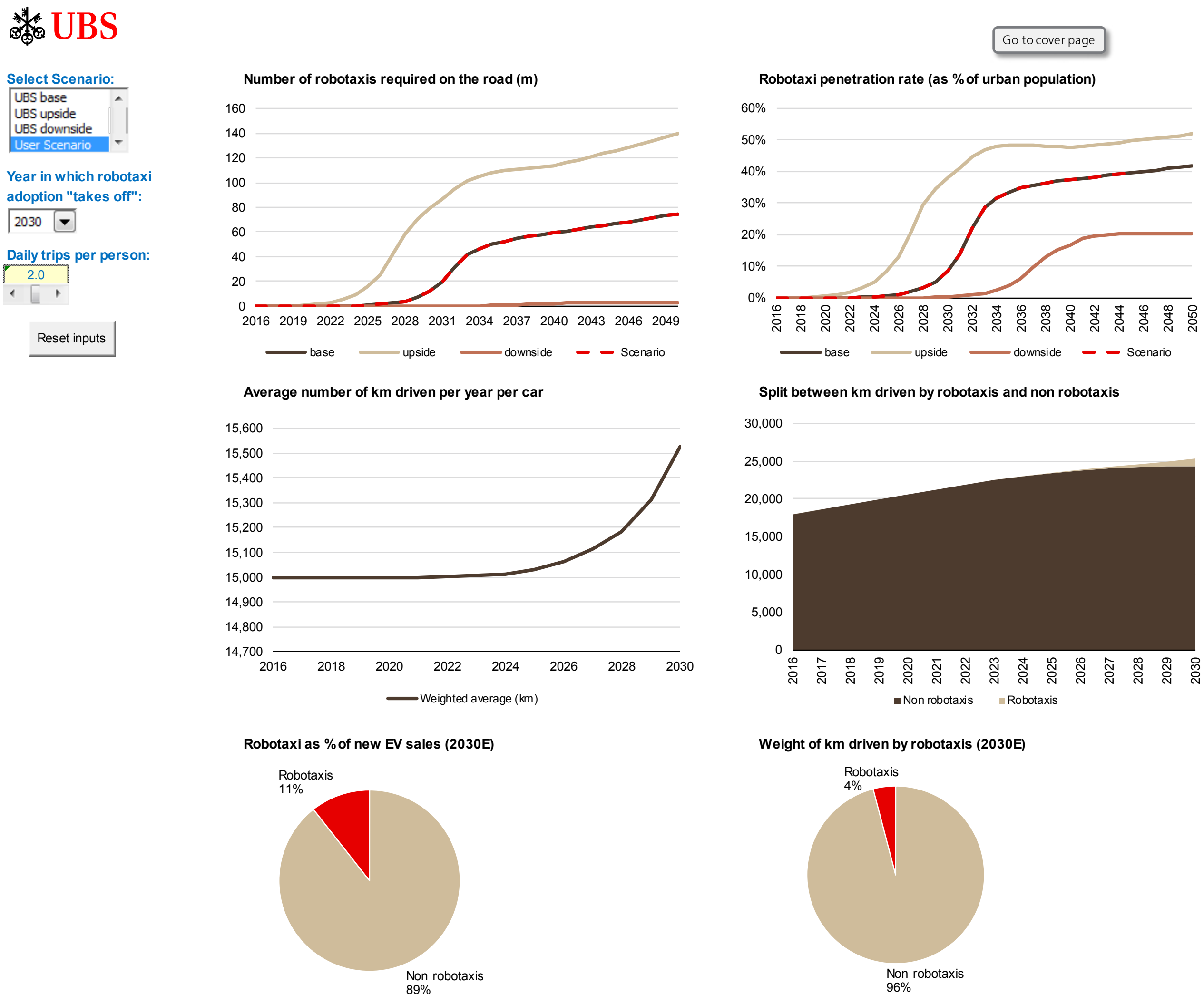
UBS robotaxi launch interactive model

Figure 14: Use your own assumptions to measure the fleet size of robotaxis…



Source: UBS

Figure 15: … and to assess the implied impact for the automotive industry



Source: UBS

What do commercial launches of robotaxi fleets mean for smart cities?

Minimising the number of robotaxis on the road

To answer this question, UBS Evidence Lab has built a simulation – looking at the real-life case of Manhattan – which uses a complex algorithm that performs dynamic optimal route generation and passenger-vehicle assignment considering vehicle capacity and rider demand.

We have built two scenarios into the simulation:

- **Scenario 1 – non-commuter,** where the goal is to minimise the size of the robotaxi fleet; and
- **Scenario 2 – commuter,** where the goal is to maximise the number of commuters serviced using a robotaxi fleet approximately equal in size to the current New York City (NYC) taxi fleet.

At this stage, the simulation assumes one passenger per vehicle. However, we believe UBS Evidence Lab could further improve its dispatching algorithm to reflect pool use of vehicles by several passengers, which would lead to further efficiencies. For more details on the methodology, please refer to the section 'How does the robotaxi simulation work?'

This section focuses exclusively on Scenario 1, which aims to gauge the minimum number of taxis required to service the existing demand for NYC taxi trips. In other words, we try to identify how many NYC taxis can be removed from the road when servicing existing demand using a robotaxi fleet. We have analysed both weekdays and weekends.

Our most striking findings

- The revenue potential of the robotaxi fleet could reach >$2trn on a global basis, higher than we were previously forecasting (in our AV Q-Series)
- The fleet of city taxis could be reduced by **two-thirds**, on our estimates. In other words, the current taxi fleet could become **67% more efficient** if the existing taxis were converted into robotaxis.
- The **average fare paid by passengers could fall by more than 80%** and become cheaper than a metro ticket. In such a scenario, the robotaxi fleet would still generate a healthy profitability margin of more than 30%.
- Managing a robotaxi fleet could generate a **90% profitability margin**. This is unlikely to ever happen given competition/regulation/new entrants. On a daily basis (a 24-hour shift), the revenue potential of the simulation is $3.3m for either a weekday or a weekend day. This translates into $1.2bn on an annual basis.
- Some **excess capacity** is required to properly respond to surges in demand. We estimate that c70% more robotaxis are needed to address this. Excess capacity would not, however, be a major bottleneck for the fleet operator, for the following reasons: (1) the economics of managing the fleet are extremely attractive (as we discuss later); and (2) there could be scope to further improve the dispatching algorithm / cost function to better respond to peak demand.

- **The utilisation rate of the robotaxi fleet would reach c50%** over a 24-hour shift. That is twice as high as Uber/Lyft's utilisation rates today, and 10 times higher than a private car.
- The introduction of robotaxis should **accelerate the penetration of electric cars**: the running cost of an EV robotaxi fleet is about one-third cheaper than that of an internal combustion engine (ICE) robotaxi fleet.
- **Only nine charging stations** are required to cover the daily electricity needs of the robotaxi fleet.
- **The market entry costs look extremely low,** at an estimated daily running cost (excluding depreciation) of just $40 per vehicle. The scope of a robotaxi fleet could therefore be much larger in highly dense areas in the developed world.

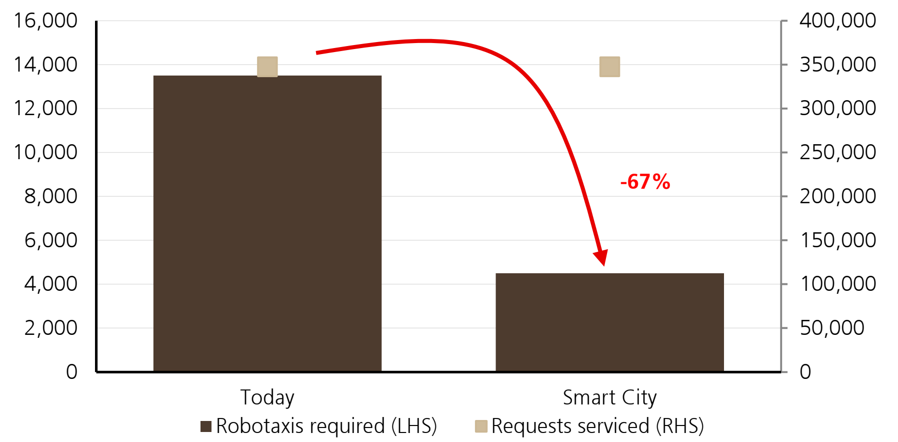
The fleet of city taxis could be reduced by two-thirds

9,000 taxis removed from the streets of Manhattan

The introduction of robotaxi fleets would lead to an projected reduction of 67% of the current taxi fleet. In other words, about 9,000 vehicles would be removed from the roads of Manhattan once we shift towards robotaxi fleets, and the current taxi fleet has the potential to become 67% more efficient if taxis were converted into robotaxis. The dispatching algorithm selects the optimal route every time. According to the New York City Taxi & Limousine Commission, there are more than 13,000 active medallion taxis during peak activity periods.

The dispatching algorithm shows that the current demand for taxis could be serviced with 67% fewer vehicles

Figure 16: By how much could the (robo)taxi fleet be reduced in a smart city?



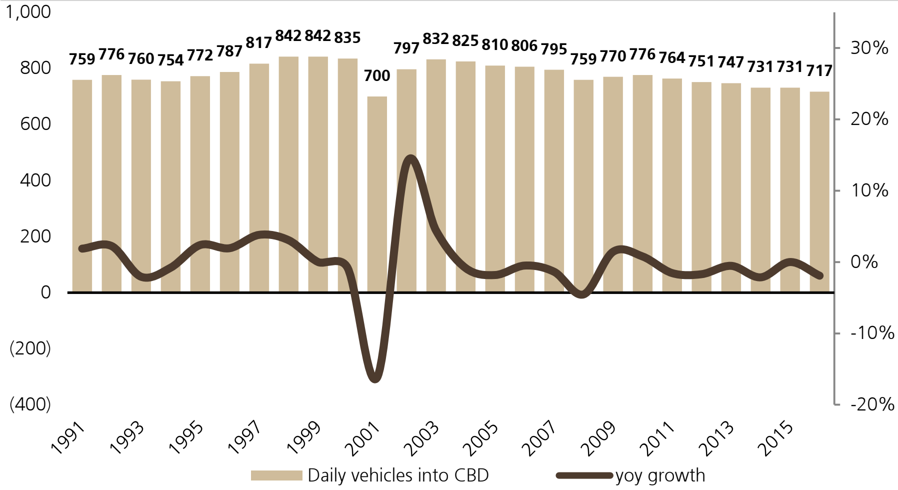
Source: UBS Evidence Lab

Note: "today" shows the number of traditional taxis available

The number of vehicles entering NYC CBD should fall further

While the total number of vehicles entering the central business district of NY has been declining over the past 10 years (Figure 17), the introduction of robotaxi fleets should accelerate this downward trend.

Figure 17: Daily vehicles into [central business district] (CBD), in thousands



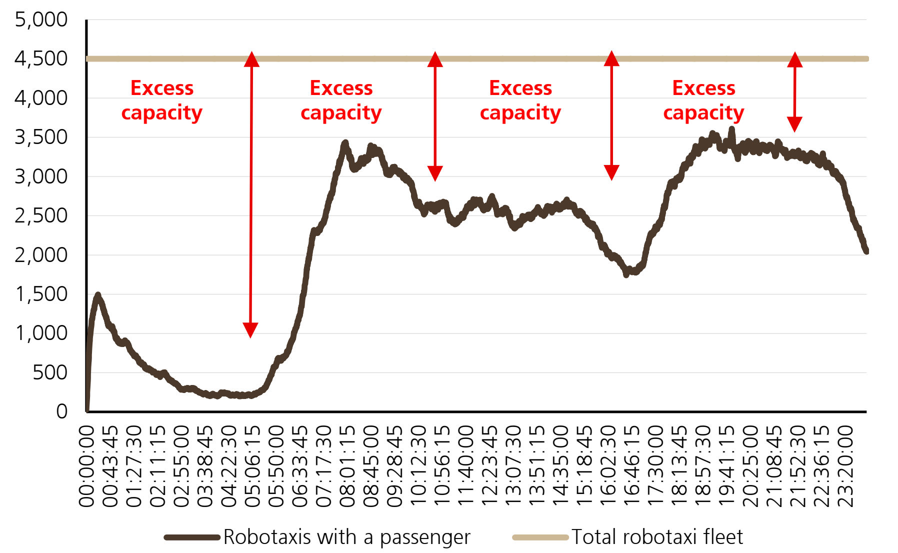
Source: New York Department of Transportation

Some excess capacity is required

In our Autonomous Vehicle Q-Series, we highlighted asset utilisation as a key risk for the fleet manager. The simulation clearly shows that excess capacity is required to fully cover peak demand hours. We estimate that c70% more robotaxis are needed to properly respond to surges in demand.

A fleet manager would need 70% more robotaxis to respond to surges in demand

Figure 18: Excess capacity required to service demand (# of robotaxis)



Source: UBS Evidence Lab

One key hurdle for the mass adoption of robotaxis will be rush/peak hours. We see several potentially mitigating factors:

The peak/rush hour pattern might change in a smart city

- **Changes in consumer behaviour:** As cars may become an extension of someone's home or office, we think behaviour and individuals' schedules could change and adapt, leading to a smoother demand pattern during the day.
- **Effective passenger occupancy/sharing:** We will do more work on this topic in the future to assess the impact of pooling in the simulation.

- **Smart traffic lights/infrastructure:** Connected cars can enable significant improvements in traffic flow. MIT used travel data to show that "smart" traffic lights (enabling car traffic based on speed and cross-traffic) could manage twice as much traffic with the same amount of traffic, almost eliminate wait times, reduce congestion at intersections, reduce travel times, and lower emissions.

Excess capacity will not be a major bottleneck, in our view

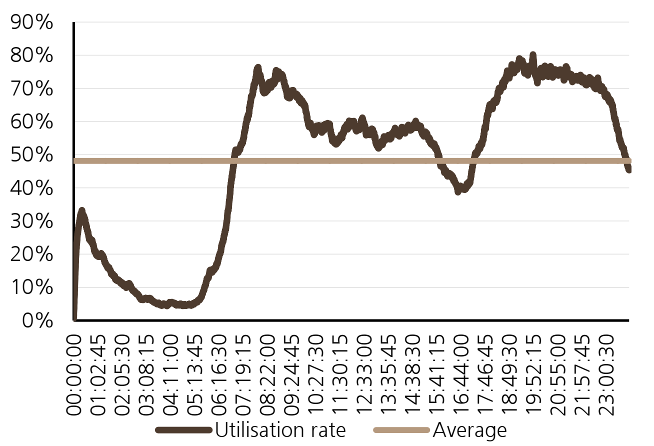
All in all, we think this excess capacity will not be a major bottleneck for the following reasons: (1) the economics of managing the fleet should be extremely attractive (discussed later); and (2) there could be scope to further improve the dispatching algorithm / cost function to better respond to peak demand.

The robotaxi fleet utilisation rate should reach c50%

Much higher utilisation rate for robotaxis

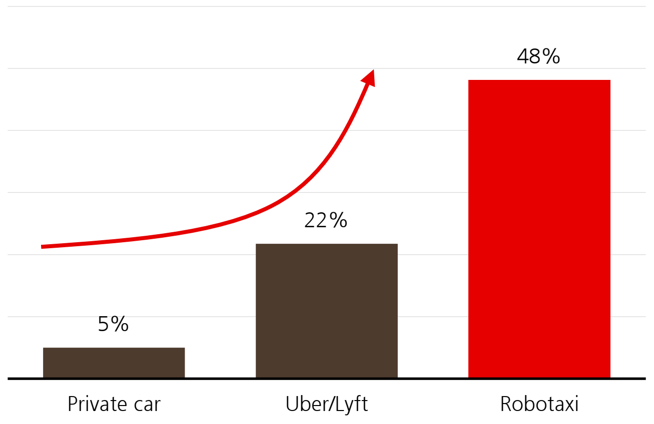
During a weekday, the average utilisation rate over a 24-hour shift stands just below 50%, with peaks of 80% at around 8:30am and 7.00pm and a low of 5% in the early-morning hours. According to the New York City Taxi & Limousine Commission, the utilisation rates of Uber and Lyft already stand at similar levels. However, our understanding is that this utilisation rate is based on the duration of the driver's shift (i.e. around 8-10 hours). Therefore, their equivalent utilisation rate over a 24-hour shift would be 20-25% (Figure 20).

Figure 19: Robotaxi fleet's utilisation rate throughout a weekday



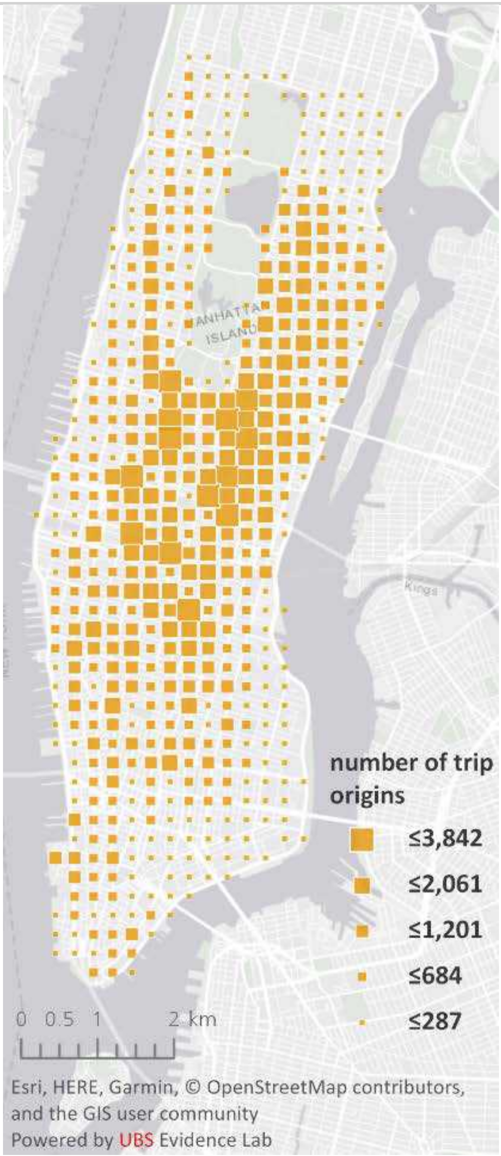
Source: UBS Evidence Lab

Figure 20: Average utilisation rate over a 24-hour period



Source: UBS Evidence Lab, New York City Taxi and Limousine Commission

Figure 21: Most popular areas for demand



Source: Esri Basemap, UBS Evidence Lab

Figure 22: Most popular destinations

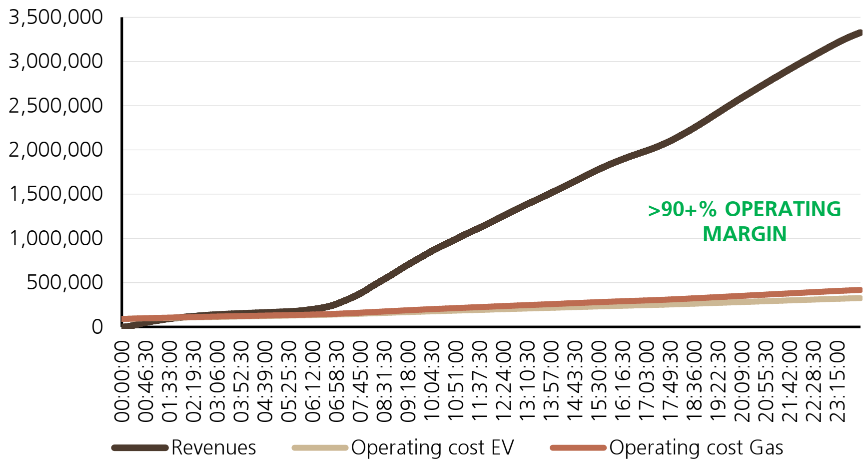
Source: Esri Basemap, UBS Evidence Lab

Managing a robotaxi fleet could generate a 90% profitability margin

$1.2bn annual revenue potential with a fleet of 4,500 robotaxis

We have used the simulation to estimate the revenue and profitability potential of managing a fleet of robotaxis. The numbers appear extremely attractive: we estimate that the profitability margin (including depreciation) of the fleet could reach an impressive 90% (for an EV fleet). This is unlikely to ever happen given competition/regulation/new entrants. On a daily basis (24-hour shift), the revenue potential of managing a fleet of 4,500 robotaxis is $3.3m for either a weekday or a weekend day. This translates into $1.2bn on an annual basis.

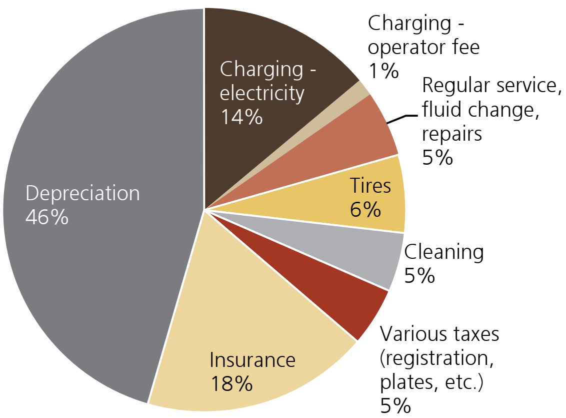
Figure 23: Robotaxis' fleet profitability profile during the day ($)



Source: UBS Evidence Lab

The total daily operating cost amounts to c$320k. Our analysis does not include teleoperator, which would add c$35k to the overall cost (assuming one teleoperator looks after 50 vehicles). The largest cost item is depreciation, followed by insurance and electricity. Tires represent 6% of the overall cost.

Figure 24: Daily cost breakdown of the robotaxi fleet (%)



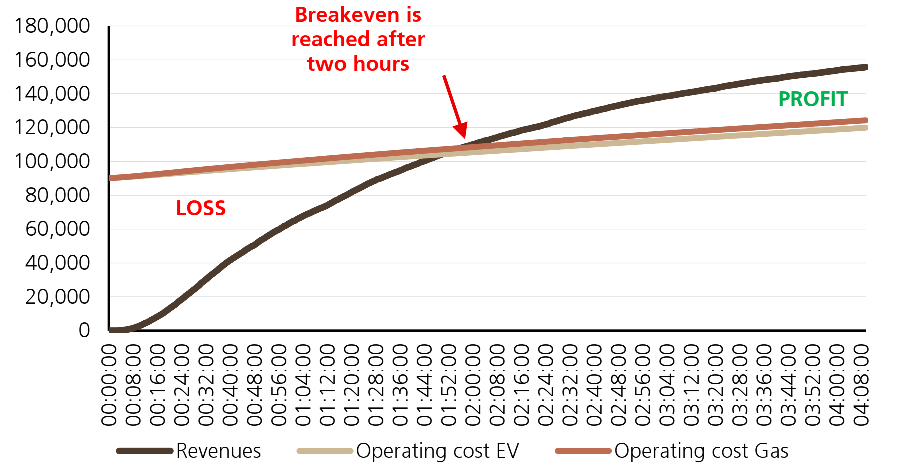
Source: UBS estimates

It takes up to two hours for the robotaxi fleet to reach profitability breakeven

It takes c2 hours on a weekday and less than one hour during the weekend to reach profitability breakeven

The fleet of robotaxis can rapidly reach profitability breakeven and become profitable within only two hours of service of a daily shift. In other words, within two hours, all the daily operating costs are covered by the sales generated. It is worth noting that the time window between midnight and 2am is one of the quietest periods of the day. Therefore, if we were to launch the fleet of robotaxis around 7am (close to the first daily demand peak), it would be much faster to reach profitability breakeven. During the weekend, the simulation reaches profitability breakeven within less than one hour.

Figure 25: When does the robotaxi fleet reach profitability breakeven?



Source: UBS Evidence Lab

The cost of a trip could fall by more than 80%

The simulation shows that the average cost of a trip (i.e. the fare paid by passengers) is c$10. This compares with an average yellow cab fare ranging between $10 (mid-town) and $13.6.

The average fare paid could fall by more than 80%; the robotaxi fleet still generates healthy profitability margins of more than 30%

As discussed earlier, the profitability margin potential of a robotaxi fleet is extremely high. On that basis, we think this level of profitability is unsustainable in the long run. We estimate the cost of a trip could fall by more than 80% and reach $2, which would be lower than the cost of a metro ticket. We discuss the impact of a robotaxi fleet on mass transit in the next section. Assuming an average fare of $2, the robotaxi fleet would still generate a strong profitability margin of c40%.

Figure 26: Trip data – robotaxis vs today

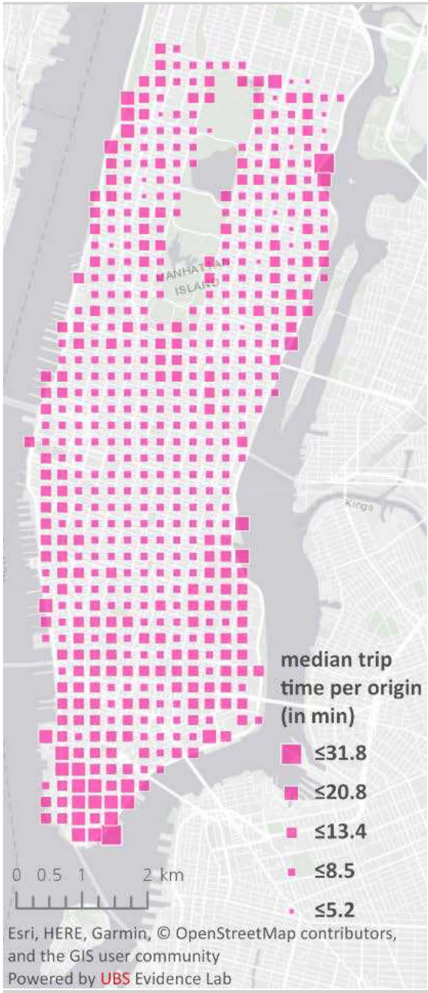
	Today	Weekday	Weekend
Average trip fare ($)	**10.3**	**9.8**	**10.1**
Reduction potential (%)	*0%*	*80%*	*80%*
Average trip time (min)	11	9	10
Average wait time (min)	na	2	1
Average distance driven per trip (km)	**4.2**	**3.2**	**3.3**
Number of daily trips per vehicle	26	75	73

Source: NYC TLC, UBS estimates

Figure 27: Wait time distribution (min)

Source: Esri Basemap, UBS Evidence Lab

Figure 28: Trip time distribution (min)



Source: Esri Basemap, UBS Evidence Lab

Figure 29: Revenue trip per time ($)

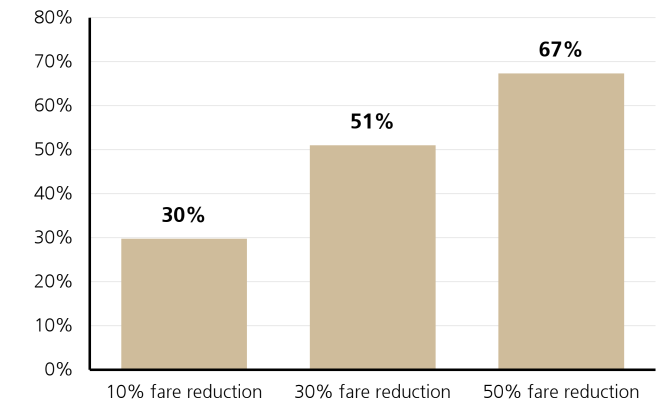
Source: Esri Basemap, UBS Evidence Lab

Some price elasticity

Let's now discuss price elasticity and how consumers are likely to respond to any potential reduction in fares. The recent UBS Evidence Lab consumer survey on "ride-on-demand" (ROD) points to price elasticity of demand, with 30% of the current ROD users saying they would increase usage by more than 20% if fares dropped by 10%. These figures rise to 51% of respondents on a 30% fare drop and 67% of respondents on a 50% decline in prices (Figure 30).

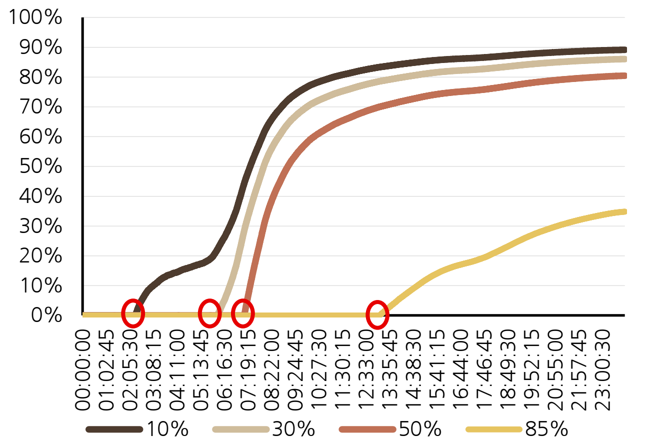
We have assumed various level of price reduction for the passengers: 10%/30%/50% and 85% (Figure 31). In most cases, the profitability of the robotaxi fleet remains well above 70% and the profitability breakeven is reached within a maximum of 7 hours (Figure 31). In our most extreme scenario (ie, fare reduction of 85%), the fleet will generate an operating margin of more than 30% during a 24-hour shift.

Figure 30: ROD users who would increase usage by more than 20% for a given price reduction (in 2018)



Source: UBS Evidence Lab 2018 ride-on-demand consumer survey.
Note: Includes the US, UK and France

Figure 31: Profitability margin sensitivity at different levels of price reduction



Source: UBS Evidence Lab
Note: The red bubble shows when the profitability breakeven is reached

At this stage, we have found no evidence that pricing is becoming more competitive. For more details on the recent trends, please refer to UBS Evidence Lab: Are consumers ready to shift from private cars to ride-on-demand?

More competition should drive fares down further

In the simulation, only one operator covers all the passengers' requests. The profitability margin would surely attract new entrants. Adding regulation, we think it is highly unlikely that the robotaxi fleet market will 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.

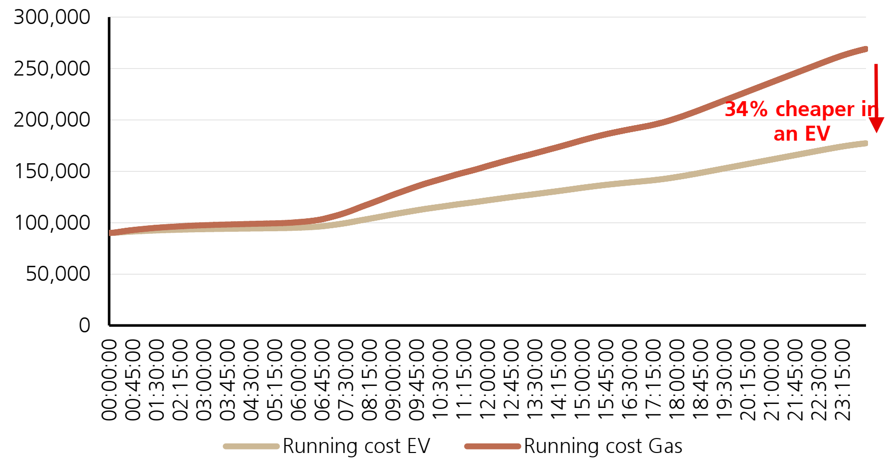
Robotaxis are likely to become seamlessly integrated into public transport systems, and could be run on a concession basis (see later in the report for our discussion of the impact on public transport). It might well be that, once a concession is granted, only a small number of firms would be allowed to operate robotaxis in a specific city. Such a model might turn out to be the most profitable one, but would likely require a high degree of vertical integration on the part of the provider. In North America, regulation is more of a local issue, not least because there is less cannibalisation of public transport networks. Nonetheless, we think that any given metro area can only handle 3-4 players before unit economics become too difficult to manage for long-term profitability. We discuss this in more detail in our section on the impact of robotaxi fleets on mass transit.

Robotaxi fleet should accelerate EV penetration

An EV robotaxi fleet offers much more attractive economics

Let's first look at the relative running cost metrics (ie, excluding depreciation). The running cost of an EV robotaxi fleet is about one-third cheaper than that of an ICE robotaxi fleet (Figure 32). At the end of our 24-hour shift, the difference amounts to almost $100k. The obvious choice for the fleet operator is thus to choose electric cars.

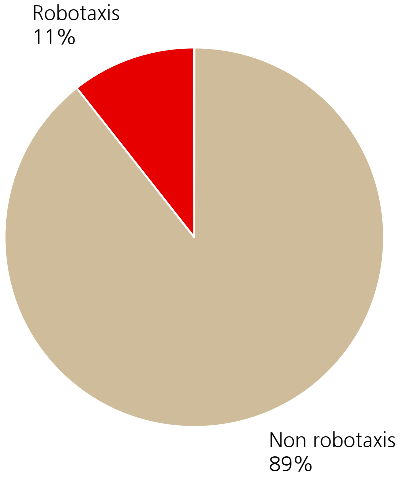
Figure 32: Relative running costs EV vs gasoline ($)



Source: UBS Evidence Lab
Note: Running costs excludes depreciation

The launch of commercial fleets of robotaxis should accelerate EV penetration, as an EV fleet is cheaper to run (discussed above) and easier to manage from a logistics standpoint. For instance, in the future, EVs will be able to recharge themselves without human intervention as induction plates become widespread.

Figure 33: Robotaxis as % of new EV sales (2030E)



Source: UBS estimates

Only nine charging stations are required

In this section, we try to gauge the number of charging stations that would be required to recharge the robotaxi fleet on a daily basis. We found that only nine charging stations are required to cover the daily needs of the 4,500-robotaxi fleet. Most cars will be able to last two days before a charge is required. As a comparison, there are today about 30 gas stations in Manhattan. If the robotaxi fleet was running on gasoline, only three gas stations would be required. The simulation assumes a battery capacity per robotaxi of 60kwh. We note that there is scope to use smaller batteries in order to recharge faster during off-peak hours. We show below that each robotaxi needs to recharge every two days.

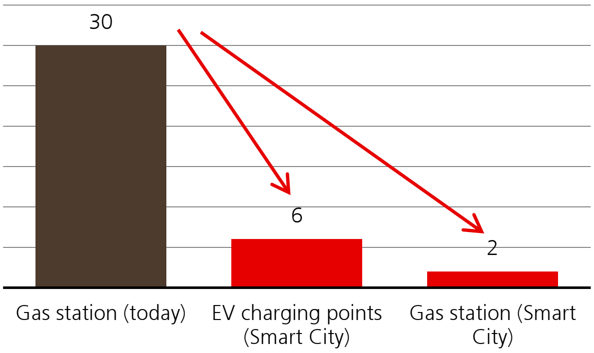
Figure 34: Number of charging stations or gas stations required for the robotaxi fleet

Electric vehicle		Gasoline vehicle	
Number of km driven by each robotaxi (full day)	246	246	Number of km driven by each robotaxi (full day)
Average battery range (km)	500	8	Fuel consumption (l/100km)
		60	Fuel tank size (l)
Number of days on a single charge	2	3	Number of days on a single tank
Number of robotaxis that requires a full charge every day	**2,210**	**1,473**	**Number of robotaxis that requires a full tank every day**
Charging output (kwh)	150		
Average battery size (kwh)	60		
Time required for a full charge (h)	0.4	0.1	Time required for a full tank (h)
Time required for a full charge (min)	24	5	Time required for a full tank (min)
Time gap in between charges (min)	10	10	Time gap in between refuel (min)
Total time required for full charge (min)	**34**	**15**	**Total time required for full tank (min)**
Total time required to recharge the fleet (min)	75,130	22,097	Total time required to fuel the fleet (min)
Total time required to recharge the fleet (h)	1,252	368	Total time required to fuel the fleet (h)
Number of charging points required	52	15	Number of nozzles required
Number of charging points per charging station	6	6	Number of nozzles per charging stations
Number of charging stations required	**9**	**3**	**Number of gas stations required**

Source: UBS estimates

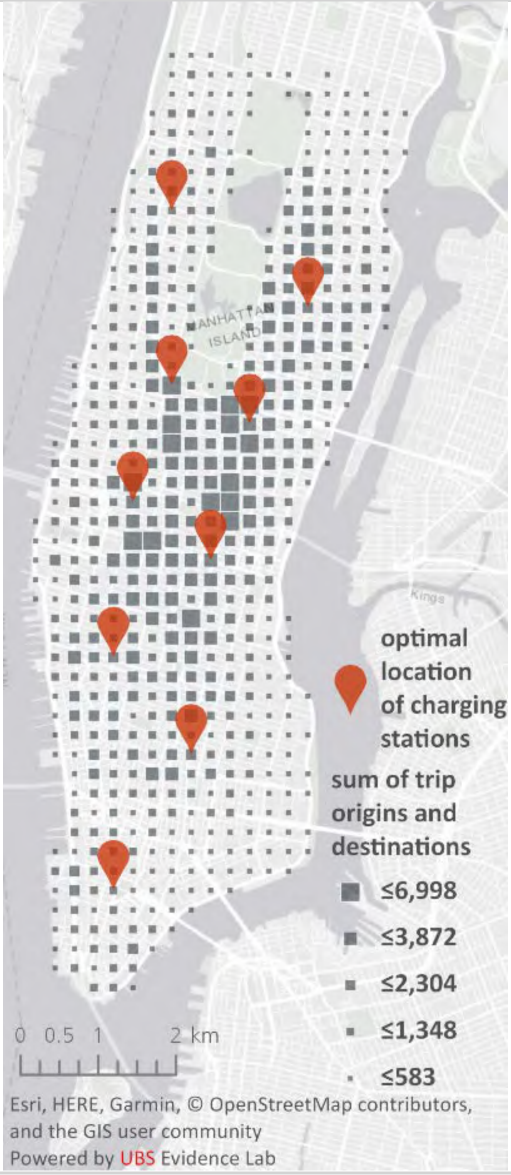
It should not be an issue to find the space needed to build those charging stations. In Figure 36, we show where we think it would make the most sense to locate the charging stations. Optimal locations of charging stations were defined in order to maximise coverage. The model chose facilities such that as much demand as possible was covered within a 15-minute drive-time in the most efficient way, ie, to minimise the distance between demand point and facility. Demand was defined as the sum of trip origins and destinations (in other words, sum of trip start and endpoints) within a 500m x 500m square.

Figure 35: Number of gas stations vs charging stations required in Manhattan



Source: UBS, New York Times

Figure 36: Where should the charging stations be located?



Source: Esri Basemap, UBS Evidence Lab

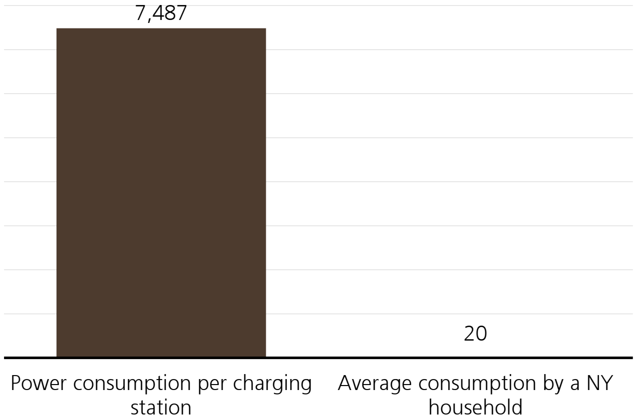
What does this all mean for electricity consumption? We estimate that the daily power consumption of a charging station will be c7,500kWh, which is equivalent to the daily consumption of almost 400 households living in NYC.

Figure 37: Daily power consumption per charging station (kWh)

Number of robotaxis that requires a full charge	2,210
Price per kWh ($)	0.3417
Average battery size (kwh)	60
Daily charging price (€)	**45,304**
Power consumption (kWh/100km)	12
Number of km driven by each robotaxi (full day)	246
Total power consumption (kwh)	**65,105**
Daily power consumption per charging station (kwh)	**7,487**

Source: UBS estimates

Figure 38: Power consumption per charging stationversus average New York household consumption (kwh)



Source: UBS estimates, electricity local

Limited impact on congestion

Our simulation does not show any major bottlenecks due to heavy traffic conditions. Obviously some streets will be materially more used than others, as shown in Figure 39.

The impact is likely to be mitigated by the fact that parking space will no longer be required, allowing more vehicles to drive around the city. The International Transport Forum estimates that all on-street parking could be removed and more than 80% of off-street parking will no longer be needed. In the urban United States, the automobile (open and closed parking) consumes close to 50% of the land area of cities. In Los Angeles, this figure approaches two-thirds. The network used in the simulation has 770km of road.

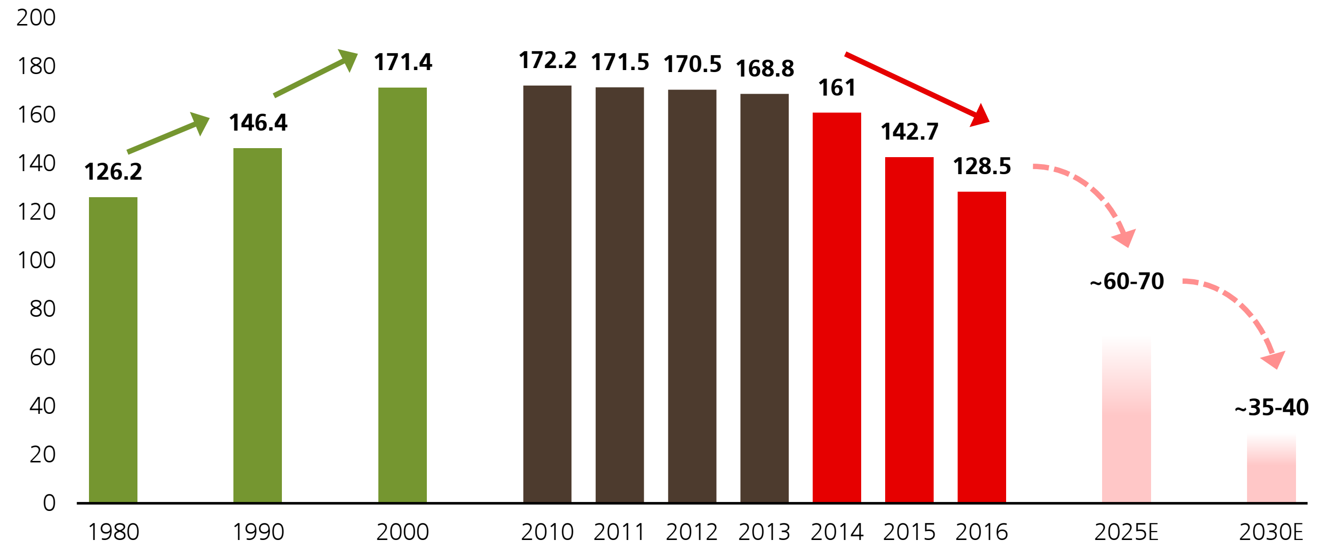
Figure 39: The most-used streets

Source: UBS Evidence Lab

More than 300k daily trips by the robotaxi fleet

Over the 24-hour shift, UBS Evidence Lab has been able to simulate 337k trips. As a comparison, yellow cabs undertake 85,000 daily trips that either pick up or drop off in Midtown. About 20% of these trips never leave the area. The simulation covers a larger area than Midtown only (south of 100th Street). According to the New York Department of Transportation, the number of city taxi trips has been falling since 2013. Assuming the same declining annual run-rate of close to 10% between 2013 and 2018, the number of annual city taxi trips could reach 35-40m in 2030.

Figure 40: Number of annual trips for city taxis (m)

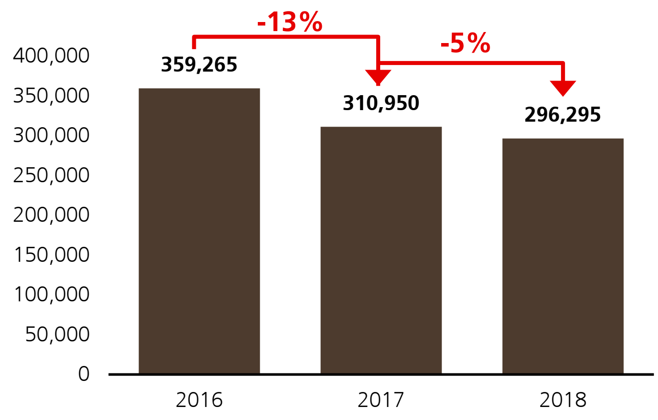


Source: New York Department of Transportation

Note: Assumes city taxi trips experience the same declining run-rate as seen between 2013 and 2016

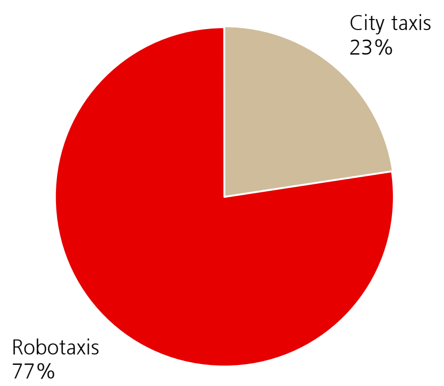
If we assume the number of daily trips stays constant until 2030, less than 25% of the trip could be made by city taxis (Figure 42).

Figure 41: Daily average trips by "medallion taxi"



Source: TLC Trip Records (2018 data is as of June 2018)

Figure 42: Daily trip mix in 2030E



Source: UBS estimates

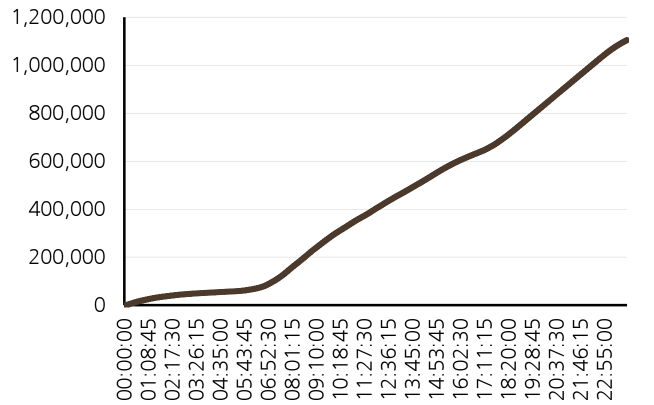
The number of km driven will increase by a factor of 20x …

Fleet size is two-thirds smaller

According to the NYC Department of Transportation, the fleet of taxis picking up and dropping off passengers within the Midtown area drive a total of 1,395 miles (or 2,300km) per hour averaged over a full day. The simulation covers a larger area (south of 100th Street), but we estimate the fleet of robotaxis drives a total of 46,000km per hour, which is 20x higher (Figure 44).

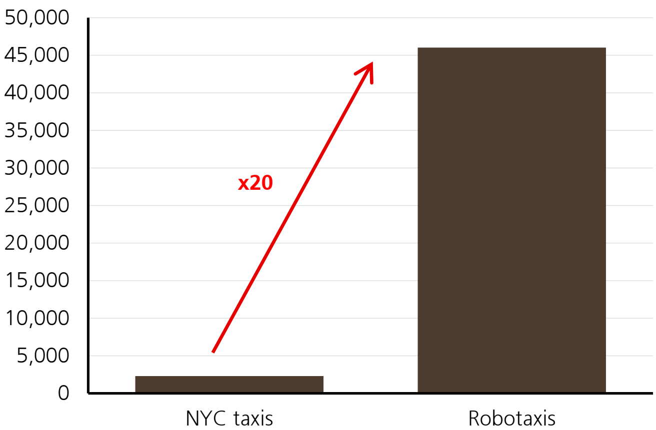
Overall, the fleet of 4,500 robotaxis drives 1.1m km during a 24-hour shift.

Figure 43: Cumulative number of km driven by the robotaxi fleet



Source: UBS Evidence Lab

Figure 44: Distance driven per hour by the robotaxi fleet (km)



Source: UBS Evidence Lab

What are the key surprises when focusing on weekends?

We have also conducted the simulation during several weekends in order to see if there were any major differences from the weekday picture. The operating metrics are actually very similar. The key difference is the time it takes for the simulation to reach breakeven. It takes less than one hour during the weekend compared to close to two hours during a weekday. The key reason is the higher utilisation rate after midnight during the weekends.

Figure 45: Non-commuter scenario – weekday vs weekend

	Scenario 1		
Non-commuter scenario	**Weekday**	**Weekend**	**Key surprises from Weekend vs Weekday**
Number of robotaxi	4,500	4,500	
Serviceability rate (%)	*97.9%*	*98.4%*	
Total requests	347,405	338,407	
Total daily trips	337,921	329,786	
Average utilisation rate (%)	**48%**	**50%**	**The utilisation rate is higher during weekends**
Peak utilisation rate (%)	*80%*	*81%*	
Overall revenue of the fleet ($m)	3.3	3.3	
Average revenue per passenger or average trip cost ($)	9.8	10.1	
Revenue of the fleet/per taxi ($)	739	741	
Gasoline cars:			
Operating costs (incl. depreciation) ($)	417,007	420,833	
As % revenue	*87%*	*87%*	
Electric cars:			
Operating costs (incl. depreciation) ($)	325,253	327,118	
As % revenue	*90%*	*90%*	
How much time does it take to reach breakeven?			
Gasoline cars	1:56:15	0:50:15	**The profitability break-even point is reached much more rapidly**
Electric cars	1:50:00	0:48:45	
Trip data:			
Average trip time (min)	9	10	
Average wait time (min)	2	1	
Average delay time (min)	2	1	
Distance driven by the fleet (km)	1,104,859	1,128,479	
Distance driven by the fleet/hour (km)	46,036	47,020	
Average distance driven per robotaxi (km)	246	251	
Other:			
Electricity consumption of the fleet (kwh)	**65,105**	**67,918**	**The electricity consumption is similar**

Source: UBS Evidence Lab

Will robotaxis disrupt mass transit?

We think robotaxis could rapidly become a mode of transport of choice within the urban landscape.

Maximising the number of commuters with a robotaxi fleet approximately equal in size to the current NYC taxi fleet

In this section, we have leveraged the simulation to gauge the maximum number of commuters that could be serviced using the same number of city taxis as are available today on the streets of Manhattan. In other words, in this scenario ("Scenario 2 – Commuter"), we maximise the number of commuters that can be serviced with a robotaxi fleet approximately equal in size to the current NYC taxi fleet.

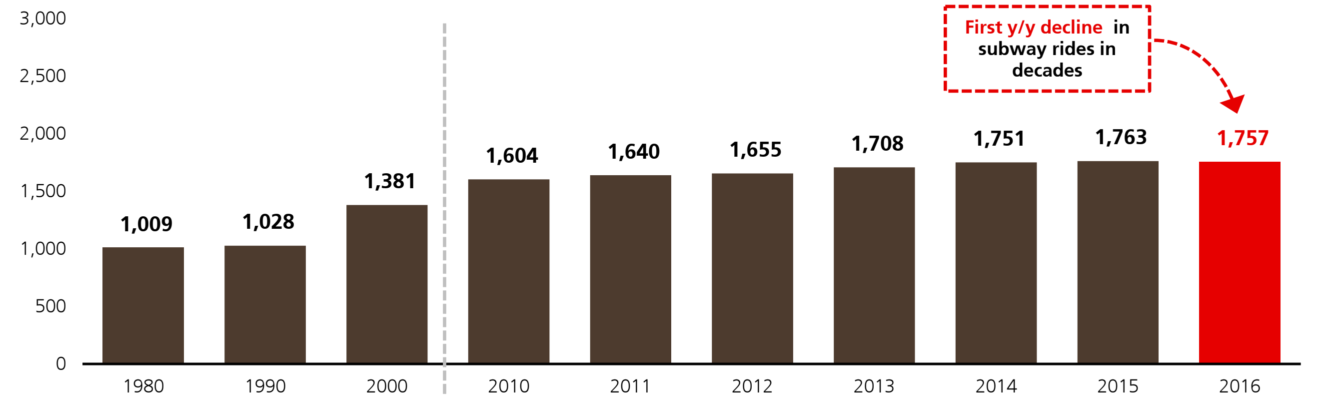
Our most striking findings

- With 13,500 robotaxis, we could service the entire existing NYC taxi daily request (Scenario 1) and additionally, **15% of all public transport users** within Manhattan.
- A robotaxi fleet would price-compete with public transport. Given the high level of profitability of the robotaxi fleet (despite the fare declining by 70%), **the cost of a robotaxi trip and public transport would likely be on a par in the long run.**
- Robotaxi users would be able to **more than halve their commute time** within Manhattan.
- The utilisation rate of the robotaxi fleet would more than halve compared to our Scenario 1, given the **higher excess capacity required** to cover peak hours.
- **Only 12 charging stations** would be required. That's three more than in Scenario 1 – commuter.
- The number of km driven per hour would increase by a factor of **27x**.

Robotaxis likely to be integrated into the public transport system

Subway rides might come under pressure in the long run. In this section, we find that the launch of commercial fleets of robotaxis is likely to accelerate this shift. Ultimately, we think the robotaxi fare has scope to be on a par with the cost of a metro ticket today. Furthermore, commuters should enjoy a better commuting experience and save time. On the other hand, the fluidity of a typical robotaxi network could leave some areas under-serviced, potentially leading to a postcode lottery for affordable transport. Moreover, MIT researchers found no price at which people were willing to share rides – this pattern would if anything exacerbate potential neglect by postcode, by not making it worthwhile to allocate vehicles.

Figure 46: Subway ridership in New York City (m)



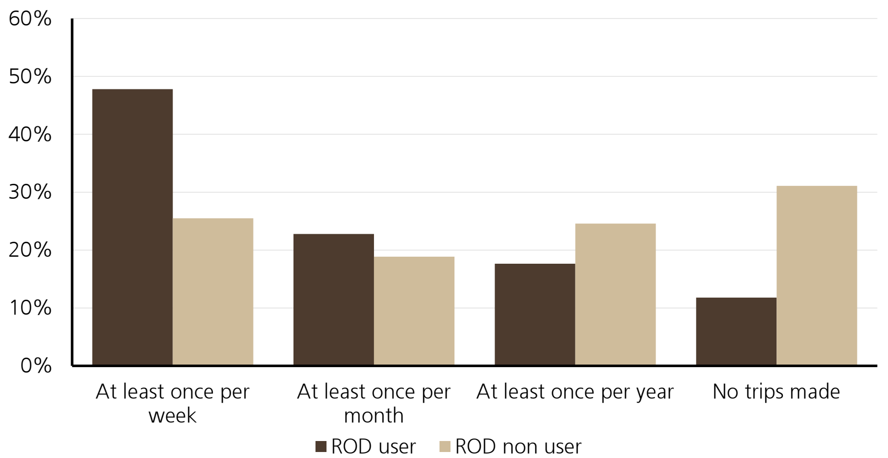
Source: New York Department of Transportation

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 a small number of firms are allowed to operate robotaxis in a given city. It is therefore important for the platforms to develop close relationships with the municipalities.

ROD users still rely heavily on public transport

As shown in Figure 47, analysis of the UBS Evidence Lab survey data indicates that ride-on-demand usage and usage of public transport go hand in hand. About 50% of consumers who have used ride-on-demand in the past also rely on public transport at least once a week.

Figure 47: Ride-on-demand users rely on public transport more frequently



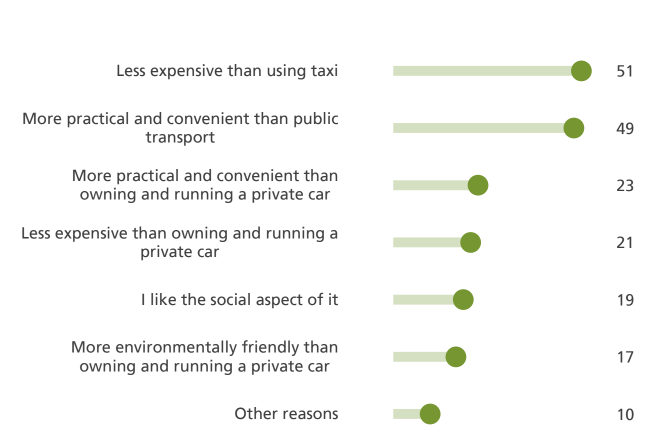
Source: UBS Evidence Lab 2018 ride-on-demand consumer survey.
Note: Percentage of respondents selecting frequency of a given usage category. Includes the US, UK and France

Robotaxis should improve the commuter's experience

Last year, UBS Evidence Lab conducted the second wave of its ride-on-demand (ROD) survey. It interviewed more than 16,000 consumers in six key markets. For the detailed conclusions, please refer to "Are consumers ready to shift from private cars to ride-on-demand?"

We found that the key reasons why consumers decide to choose ROD are (1) its cost advantage over traditional taxis, and (2) its convenience versus public transport. All In all, pricing and convenience were cited as the top reasons for choosing to use a ROD service (Figure 48).

Figure 48: Main reasons for choosing ROD (in %)



Source: UBS Evidence Lab 2018 ride-on-demand consumer survey
Note: Multiple mentions possible. Includes the US, UK and France

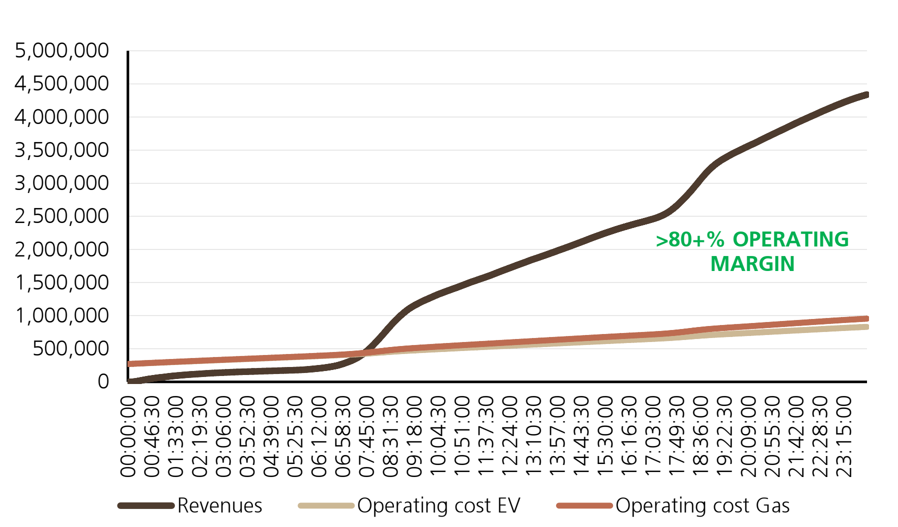
Figure 49: Activities done when using ROD (in %)

Source: UBS Evidence Lab 2018 ride-on-demand consumer survey
Note: Multiple mentions possible. Includes the US, UK and France

What if the cost of a robotaxi trip is equivalent to a metro ticket?

Let's first address the cost issue. Similar to 'Scenario 1 – non commuter', we have used the simulation to estimate the revenue and profitability potential of managing a fleet of robotaxis. This time, we include commuters in the picture. We estimate that the profitability margin (including depreciation) of the fleet could reach more than 80%. As a reminder, in our 'Scenario 1 – non commuter', the profitability margin stood above 90%. On a daily basis (24-hour shift), the revenue potential is $4.3m.

Figure 50: Robotaxi fleet profitability profile during the day ($)

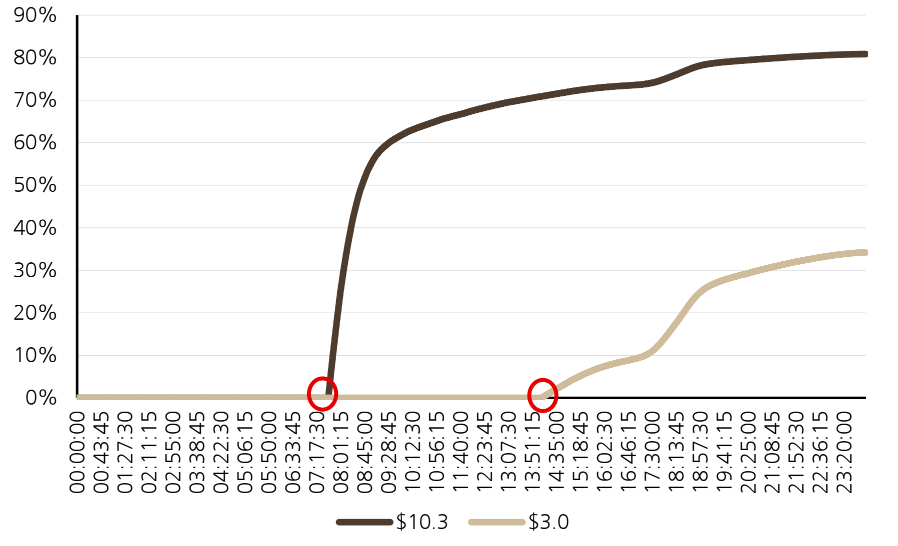


Source: UBS Evidence Lab

The cost of a robotaxi trip and public transport should be on a par

Our simulation shows that the average cost of a trip (the fare paid by passengers) is $10.30. As shown in Figure 50, the profitability margin potential of the robotaxi fleet is extremely high. This is unlikely to be sustainable in the long run. If we use the cost of a SingleRide ticket of $3 for the average trip fare in a robotaxi, the profitability margin of the robotaxi fleet drops from 80% to c35%. On that basis, given the high level of profitability (despite the fare declining by 70%), we believe it is very likely that the cost of a robotaxi trip and public transport will be on a par.

Figure 51: What would be the profitability margin of the robotaxi fleet if the average trip cost was in line with that of a metro ticket?



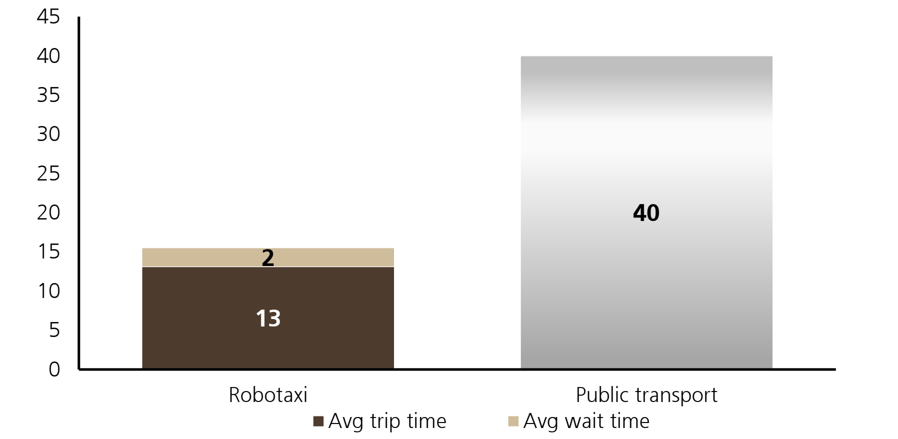
Source: UBS Evidence Lab
Note: The red bubble shows at what time breakeven is reached

The commute time falls sharply

The commuter would not only benefit from the same fare; they would also be able to reduce materially the time taken to get to or from work. The simulation shows that the commute time would be c15 minutes in total for one leg. As discussed earlier, the simulation captures only the commuters within Manhattan.

Average commute time would fall to 15 minutes

Figure 52: Total commute time (minutes; one leg) – robotaxi vs public transport

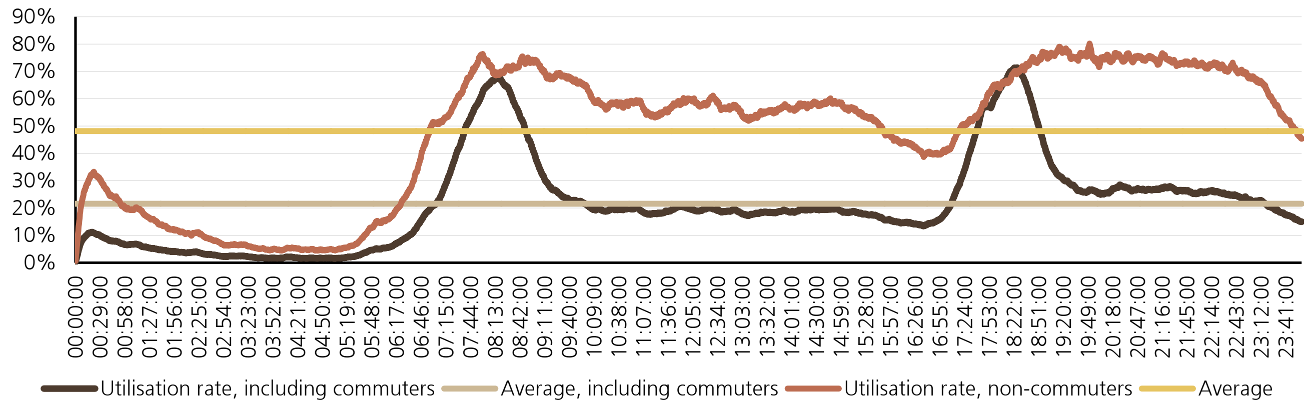


Source: UBS Evidence Lab

The utilisation rate of the robotaxi fleet drops materially

Both the commuter and the non-commuter scenarios follow a similar pattern during the day, with peak hours reached between 7.00 and 9.00am and 5.00 and 7.00pm. However, the average utilisation rate under 'Scenario 2 – commuter' is more than 50% lower than under 'Scenario 1 – non-commuter' (22% vs 48%).

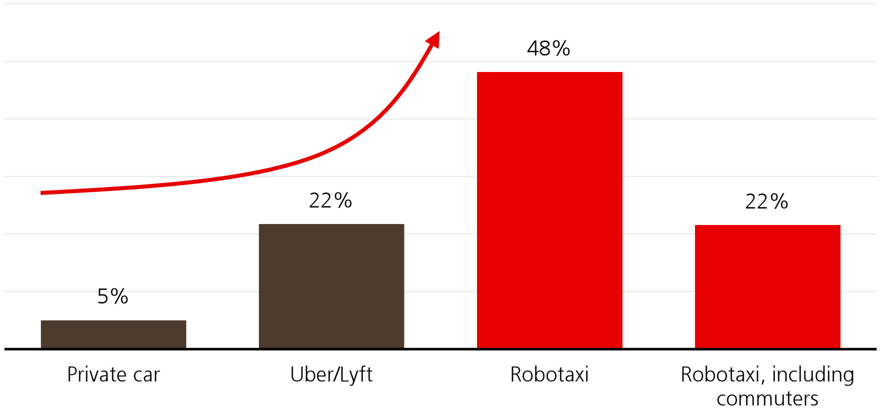
Figure 53: Utilisation rate throughout the day – commuter vs non-commuter scenario



Source: UBS Evidence Lab

The utilisation rate under Scenario 2 is similar to the utilisation rate of Uber and Lyft.

Figure 54: Average utilisation rate over a 24-hour period

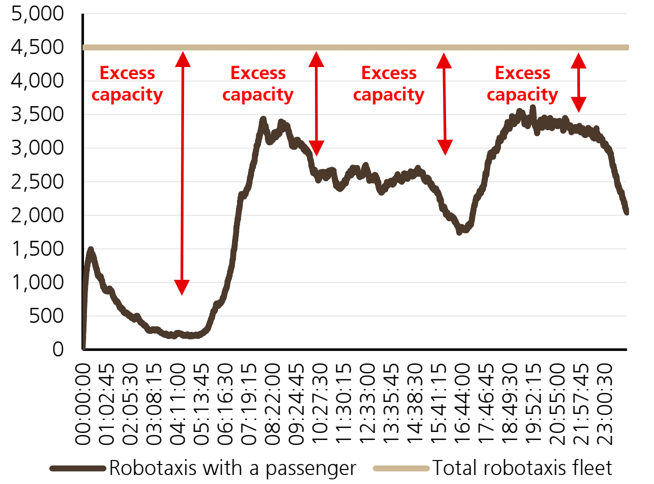


Source: UBS Evidence Lab, New York City Taxi & Limousine Commission

More excess capacity required

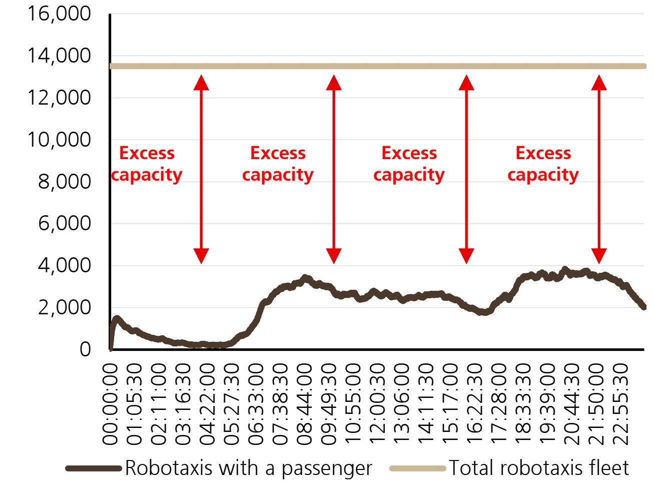
As a result of the lower utilisation rate discussed above, the excess capacity of the robotaxi fleet has to be meaningfully higher when we incorporate commuters.

Figure 55: Excess capacity required to service demand (# of robotaxis), excluding commuters



Source: UBS Evidence Lab

Figure 56: Excess capacity required to service demand (# of robotaxis), including commuters



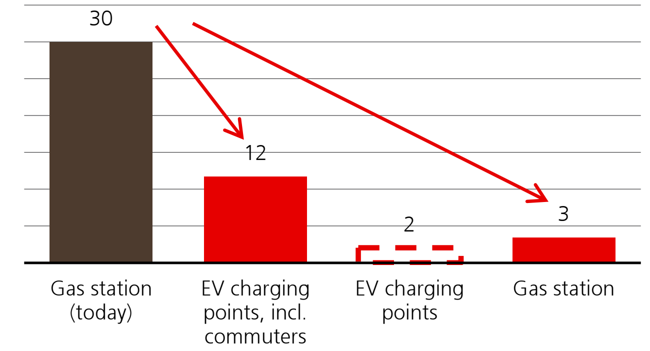
Source: UBS Evidence Lab

The number of charging stations required rises to 12 (from nine) when including commuters

We again try to gauge the number of stations that will be required to recharge the robotaxi fleet, but this time including commuters. We estimate that 12 charging stations are required. This is only three more than in 'Scenario 1 – non-commuter' despite the fleet size being three times larger than in our commuter scenario. The key reason for this is the fact that the number of km driven daily by the average robotaxi is "only" 110km, compared to 246 in Scenario 1 – Non-commuter.

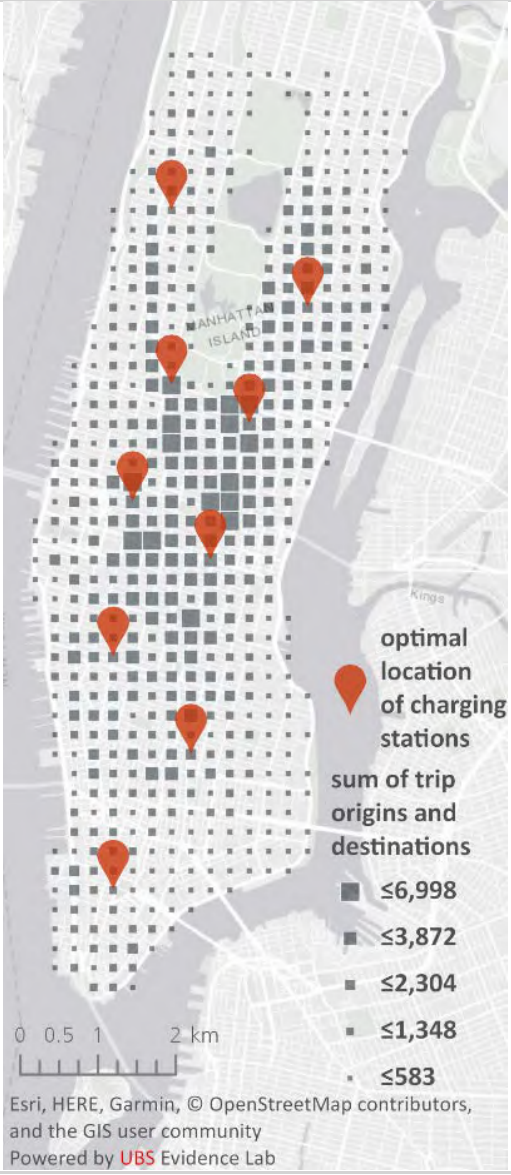
It should not be an issue to find the space needed to build those charging stations. In Figure 36, we show where we think it would make the most sense to locate the charging stations given the demand profile of the simulation.

Figure 57: Number of gas stations vs charging stations required in Manhattan



Source: UBS, New York Times, UBS estimates

Figure 58: Where should charging stations be located?



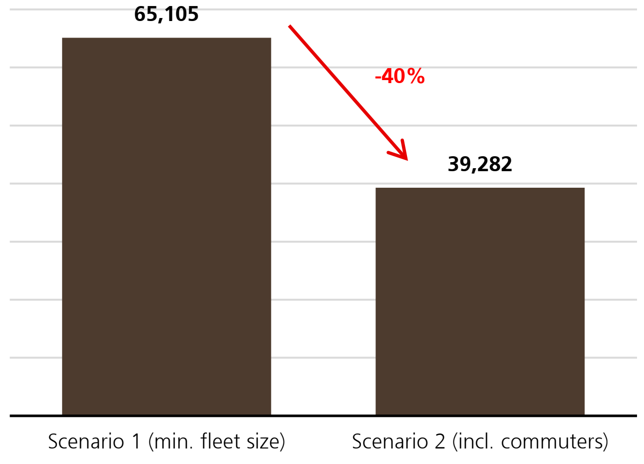
Source: UBS Evidence Lab

The daily electricity consumption drops by 40%

The total daily power consumption is about 40% lower in Scenario 2, which is including commuters. The key reason behind that is the lower number of km driven by each robotaxi daily mentioned earlier. In other words, the robotaxi fleet in Scenario 1 (4,500 robotaxis) needs to be fully recharged every two days compared to every 5 days in Scenario 2 (13,500 robotaxis). The total daily power consumption will reach close to 65,000kwh in Scenario 1, which is equivalent to the daily consumption of 3,250 households in Manhattan.

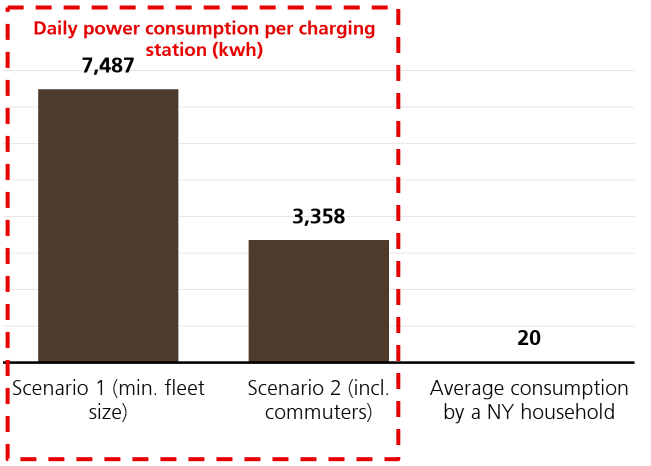
If we now look at consumption per charging station, the daily consumption in Scenario 2 is less than half that of Scenario 1 (Figure 60).

Figure 59: Total daily power consumption – minimising robotaxi fleet vs including commuters (kwh)



Source: UBS estimates

Figure 60: Comparison between daily robotaxi fleet needs and average household consumption in NY (kwh)

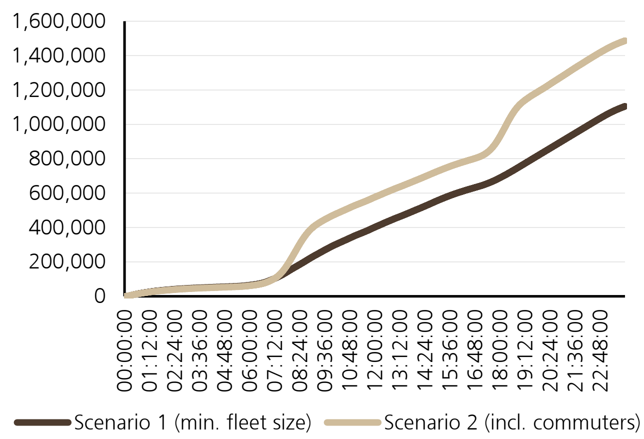


Source: UBS estimates, electricity local

The number of km driven increases by a factor of 27x

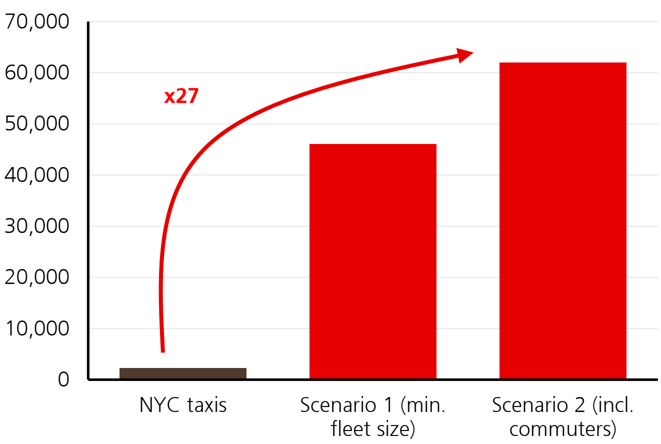
The simulation shows that the robotaxi fleet drives a total of almost 1.5m km over a 24-hour shift in Scenario 2 – including commuters. This is only 35% more than in Scenario 1, despite the overall fleet being three times larger. The number of km driven per hour by the fleet is more than 60,000km, which is about 27x higher than the distance driven per hour by a New York City taxi in Midtown Manhattan.

Figure 61: Cumulative number of km driven by the robotaxi fleet



Source: UBS Evidence Lab

Figure 62: Distance driven per hour by the robotaxi fleet (km)



Source: UBS Evidence Lab

What are the key surprises from Scenario 2 (Commuter) vs Scenario 1?

Let's now compare the key differences between our non-commuter scenario (Scenario 1) and our commuter scenario (Scenario 2). The first key takeaway is that the fleet is much less efficient when we increase the number of vehicles on the road as the excess capacity required is higher. As a consequence, the utilisation rate falls from 48% in Scenario 1 to 22% in Scenario 2. Despite having a robotaxi fleet that is three times larger, the revenue generated is "only" 30% higher. The profitability metrics in Scenario 2 nevertheless remain highly attractive.

Figure 63: Commuter vs non-commuter scenario – what are the key differences?

	Scenario 1	Scenario 2	
Non-commuter vs commuter	**Non-commuter**	**Commuter**	**Key surprises from Scenario 2, vs Scenario 1**
Number of robotaxis	4,500	13,500	
Serviceability rate (%)	97.9%	98.3%	
Total trips simulated	347,405	430,256	
Total daily trips	337,921	421,118	
Average utilisation rate (%)	*48%*	*22%*	**The utilisation rate is >50% lower**
Peak utilisation rate (%)	*80%*	*71%*	
Overall revenue of the fleet ($m)	3.3	4.3	**The revenue generated is "only" 30% higher**
Average revenue per passenger or average trip cost ($)	9.8	10.3	
Revenue of the fleet/per taxi ($)	739	321	
Gasoline cars:			
Operating costs (incl. depreciation) ($)	417,007	954,878	
As % revenue	*87%*	*78%*	
Electric cars:			
Operating costs (incl. depreciation) ($)	325,253	831,434	
As % revenue	*90%*	*81%*	**Robotaxi will price compete with public transports**
How much time does it take to reach break-even:			
Gasoline cars	1:56:15	7:41:00	
Electric cars	1:50:00	7:38:45	**It takes a quarter of a day to reach breakeven**
Trip data:			
Average trip time (min)	9	10	
Average wait time (min)	2	2	
Average delay time (min)	2	2	
Distance driven by the fleet (km)	1,104,859	1,486,473	
Distance driven by the fleet/hour (km)	46,036	61,936	
Average distance driven per robotaxi (km)	246	110	**The daily distance driven is 50% lower**
Other:			
Electricity consumption of the fleet (kwh)	65,105	39,282	**The electricity consumption is lower despite 3x more vehicles**

Source: UBS

The main impacts on the auto industry

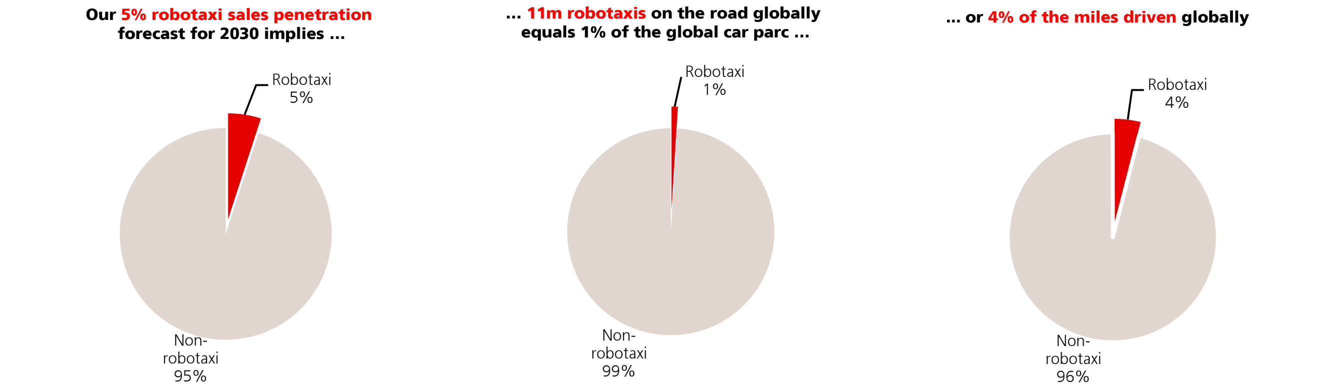
Key conclusions

- We delay our forecast for the adoption of robotaxis by a **year or two** to reflect: (1) the higher efficiency of the fleet as shown in the simulation (ie. fewer cars are required to cover the overall demand; (2) our new forecast split between DM, EM excluding China, and China; and (3) comments from industry participants that developing the technology might take longer than initially planned.
- We reduce our forecast for the fleet of robotaxis from 26m to 11m in 2030 (we now reach 26m between 2030 and 2032). Furthermore, we now assume that robotaxis will represent **c5% of new car sales** (from 12% before).
- In the long term, we see **new car sales running about 5-10%** lower than our current estimates because of the launch of robotaxi fleets (and the shift from private car ownership).
- Robotaxi fleets are set to be a material contributor to EV powertrain growth. **More than 10% of global EV sales** will be related to robotaxis in 2030, in our view.
- Our simulation shows that a robotaxi will drive **about 6x more than a private car today**. This would lead to the number of kilometres driven per car increasing from 15,000/year to about 15,600/year. In 2030, we believe robotaxis will contribute c5% of the kilometres driven in the urban world.
- As discussed in the previous sections, we have looked in detail at the economics of managing a robotaxi fleet. Given the high level of profitability and the lower cyclicality of the revenue stream, **OEMs should consider entering this field, especially in a concession scenario**.
- **Tire makers are the biggest winners within autos,** in our view. We see a net revenue uplift of 50% by 2040E as the number of miles driven per vehicle increases.

Putting the robotaxi potential into context in three key charts

We now estimate that the penetration of robotaxi sales will be 5% in 2030. The overall fleet should reach 11m vehicles by then, equivalent to 1% of the global car parc and c4% of the miles driven globally. All those metrics should expand exponentially as the adoption rate of robotaxis accelerates: we currently assume 8% of the urban population in 2030, rising to around 37% in 2040.

Figure 64: Putting our 2030 base-case scenario into context

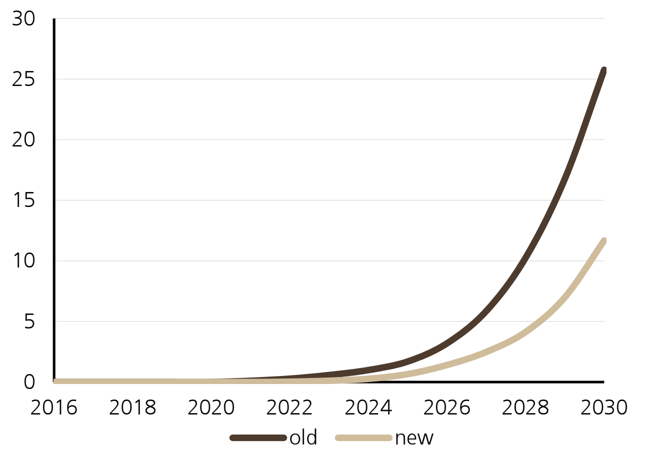


Source: UBS estimates

What has changed and why are we reducing our robotaxi forecasts

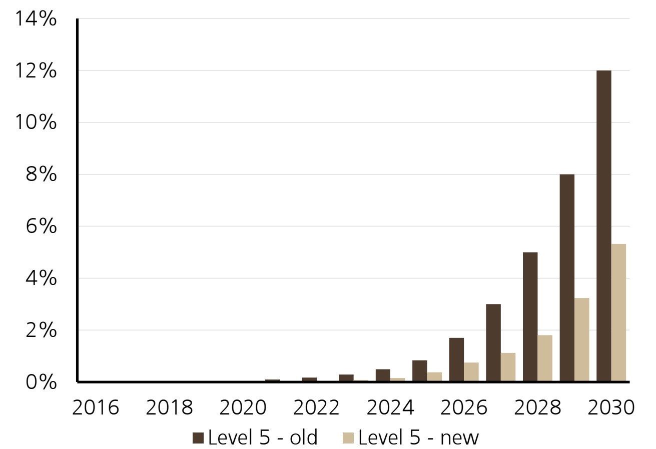
We delay our forecast for the adoption of robotaxis by a year or two to reflect: (1) our new forecast split between DM, EM excluding China, and China; and (2) comments from industry participants that developing the technology might take longer than initially planned. We reduce our forecast for the fleet of robotaxis from 26m to 11m in 2030. Furthermore, we now assume that robotaxis will represent c5% of new car sales (from 12% before).

Figure 65: Number of robotaxis required on the road (m) – old vs new estimates



Source: UBS estimates

Figure 66: Penetration of robotaxis (as % of new car sales)



Source: UBS estimates

We have separated the (urban) world into three zones: (1) developed markets; (2) China; and (3) emerging markets excluding China. For each region, we are assuming different adoption rates and a sharp increase in the S-curve happening at various points in time.

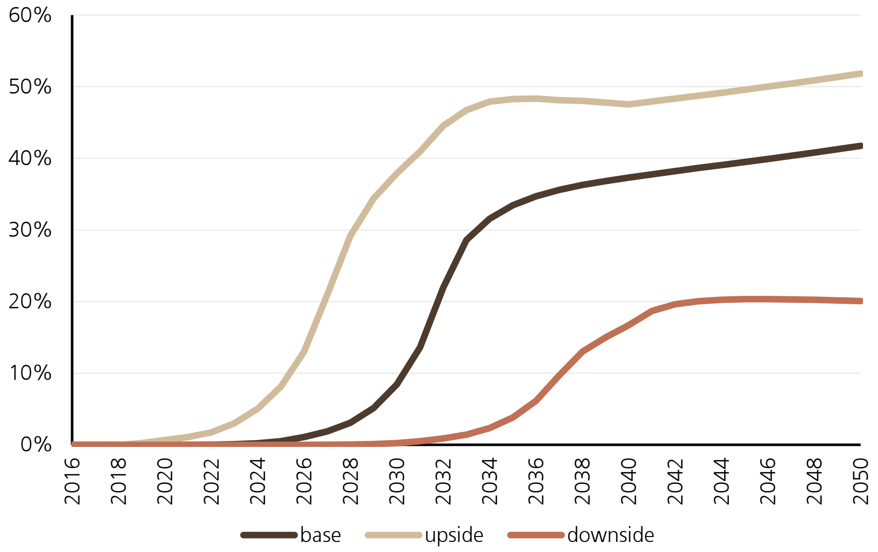
We assume 80% of the urban population use robotaxis by 2040

For instance, in our UBS base case, we assume the adoption rate of robotaxis in developed markets will be 80% of the urban population by 2040, with the sharp increase in the S-curve happening around 2030. In China, we expect the same level of adoption, but with a lag of about one year. In emerging markets, we expect an adoption rate of no more than 2% in 2030.

Stress-testing our forecasts

- **UBS base case:** We assume the adoption rate of robotaxis will be 40% of the urban population in 2050, with the sharp increase in the S-curve happening around 2030.
- **UBS upside case:** We assume the adoption rate of robotaxis will be >50% of the urban population by 2030, with the sharp increase in the S-curve happening around 2025.
- **UBS downside case:** We assume the adoption rate of robotaxis will be 20% of the urban population by 2050, with the sharp increase in the S-curve happening around 2035.

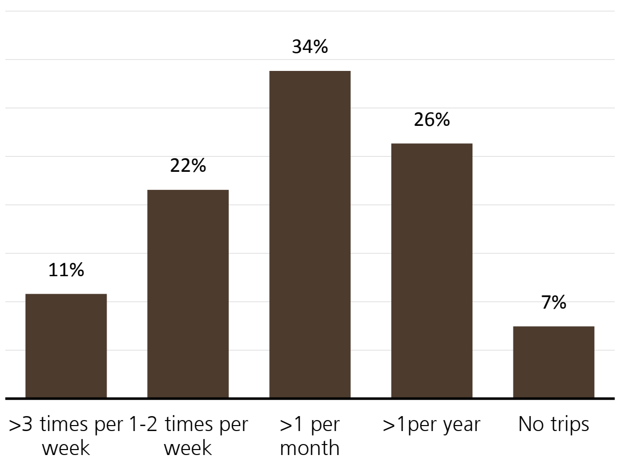
Figure 67: UBS scenarios for robotaxi penetration (as % of urban population)



Source: UBS estimates. Note: Urban only

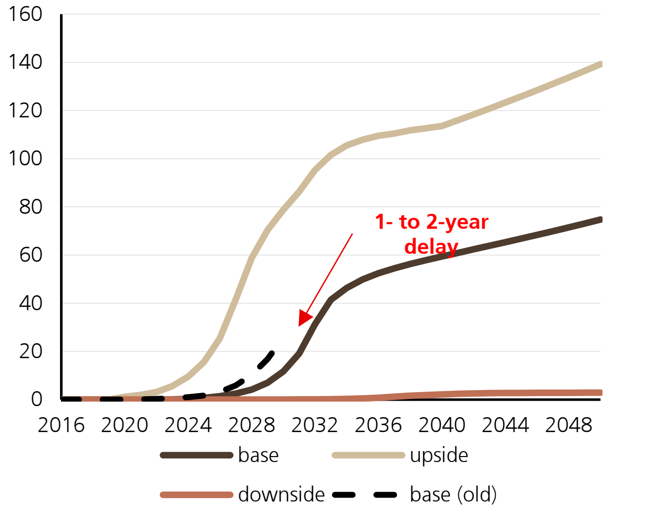
Based on the three scenarios above, we have used the simulation to compute the number of robotaxis required on the road to meet the demand for trips. We have also made the following assumptions on the number of daily trips: (1) our base case assumes two daily trips; (2) our upside case assumes three daily trips; and (3) our downside case assumes no change compared to today's behaviours. On the latter, we leverage the data from the recent UBS Evidence Lab consumer survey on ride-on-demand. We found that ride-on-demand users take 1.1 trips per week on average, which translates into 0.16 daily trips – assumptions we use in our downside case. See Figure 68 for the distribution of the number of trips by ride-on-demand users.

Figure 68: Expected frequency of ride-on-demand among US users



Source: UBS Evidence Lab

Figure 69: Number of robotaxis required on the road (m)



Source: UBS estimates

We have built an interactive model which enables investors to modify scenarios and see the potential impact on the auto industry.

How do we connect the simulation with our global forecasts?

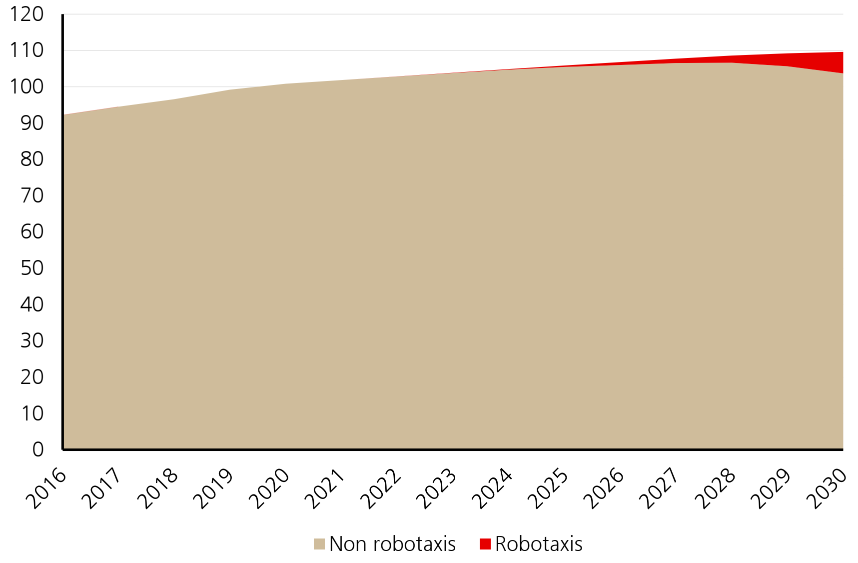
As in the past, we use the forecast for the urban population provided by the UN. We then apply the adoption curves that we described earlier. For each region (developed markets, China and emerging markets), we model different adoption curves based on income, infrastructure, cost of public transport, etc. We also assume that each robotaxi user makes two trips per day in our base case. Finally, the simulation shows that the fleet of 4,500 robotaxis can service around 330k trip requests daily. We apply this ratio to quantify how many robotaxis are required in each region.

Lower new car sales volumes

We estimate that robotaxis could represent on average 16m units sold per year during 2016 and 2050. In the long term, we see new car sales running about 5-10% lower than our current estimates. However, in the medium term, new car sales will be slightly supported until 2027, and then drop as the adoption rate of robotaxis accelerates (Figure 70). Then, new car sales will recover, thanks to:

- The higher utilisation rate of the robotaxi (about 10 times higher than that of a private car); and
- The faster replacement velocity (see methodology) – we assume an average life of a robotaxi of about three years compared to about 10 years for a private car).

Figure 70: Global car production (m)



Source: UBS estimates

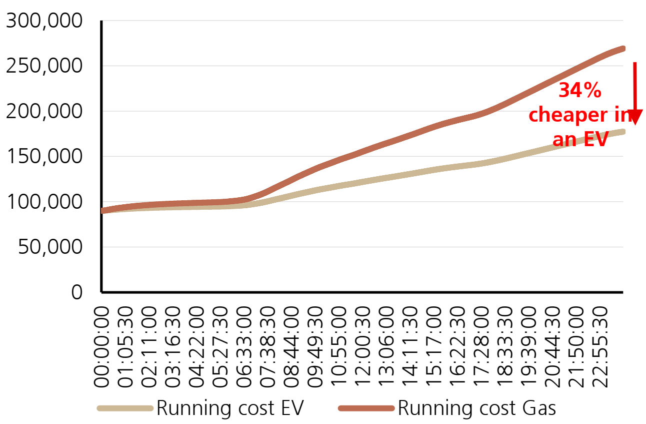
Faster shift towards electric cars?

Robotaxis will most likely be electric. We estimate that robotaxis will represent >10% of global EV sales by 2030. The simulation also showed that the daily cost of running an electric robotaxi fleet is about a third cheaper than an ICE fleet. Robotaxis could also help stabilise the grid during peak electricity demand (if there is lower demand for transport).

> 10% of global EV sales will be related to robotaxis by 2030E

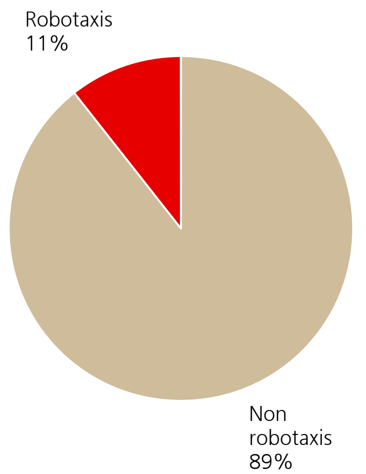
Our utilities team has concluded that: (1) the launch of robotaxi fleets will have no material impact on power consumption; and (2) the required charging infrastructure upgrade represents only 10% of total capex over the next 10 years. We discuss this in greater detail below.

Figure 71: Robotaxis – relative costs EV vs ICE ($ for y-axis and time for x-axis)



Source: UBS Evidence Lab

Figure 72: Robotaxis as % of new EV sales (2030E)



Source: UBS estimates

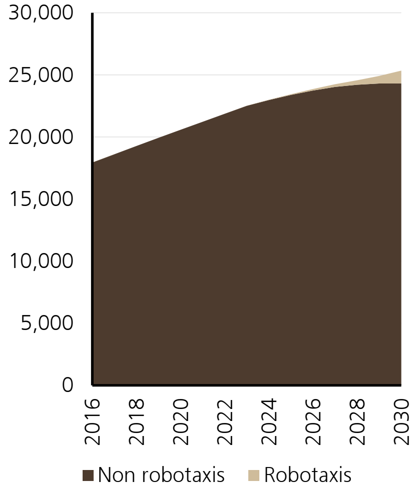
Number of kilometres driven to increase

Despite the shrinking car parc, the number of kilometres driven will likely increase, for two key reasons: (1) the time spent in vehicles will likely increase due to the lower fare charged to passengers (we see >80% price reduction); and (2) there will likely be a shift from public transport to robotaxi fleets.

The number of kilometres driven should increase globally

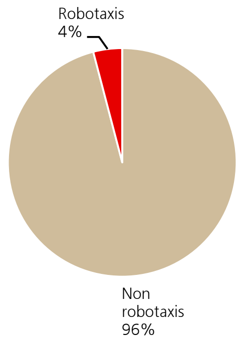
Our simulation shows that a robotaxi would drive about 6x more than a private car today. This would lead to the number of kilometres driven per car increasing from 15,000/year to about 15,600/year. In 2030, we estimate robotaxis will account for c5% of the kilometres driven in the urban world.

Figure 73: Km driven globally every year (bn)



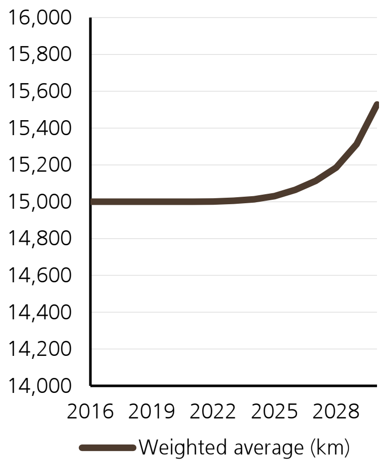
Source: UBS estimates

Figure 74: Split between robotaxi and non-robotaxi mileage



Source: UBS estimates

Figure 75: Annual mileage per vehicle (km)

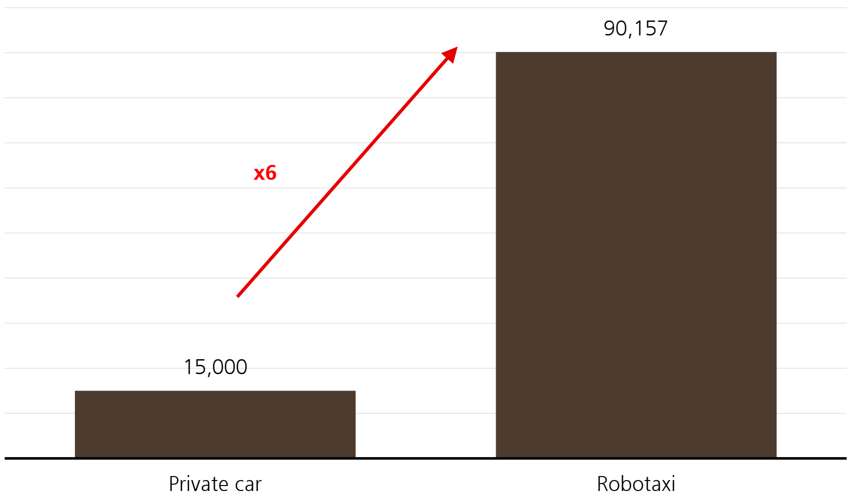


Source: UBS estimates

Tires likely to be the key beneficiaries within autos

As discussed earlier, tire makers should benefit from the higher number of km driven. The simulation shows that a robotaxi should drive on average around 250km daily, which translates into more than 90,000km on an annual basis. This is 6x more than a private car today. Therefore, even if we estimate that the size fleet could be reduced by two-thirds with the introduction of autonomous vehicles, km driven would still increase on a like-for-like basis.

Figure 76: Yearly km driven comparison – private car vs robotaxi



Source: UBS estimates

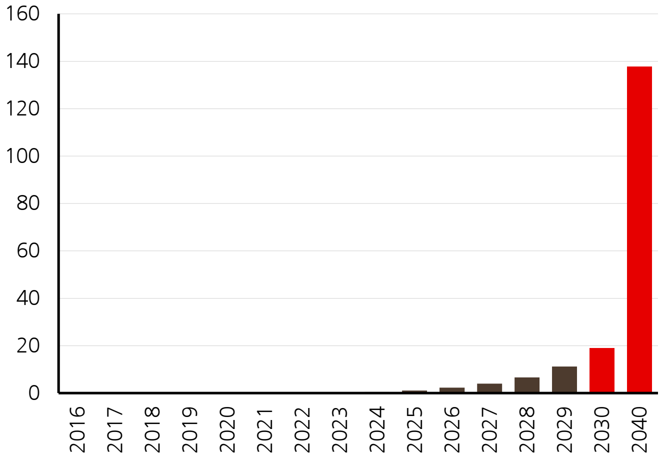
What's the incremental revenue potential?

We see the revenue opportunity related to the launch of robotaxi fleets reaching $19bn in 2030E, which is more than what Michelin generates in terms of revenue annually today selling passenger car tires. It would support industry volume growth with an annual growth rate of close to 1% between today and 2030 (with most of the impact felt post 2025).

The revenue pool for tires could increase by up to 50% by 2040E

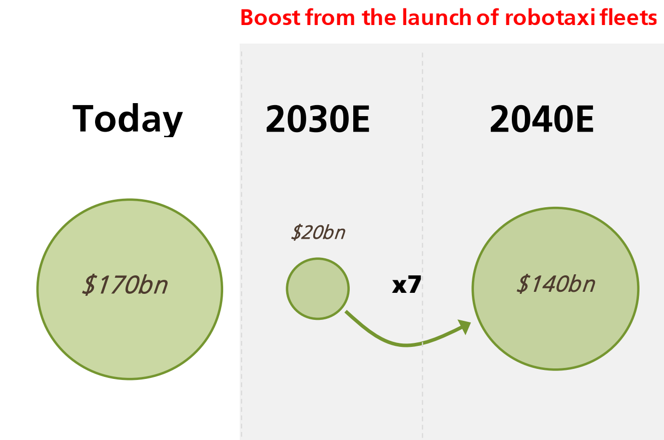
By 2040, we see the potential reaching c$140bn, which is almost the same size of the tire industry today. Even if we assume fewer private cars (and fewer miles driven for each private car), the tire industry should be a net beneficiary with an estimated uplift in the revenue pool of $78bn, or 50% compared to today.

Figure 77: Incremental revenue streams for the tire industry coming from robotaxis (€bn)



Source: UBS estimates

Figure 78: By 2040, the size of the robotaxi tire market could become as large as the industry today



Source: UBS estimates

Will the shift towards robotaxi fleets improve the tire mix?

Smaller benefit than we expected

We initially thought that tire makers would benefit from a sharp increase in mix driven by (1) the greater weight of larger tires (as robotaxis will be minivans/mini buses or large SUVs) and (2) the increasing weight of fleet buyers (looking at total cost of ownership). In other words, fleet operators have an incentive to buy a premium tire that lasts longer (i.e. needs to be replaced less often) in order to further boost the utilisation rate.

It turns out that the impact is likely to be much smaller. We assume that it takes a little over an hour to replace a set of tires. Based on the simulation, this time is worth about $31 of revenues (assuming a similar spread throughout the day). In other words, this is the amount the robotaxi fleet would lose while tires are being replaced. Replacing tires at night would allow the revenue loss to be minimised. The gap between the upfront cost of a premium vs. a budget tire is not large enough to cover the better utilisation rate achieved with a premium tire. Our analysis shows that the robotaxi fleet would save $260 per vehicle per year by choosing budget tires. As a reminder, we estimate each robotaxi will generate sales of $739 per day. Therefore, the cost benefit of choosing budget tires is almost marginal.

Figure 79: Cost gap analysis between premium and budget tires for robotaxis

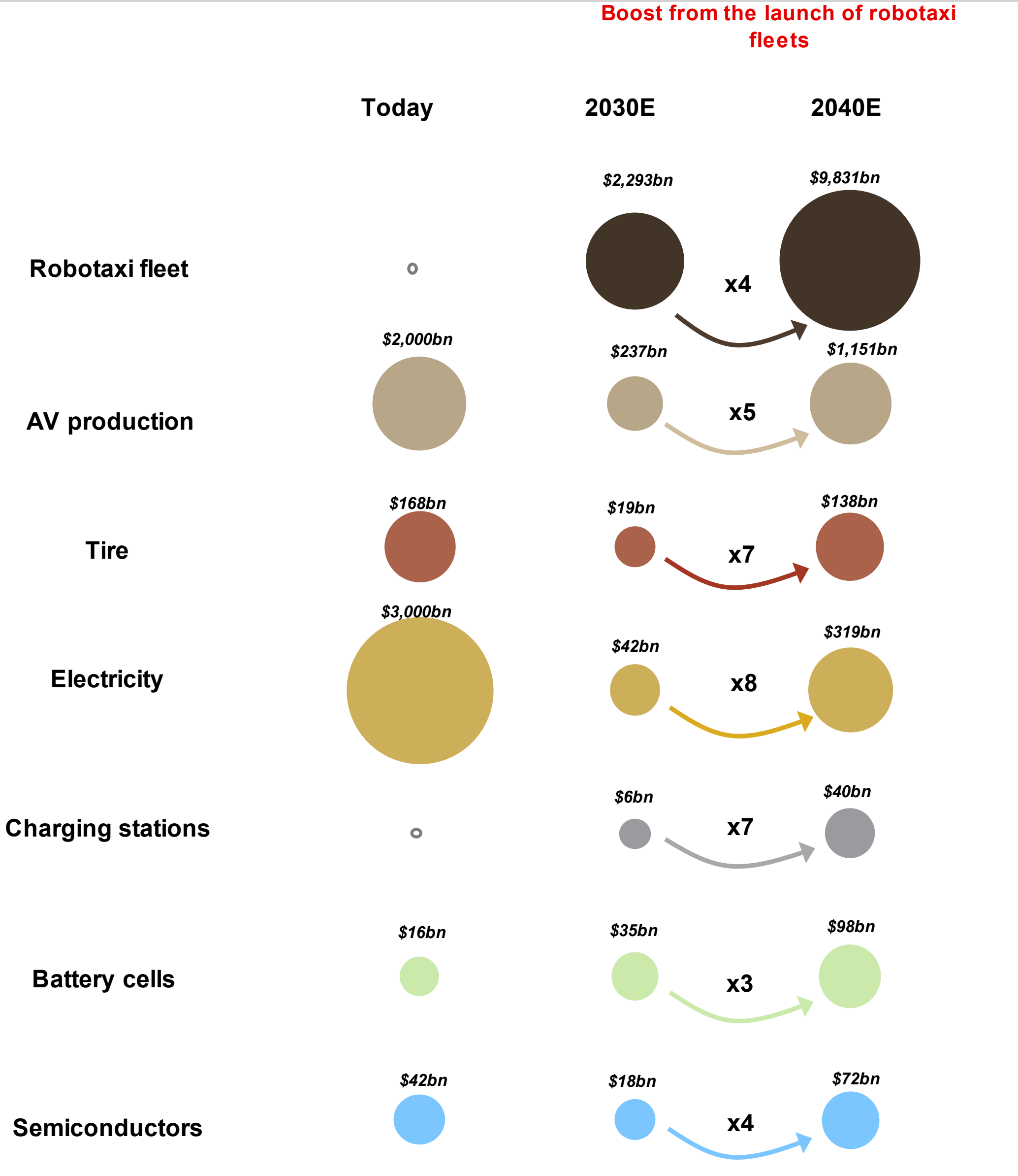
	Premium	Budget	Comment
Cost per tire ($)	212	136	- We use the average retail price for 19'' in Continental Europe
Tire cost per car ($)	846	543	
Cost difference (premium vs budget)		**-304**	
Km driven with on set of tires	50,000	30,000	- Michelin estimates its tires can last 39% longer vs other tier one brands
Km driven per car daily	246	246	
Days before replacing tires	204	122	
Times tires need to be replaced per year	1.8	3.0	
Tire installation (min)	60	60	
Time to drive to the replacement area (m)	10	10	
Hourly revenue generated by the robotaxi fleet ($)	31	31	- As per our robotaxi simulation
Revenue lost while replacing tires per year ($)	-65	-108	- Missed opportunity due to the lower utilisation rate
Cost difference (premium vs budget)		**43**	
Net cost difference per car (premium vs budget) ($)		**-260**	
Robotaxi fleet size		4,500	
Net cost difference for the fleet (premium vs budget) ($)		-1,171,733	

Source: UBS estimates

What are the largest revenue pools that could emerge?

The mass adoption of robotaxis will have far-reaching implications across many industries and will create new revenue opportunities. In this section, our global colleagues have used the simulation to gauge the impact robotaxis could have on their respective industries.

Figure 80: The launch of robotaxi fleets could have a material impact on the revenue potential of various industries



Source: UBS estimates

Note: For Utilities, we compare power prices "at the pump" with a wholesale level utility revenue pool, which is why the actual revenue upside will likely be moderately below 10%

Our **simulation** assumes that:

- The daily revenue of the robotaxi fleet is $3.3m (4,500 vehicles);
- The profitability margin is >90%;
- It takes up to 2 hours for the fleet to reach profitability breakeven each day;
- Fares could be reduced by >80%;
- The average trip length is 10min; and
- The running costs of a robotaxi are $40 daily

Our **key conclusions** are:

- Technology and platform companies have ample flexibility/optionality in potential business models; and
- Despite near-term investments, autonomous vehicle deployment has the potential to improve profitability of operating the network.

How will technology/platform companies (i.e. Alphabet/Waymo, Lyft) operate in a world of autonomous vehicles?

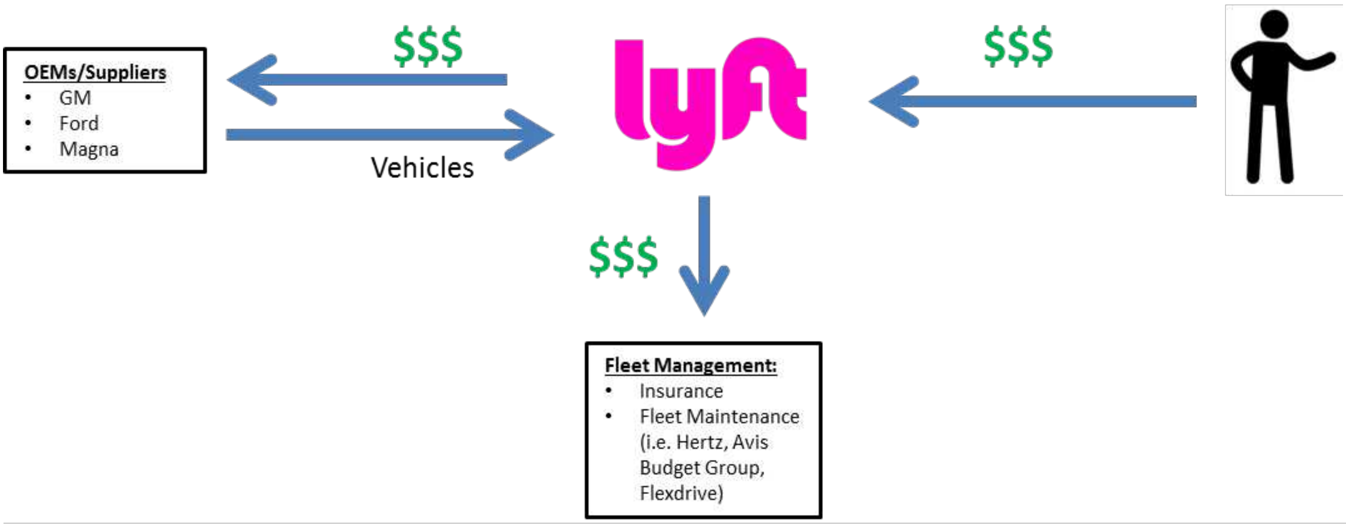
We see a number of scenarios in which tech/platform firms can operate within the autonomous ecosystem

We see a number of different scenarios in which these companies can operate within the autonomous ridesharing ecosystem, depending on when/how the technology is deployed. Since AV technology is still in its infancy, we believe most companies are trying to be as flexible as possible with their current strategies in order to give themselves optionality in terms of how they will ultimately fit into the broader landscape. We use Lyft and Waymo as examples below.

Scenario 1: Lyft operates its own 1P ("first party") fleet of autonomous vehicles

In this scenario, Lyft continues to develop AV technology in-house (competing with other AV players such as Waymo, GM Cruise, etc.) and deploys an owned-and-operated AV fleet into its existing ridesharing platform. The company relies solely on its own 1P technology and does not open the platform for other third-party AV fleets to plug into its platform. While Lyft has a competitive advantage over some other AV developers, thanks to its existing scaled platform and a direct relationship with riders, we see this as potentially the least likely scenario, given: (1) Lyft's existing partnerships with third-party platforms and prior open-sourced strategy; (2) the capital investments required to develop, deploy and maintain a fleet that is sufficiently scaled to supply its platform; and (3) this would put it in direct competition with a number of larger players in the AV market (that are likely further along from an AV technology development standpoint).

Figure 81: Lyft as a 1P-only AV ridesharing platform

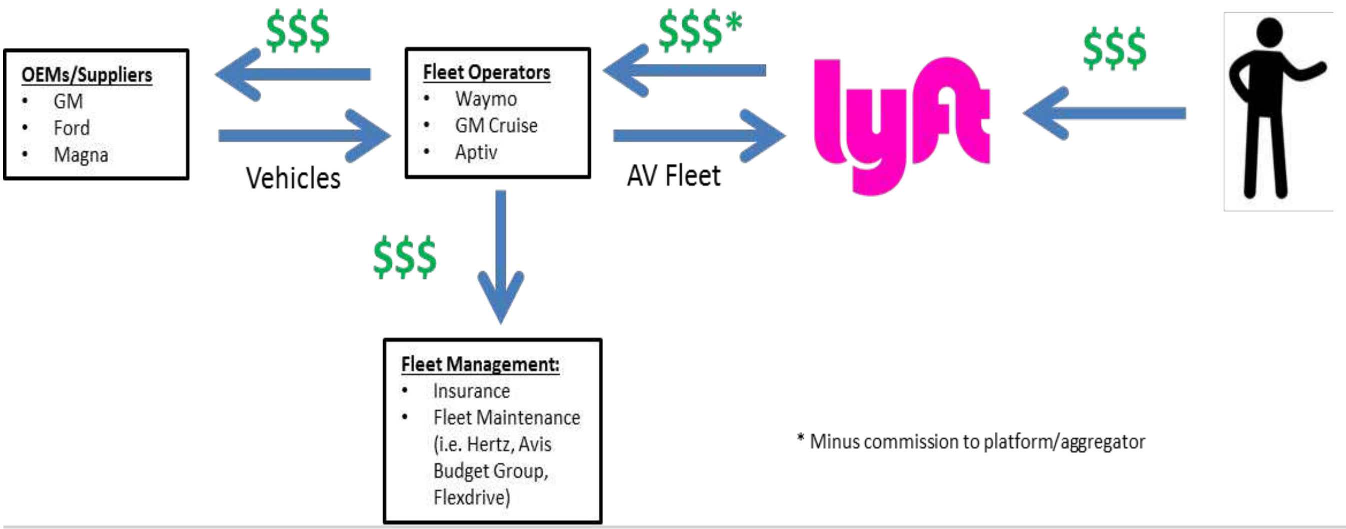


Source: Lyft, UBS

Scenario 2: Lyft acts as the platform for 3P ("third party") fleets to "plug into"

In this scenario, Lyft relies solely on third-party technology and integrates these AV fleets (Waymo, GM Cruise, Aptiv, etc.) into their core ridesharing platforms. This could result in potential upside to operating income (lower upfront R&D costs to develop AV technology, no regular capex or depreciation related to maintaining an owned and operated fleet), but the impact on revenue/take rate is open to debate (depending on the revenue-share agreement with its 3P partners).

Figure 82: Lyft as a 3P-only AV ridesharing platform



Source: Lyft, UBS

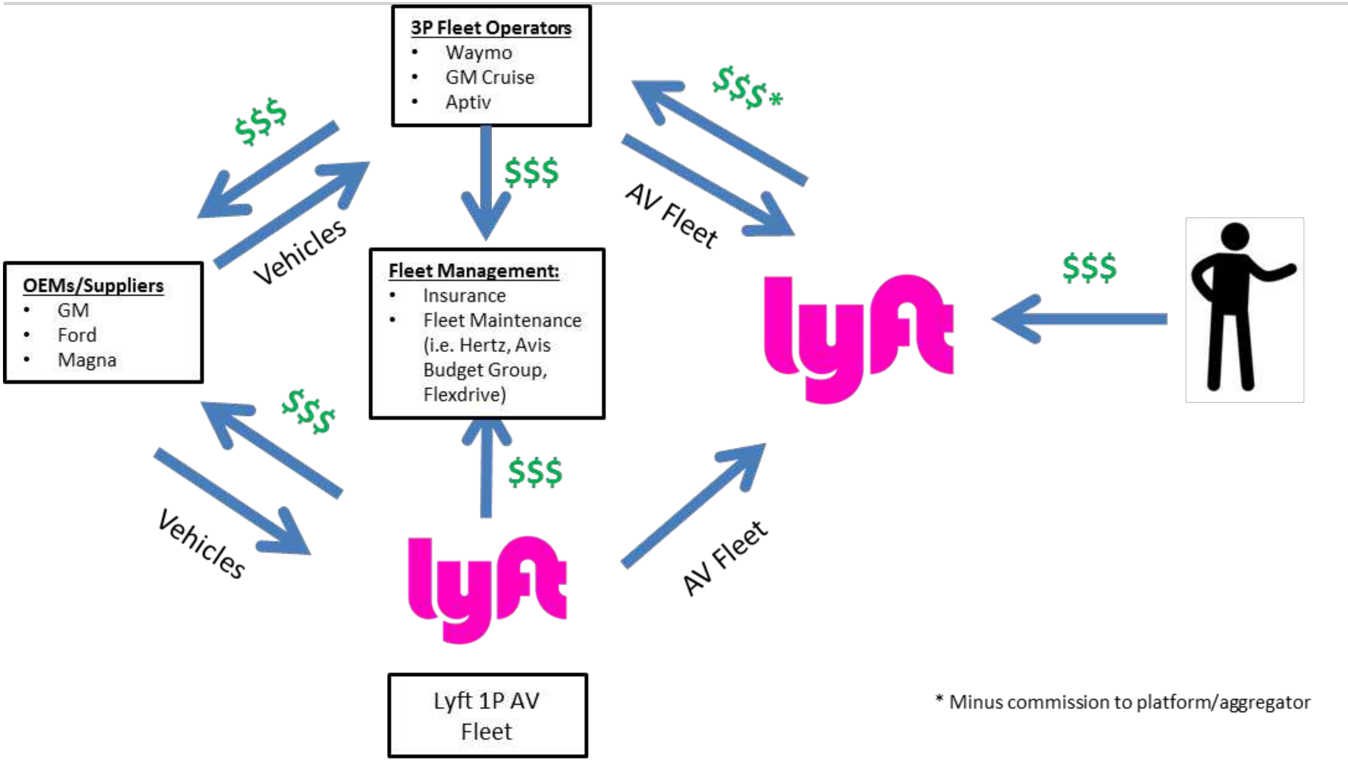
Based on our industry work, Lyft is well positioned to be a ridesharing platform of choice if third-party AV fleet operators choose to deploy their technology via partnerships with an existing platform rather than attempt to build their own ridesharing platform from scratch. Lyft has an existing partnership with Aptiv in which it operates a small commercial fleet in Las Vegas (the program has facilitated 35,000+ rides in fully autonomous Aptiv vehicles since January 2018). Additionally, Alphabet and General Motors – which are both major players in AV development through Waymo and Cruise, respectively – are shareholders in Lyft (each company has a ~5-7% stake).

Scenario 3: Lyft adopts a hybrid approach with both owned & operated (O&O) 1P and 3P autonomous fleets "plugged into" its platform

Under this scenario, Lyft continues with its dual-pronged approach and integrates both its own 1P fleet and 3P fleets into its network. We view this as potentially the most likely scenario, at least for the early deployment/adoption of AVs, given: (1) this gives Lyft optionality/flexibility to position itself in the AV landscape given the early stage of tech development and commercialization; (2) maintaining a 1P fleet gives Lyft some degree of negotiating leverage over 3P partners in a revenue-share model; (3) a lower investment is required given it can supplement 3P fleet deployment where needed vs. relying solely on its 1P fleet to facilitate demand; and (4) Lyft can maintain ownership of usage, conversion and ridership data of AVs and can use these insights to optimize its own 1P fleet deployment (similar to Amazon's 3P/1P/private label product strategy).

This scenario would likely be less capital-intensive as a 1P-only scenario (providing a tailwind to profitability) and could also potentially shorten the go-to-market time for autonomous vehicles, given that one single fleet operator will not be required to facilitate all of the consumer demand on day one.

Figure 83: Lyft as a 1P/3P hybrid AV ridesharing platform

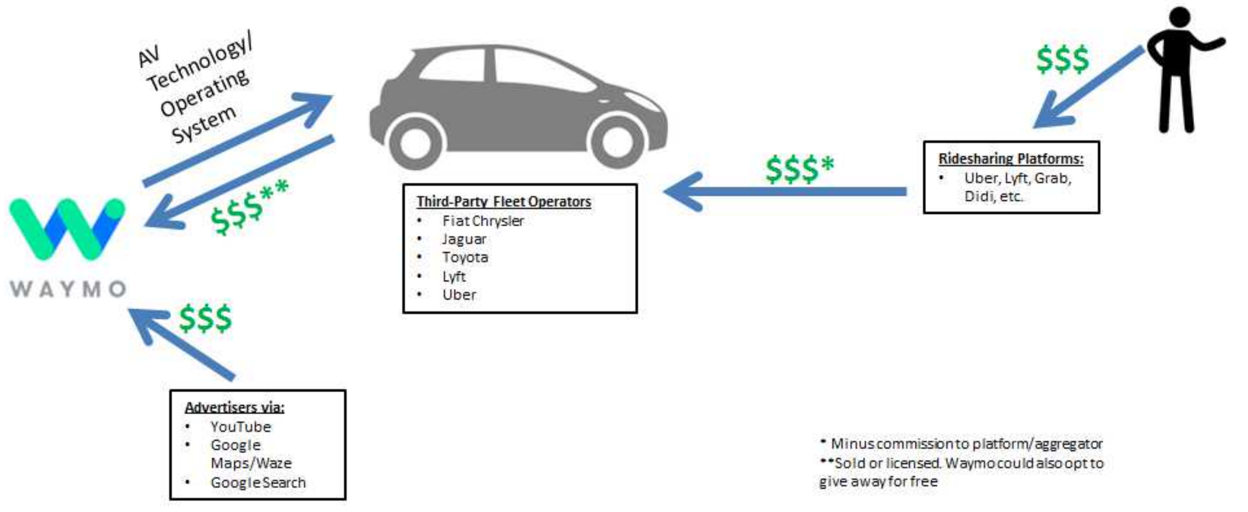


Source: Lyft, UBS

Scenario 4: Monetizing through selling/licensing technology and monetizing time spent in car

In this model, a company like Waymo could choose to simply sell or license its software to third-party autonomous ridesharing fleets. Customers would potentially be other participants that are not currently developing their own AV technology and/or those who have given up and concluded that Waymo's tech stack is simply better. Another option could be to give away the tech/OS for free but be guaranteed control over the user experience and interface within the car/app. In any scenario, should Waymo go in the direction of focusing on the technology/OS and in-car monetization, agreements would likely need to give Google/Waymo some level of ownership of the data, which could be used for local advertising purposes.

Figure 84: Waymo as AV software/technology provider



Source: Waymo, UBS

Utilities

Our **simulation** assumes that:

- The daily electricity consumption is 65,000kwh (for only 4,500 robotaxis);
- The running cost of a EV robotaxi is a third cheaper than an ICE taxi; and
- Only 9 charging stations (with 6 charging points each) are required to cover the daily electricity needs of the whole robotaxi fleet.

Our **key conclusions** are:

- The revenue pool could reach $42bn by 2030 and >$300bn by 2040, or c10% of total global electricity consumption today; and
- The charging infrastructure and grid upgrade required only represent 10% of total capex over the next 10 years.

Are robotaxis likely to impact power consumption significantly?

No. With Manhattan currently consuming around 11GWh of electricity on a daily basis, robotaxis would increase demand by only ~0.6% by 2030E. Moreover, if we assume that the density of robotaxis across the rest of the country versus Manhattan would be likely lower, we believe robotaxis would indeed have a limited impact in terms of power demand.

Robotaxis would increase power demand by only ~0.6% by 2030E in Manhattan

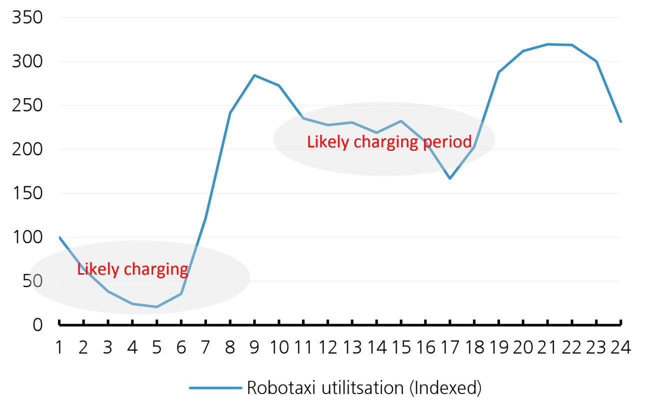
Could robotaxis impact the daily curve for power companies?

Not in a meaningful way. In other words, we believe the charging needs from robotaxis would not likely impact peak demand. As opposed to household EVs (UBS Evidence Lab: How will the growth in EVs impact global utilities?), which could indeed increase peak demand, robotaxis are likely to charge during off-peak demand periods, thus slightly smoothing the daily load curve for individual utilities, and therefore without stressing the existing system or requiring further power production and network capacity.

Robotaxi charging is likely to take place during off-peak hours

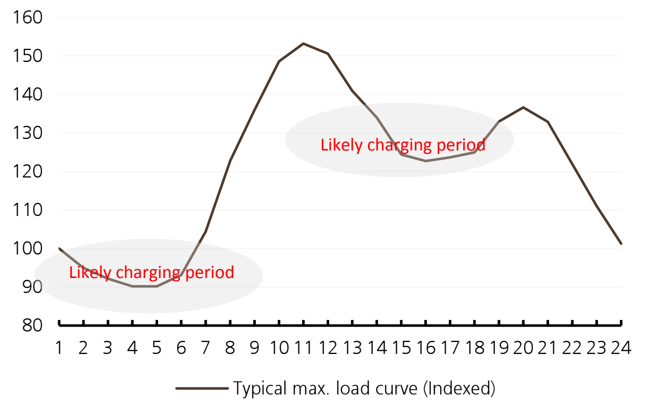
Even though the scenarios presented in this report assume that robotaxis would charge homogeneously during the day, the reality is that it could take a different pattern. As robotaxis would operate towards revenue maximisation, charging is likely to take place during off-peak hours. And as we show in Figure 85 and Figure 86, this coincides with off-peak times for power demand itself, thus with limited impact on peak demand.

Figure 85: Robotaxi potential utilisation curve over a typical 24-hour period. Charging could be concentrated during off-peak periods…



Source: UBS estimates

Figure 86: … which in turn coincides with off-peak hours for power demand (example of a daily load curve)



Source: UBS estimates

How much investment in charging infrastructure would be needed?

This is difficult to forecast, but overall we believe the impact on networks' capex for the utilities would be equally limited.

54 fast charging points, would be required to charge the 4,500 robotaxis in Manhattan

As we have explained, we forecast that around 54 fast-charging points across 9 stations would be required to charge the 4,500 robotaxis we expect to be operational in Manhattan by 2030, assuming that the vehicles are charged evenly during the day. This number could be higher if charging were concentrated in certain periods of time.

We split investments in charging infrastructure into two buckets: (1) investment in charging points and respective facilities; and (2) investment at the grid level, which includes the station-to-grid connection (mid/high-voltage), plus any capacity reinforcements needed across the main grid.

- **(1) Charging stations:** We assume a cost per fast-charging point of US$200-300k, which corresponds to the 54 points estimated in our base case. As we mentioned above, this number could increase under a more concentrated charging pattern. But even assuming the number of charging points doubles, the total investment in this infrastructure would remain limited.

- **(2) Connection/grid investment:** Even though this is difficult to estimate, by comparison with real examples, we believe that the total required investment would come in below US$1.0bn in the case of Manhattan. Take as an example the 57km high-voltage transmission line that will connect the new Hinkley Point C nuclear reactor, currently under construction in the UK (3.2GW of capacity; 25TWh of potential annual output), to the transmission grid. The line is estimated to cost around US$1.0bn, and its capacity is significantly above that required to supply all 54 (or more) charging points in Manhattan.

All combined, we conclude that the overall investment in the charging infrastructure solely dedicated to robotaxis in Manhattan would hardly surpass the US$1.0bn mark (this being an extremely upper-case estimate, in our view).

We estimate robotaxi infrastructure cost would equate to barely 10% of US utilities' total capex over the next 10 years

If we assume the same type of infrastructure is developed across 100 other cities in the US (which would cover half of the US population), the overall total cost would be significantly less than US$100bn by 2030. With US utilities' total annual capex at US$60-80bn, the robotaxi infrastructure would, in our view, represent barely 10% of these companies' total capex over the next 10 years.

Telecoms

Our **simulation** assumes that:

- The average daily utilization rate of the fleet is c50%;
- The average fare is $10 and the average trip length is 10min; and
- Each robotaxi drives c250km daily.
- Data consumed per Robotaxi is 4,000 GB per day, based on studies done by Intel, although not all of this data usage is on a live mobile network.

Our **key conclusions** are:

- The revenue pool could reach US$100-120bn by 2030 translating into revenue per car of US$10k per annum, although this could decline rapidly to US$1,200-1,500 per annum as unit costs of data continue to decline
- It is not clear how much "incremental" capex will be required to support Robotaxis. While we expect telcos to add capacity and build 5G networks as part of normal course of business, the latency requirements for Robotaxis could be higher, demanding a higher degree of reliability.

As telecom operators discuss the rollout of 5G networks, there has been much discussion about new revenue opportunities. Indeed, apart from fixed wireless, connected and autonomous vehicles (CAVs) is highlighted as one of the most promising new use-cases of 5G. As per a study by Intel, a fully autonomous vehicle will transmit 4,000 GB data per day, including cameras, LIDAR (Light detection and ranging), GPS etc. While this number is astronomical and could imply a significant revenue opportunity for telcos (using a simplistic GB based pricing), it is not clear how much of this data transmission will need to be on-line and will need a live mobile network connection (substantial amount of data transmission can be done on WiFi or Bluetooth when the car is not moving).

Indeed, in our Q-Series (link) on autonomous vehicles dated May 2018 (which was based on interviews from several auto OEM experts), our global auto team had highlighted that V2X communications and 5G networks are not a must for an autonomous car. 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. 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. Indeed, recently the 3GPP took V2X outside the URLLC use case on the assumption that separate spectrum allocation will be needed for V2X.

Using the simulations on Robotaxis (10-15mn robotaxis by 2030), and assuming 4,000 GB data consumption per day, we assume the revenue for telcos could be as high as US$10k per car per annum on access alone, translating into an incremental cUS$100-120bn in revenue, which would be 7-9% incremental on an estimated sector revenue pool of US$1.6-1.8trn by then, we estimate. While the number of robotaxis (and autonomous vehicles in general) will likely grow exponentially from 2030, we also expect unit costs for data to decline as newer technologies continue to have a deflationary impact. This could take revenue per car to US$1,200-1,500 per annum by 2040. Aside from connectivity, telcos can also benefit from a subscription-driven business model which goes beyond connectivity, and / or act as providers of data centers, but it is not yet clear whether telcos are in a position to participate in these opportunities.

Battery supply

Our **simulation** assumes that:

- The running cost of an EV robotaxi is a third cheaper than an ICE taxi;
- A robotaxi will drive c90k km per year;
- Each robotaxi will have to (fully) recharge every two days; and
- The life cycle of a robotaxi will be around 3 years.

Our **key conclusions** are:

- The revenue boost could be $35bn in 2030 and $98bn by 2040, 6x greater than today's market size; and
- Robotaxi sales will represent >10% of BEV sales in 2030.

Impact of robotaxis on battery revenue will ultimately depend on how they impact total EV volume

We expect the impact of robotaxis on battery revenue will largely depend on how they impact total EV volume in the end. The introduction of rotobaxis will likely help accelerate EV penetration initially, which will largely be positive for battery makers. A robotaxi will also likely have a longer daily driving distance than an average vehicle and hence require larger battery capacity as well. As the volume picks up, we think there could be more variables at play, such as robotaxis potentially cannibalizing new EV sales (for now we think the impact is limited). In the long term, if robotaxis lead the industry to having more standardized battery cells, this could potentially drive commoditization and have a negative long-term impact on industry profits.

Visibility as to which type of battery cell format or chemistry will best fit robotaxis remains low, in our view. In theory, robotaxis will likely require a longer battery cycle life given much higher utilization of the vehicle, which could make NCA chemistry a less attractive option than NCM given the former's shorter life cycle. However, this is also subject to how this can be offset with battery management systems and better software to improve efficiency (Q-series: Coding cars – is the autos value chain ready?). Over time, solid-state or semi-solid-state batteries could be an option, given potentially higher energy density and better safety, but the outlook for solid-state in EV remains highly uncertain.

Semis

Our simulation assumes that:

- The running cost of a EV robotaxi is a third cheaper than an ICE taxi;
- In the long term, new car sales could be 5-10% lower due to robotaxi adoption; and
- By 2030E L5 penetration could be 5% of new car sales (compared to our previous forecast of 12%).

Our **key conclusions** are:

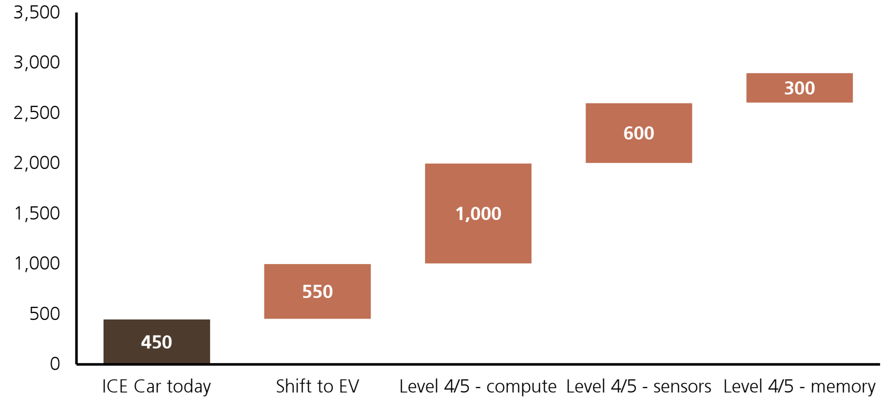
- The revenue boost could be $18bn in 2030E and $72bn by 2040E, almost double today's market size;
- Robotaxis could help increase semiconductor content per car;
- Shift to EV adds $550 per car (vs. the average of c$450 per car today); and
- L4/L5 could carry as much as $2,000 per car.

We see the shift to robotaxis as a helpful boost to the two key megatrends in autos that are significantly driving up semiconductor content per car – accelerating both the shift to EV and the shift towards L4/L5 autonomous cars.

- **Shift to EV adds $550 per car:** We estimate that shifting the car from being an ICE vehicle to being an EV (and as shown in our analysis an EV is a third cheaper as a robotaxi than an ICE vehicle) adds $550 of content per car (vs. the average of c$450 per car today). While we believe the trend towards EV is already in progress and being taken up by consumers, we believe the adoption of robotaxi fleets will only further accelerate the trend, given the economics shown in the simulation.
- **L4/L5 could carry as much as $2,000 per car:** We estimate that the content in order to enable an autonomous car could be as much as $2,000 per car (for L4/L5). This is broken down as potentially $1,000 for computing, $600 for sensors (we believe LIDAR, RADAR and cameras will all be essential), and then $300 of memory.

We assume that the figures above will still be relevant for 2030 but that further out to 2040 there could be some price reduction. We believe price reductions in the EV content will likely be limited (there is even upward pressure on pricing with the shift to higher-efficiency materials such as silicon carbide), as long as the competitive landscape remains disciplined. On the ADAS side, given the broader competition, we would see greater risk to pricing in the medium term, plus price reductions that might be expected by customers.

Figure 87: Semiconductor content steps in the roadmap to EV/autonomous ($)



Source: UBS estimates

Insurance

Our **simulation** assumes that:

- Insurance costs represents 18% of robotaxi operating costs; and
- The size of the taxi fleet could reduce by two-thirds.

Our **key conclusions** are:

- Over time, as data develops and robotaxis reduce frequency of accidents/ injuries whilst controlling severity (i.e. cost of repair), premiums could reduce;
- That said, the liability component of insurance is likely to increase, which could lead to broadly stable insurance costs overall; and
- For the insurance sector, we would envisage a manageable impact from robotaxis. Whilst traditional motor fleet premiums could fall, robotaxis would be a small part of the market. In addition, there would likely be some offset from increased liability insurance.

How could the insurance business model change?

Marginal impact on the commercial insurance sector overall

The rising penetration of robotaxi fleets could have an impact on commercial insurance premiums. Taxis typically fall under motor fleet commercial insurance, which would have a property and liability component. As it stands, insurance premiums (i.e. revenue) from taxi/executive car services represent a small component of overall commercial premiums globally.

Whilst a reduction in the fleet of taxis would likely lead to traditional motor fleet premium reductions, there would likely be additional general liability coverage purchased by manufacturers, assuming the manufacturer would retain the liability risk for autonomous vehicles generally. This could be a potential offset to any lost premiums in the traditional fleet motor insurance market.

How will insurers price premiums if the frequency of crashes declines as cars become safer once the human element is removed?

The theory goes that as vehicles and roads become smarter, the frequency of crashes should fall, but severity (cost to repair) will rise. Thus far, severity has risen, but frequency has not declined due to faster acceleration of hybrid vehicles and distracted driving (mobile phones). In time, we would expect frequency to fall, but it is likely severity will continue to rise and the liability component will also grow. We do not expect the insurable risk pool to contract in the medium term.

More generally, when it comes to the likes of driverless cars, robotaxis etc, whilst still some time away, we wonder whether the current model of a retail insurance customer buying fairly regimented insurance protections via a price comparison website or agent/broker will stand the test of time. In fact, one of the key strategic reasons AXA bought XL Group in early 2018 was its view that insurance will transition away from retail towards commercial.

Car rental

Our **simulation** assumes that:

- The daily revenue of the robotaxi fleet is $3.3m (4,500 vehicles);
- The profitability margin is >90%;
- It takes only two hours for the fleet to reach profitability break-even; and
- Cleaning represents 5% of the daily operating cost of the fleet.

Our **key conclusions** are:

- Rental companies appear natural partners for the platforms; and
- Rental companies already have years' worth of data on the customer.

Who will win among OEMs and rental companies?

Given the asset-light model of the platforms (Uber, Lyft), they should have no interest in owning the fleet. Thus, partnerships with either car rental companies or OEMs seem the most likely scenario to us. OEMs are well positioned as they own the technology of the vehicles. However, the car rental companies' edge is years' worth of data on the customer (typical routes, preferences), which we regard as a key advantage in the long term. Overall, we think the winner will depend on the pace of adoption of robotaxis. The quicker robotaxis are adopted, the more likely it is that car rental companies will win the race, in our view; the longer it takes, the more time OEMs have to gather knowledge.

"Look and feel"

We think one of the main prerequisites for an increasing adoption rate of robotaxis is a car's look and feel when the next customer uses it. This makes fleet management (maintenance, repairs, cleaning, etc.) more important, and this is an aspect where car rental companies have an advantage over OEMs. We expect competition among OEMs and car rental companies for winning the fleet management business to remain high.

Who is best positioned to develop partnerships with the platforms?

Some players have started signing partnerships

While rental car companies have positioned themselves in the broader mobility space, their exposure to robotaxis is still limited. Figure 88 shows that, while most car rental companies are involved in ride-on-demand services, only very few are active in the robotaxi segment (highlighted grey). Avis, Hertz and Enterprise have signed co-operation agreements to support its development, but these agreements so far only extend to a limited number of cars. Their European counterparts, Europcar and Sixt, have not made moves in this direction yet.

Sixt has taken a different approach by launching its own mobility platform, which integrates car rental, car sharing and ride hailing. In terms of ride hailing, it offers a third-party platform that aggregates other ride hailing providers, such as Lyft. If the platform proves successful, Sixt could benefit from robotaxi revenues through commissions earned via the platform.

Figure 88: Most car rental companies are involved in ride hailing, only a few in robotaxi development

Car-rental	Partnerships / own platform	Comment
Avis	Lyft	Rents cars to Lyft drivers
	Waymo	Co-operates in testing self-driving cars
Europcar	Brunel	Acquired ride hailing platfrom Brunel
Enterprise	Rideshare and Zimride	Van pooling and online ride matching
	Voyage	Co-operates in testing self-driving cars
Hertz	Uber	Rents cars to Uber drivers
	Apple	Co-operates in testing self-driving cars
Sixt	myDriver (Sixt One)	Own ride hailing and own platform solution

Source: Company data, UBS

Flexibility of the fleet is also important. In this respect, Sixt is best positioned, as its average fleet holding period is only six months, versus an average of 12-24 months at competitors. Therefore, if robotaxis are increasingly adopted, Sixt could change its fleet mix more easily.

How can car rental companies leverage their existing networks?

Car rental companies could leverage their existing station networks as the robotaxi fleet will need parking space, which is limited in cities. If they continue digitalising the rental process (i.e. through counter-less rentals), this would also make it easier for customers to rent self-driving cars.

Real estate

Our literature review found:

- The network used in the simulation has 770 kilometres of road; and
- Estimates for car parking spaces in the US range from 105 million to 2 billion, or 0.03-0.5% of the surface area. However, in the urban US, the automobile (open and closed parking) consumes close to 50% of the land area of cities.

Our **key conclusions** are:

- The launch of robotaxi fleets could materially reduce the number of on-street parking spaces required, freeing up land for alternative use;
- Location desirability may change if the commute time can be spent more productively; and
- In the long run, we see limited threat to central business districts.

In the long run, wide-scale adoption of robotaxis could have a profound impact on the real estate sector, although the theme competes and interacts with a number of other mega-trends (urbanisation, other technological advances including e-commerce, etc.) making the ultimate impact difficult to predict.

At the margins, a reduction in car ownership stemming from the increased use of robotaxis, and the potential for a much smaller taxi fleet, are likely to impact demand for parking and petrol stations, impacting short-term cash flows, but freeing up land for alternate (and possibly higher-value) use. This includes, for example, parking lots around shopping malls and apartment buildings as well as standalone parking spaces and facilities.

More fundamentally, location desirability may shift if commuters and shoppers rethink their journey times, given the finding that average fares could fall 80%+. This could have a profound impact on land values, particularly given the conventional wisdom that real estate is about "location, location, location". Marchetti's constant holds that average commute times are 30 minutes one-way. If those 30 minutes can be spent productively (e.g. being driven by a robotaxi where they can work for instance) it is conceivable that commuters will tolerate longer drive times, contributing to suburban sprawl, running against the global current trend of urbanisation. This could lead to a flattening of real estate prices as the location premium of being close to a transport node diminishes. However, if individuals do start to live further apart, the social need for community and in-person contact could strengthen. Thus, centralised offices, retail and leisure facilities may increase in importance and their location premiums could increase. On that basis, we are sceptical about the prospect of a threat to central business districts (CBDs) from the rise of robotaxis.

Capital goods

Our **simulation** assumes that:

- Only 9 charging stations (with 6 charging points each) are required to cover the daily electricity needs of the whole robotaxi fleet; and
- The running cost of an EV robotaxi is a third cheaper than an ICE taxi.

Our **key conclusions** are:

- The reduction in new car sales could have a material impact since auto capex forms c10% of the sector revenues; and
- The shift towards EV could create incremental demand for automation players.

With a reduced number of cars on the road, we see an adverse impact on overall auto capex and automotive consumables spend, which forms about 10% of sector revenues. For instance, in terms of consumables, an EV could have up to 75% fewer moving parts and about 50-75% fewer bearings versus a traditional ICE vehicle. On the other hand, a shift to EVs would also imply incremental capex from factory upgrades given the higher number of platforms and the grid upgrade implications from the proliferation of an EV charging infrastructure.

We see automation players prepared to serve incremental demand from any platform switches or incremental capex in the space (the product is there). Assuming that robotaxis are electric and autonomous, this will support the penetration of EVs, which, in turn, has implications for the sector. For instance, German car manufacturers are planning to upgrade existing lines, and we expect VW, BMW and Daimler to spend €30bn, €10bn and €8bn, respectively, over the next five or so years on EV, much of which will be on platform, plant and products. It has not been disclosed how much of this will go towards tooling, but we expect upgrades to existing lines. We believe the industry is ready for this transition and will give companies such as Siemens, ABB, Hexagon and Kuka the opportunity for holistic discussions around production set-up. We see Siemens as particularly well positioned given its front-to-back offering, from design software to motion control and factory automation. Component suppliers (SKF, etc.) will need to adapt their products, but we think this is a core topic for management teams at the moment.

ESG

Our **simulation** assumes that:

- The running cost of a EV robotaxi is a third cheaper than an ICE taxi; and
- The trip fare could be reduced by >80%.

Our **key conclusions** are:

- Transition technologies for low carbon mobility are developing rapidly;
- This simulation suggests significant gains in the form of fewer road accidents, less on-street car parking and less congestion;
- If jobs are put at risk, and access to mobility fails to improve in areas that need it, the regulator would have a reason to impose conditions of operation; and
- Either structure (concentrated ownership or distributed ownership of the EV robotaxi business) could bring significant benefits.

Will robotaxis accelerate the transition to low carbon mobility?

In our July 2018 Powerpoint presentation "Climate change through the lens of energy and mobility transitions in UBS research", our compilation of reports across a number of sectors covered in UBS research contained a clear narrative:

- Regulatory, market and social forces increasingly incentivise the reduction of carbon intensity;
- However, greenhouse gas emissions are still too high (p. 6);
- Deepening into alternative energy outside the core oil and gas activities in the integrated oil sector has yet to be convincingly articulated (p. 10);
- On the other hand, alternative energy costs are falling rapidly (p. 7); and
- On the other hand again, transition technologies for low carbon mobility are developing rapidly (pp. 8-9).

Market forces can change energy systems rapidly

The robotaxi simulation we have conducted continues the trend described in the fifth bullet above. The economics for electric mobility, in the form of robotaxis, captured in this report are encouraging in suggesting that some aspects of the energy system have the potential to be changed very rapidly by market forces. Considering the high profile of climate change campaigns in civil society, recognised in initiatives such as the Green New Deal in the US, positive momentum for clean energy in these developments (which have a key role to play in facilitating the transition to green mobility) is to be generally be welcomed. The ICE is, moreover, problematic in other ways: many cities worldwide are struggling to reduce particulate emissions in cities because of their adverse impacts on human health over the long run. Road accidents kill many people every year. Congestion and on-street parking reduce the amenity value of public spaces.

Will the regulator facilitate or block the launch of robotaxi fleets?

Inequality: the costs of climate change and the benefits of mitigation and adaption tend to be unfairly distributed

The very existence of the Green New Deal highlights a problem inherent in "greening" energy and transport, and this is that the costs of climate change and the benefits of mitigation and adaptation policies tend to be unfairly distributed. Asking what would happen if (at the extreme) conventional taxis were replaced by robotaxis, we think the main issue is likely to be increased inequality. Whether regulators facilitate or block the idea of the robotaxi is likely to depend on politics with a small p: in other words, if jobs are put at risk, and access to mobility fails to improve in areas that need it, the regulator would have a reason to impose conditions of operation. (c.f. the real estate sector, where there is a requirement for a component of affordable housing in new developments.)

A UBS autos comment following an MIT event asked: "Will autonomous cars be environmental heaven or hell?" The MIT Senseable City Lab believes autonomous vehicles have the potential to deliver "fewer miles travelled, less congestion and less emission," i.e. the heaven scenario. However, the opposite is also possible: that autonomous vehicles "could result in a large increase in travel and emissions."

With this in mind we also think it is important to take the impact of ride hailing services on public transport into account. Regardless of how much more efficient individual journeys can be made through the advent of robotaxis and various algorithms, and how "green" those can be (if made in electric vehicles), a basic mathematical problem remains. In densely populated urban areas, mass transit in the form of buses, metro systems, light rail and the like *moves more people more efficiently* than any type of car.

Regardless of how efficient and 'green' journeys can be made by robotaxis, in urban areas, mass transit moves more people more efficiently than any car

Robotaxi fleet: concentrated ownership or distributed ownership?

From the perspective of sustainable investing, the main questions are practical ones, because the impact of the hypothetical scenario described in this report is likely to be shaped by other contextual factors. For instance, in the kitchen debate report last year, we noted that the most important impact of the change was likely to be an increased concentration of a previously fragmented industry in a smaller number of hands. This might have both positive and negative consequences: it might be easier to reduce food waste on the one hand, but, in another inequality issue, access to affordable food might potentially be compromised in the context of monopolistic provisioning. The experience of the sharing economy in the leisure and transport industries is also a relevant paradigm for comparison. Market disruption opened up the market for improved efficiency in resource usage, but on the downside weaker stakeholders (employees and communities) tended to lose out.

For robotaxis, we think the extent to which existing taxi forms and their employees would lose out might depend on competition questions. The "EV robotaxi" market could be one very large market, owned, controlled or operated by a small number of people or firms (which would be bad for equality). On the other hand, it could also take the form of a co-operative model in which the relevant unit could be the community, with the possibility of replacement jobs for at least some former drivers, or, indeed, the possibility of non-driving service providers in the vehicles themselves (breakfast, tutoring, on the way to the destination!).

We think the extent to which existing taxi forms and their employees would lose out might depend on competition questions

In our view, either structure (concentrated ownership or distributed ownership of the EV robotaxi business) in the context of a significant transition from conventional ICE taxis to robotaxis could bring significant benefits, in the form of more efficient (and cheaper) mobility, facilitating access to work, education, and healthcare. On the other hand, in the context of a large centralised market structure, access to cheaper mobility itself might potentially be determined by post-code, undermining the positive access story. A distributed structure of ownership could (subject to funding being available) lead to a better distribution of the infrastructure needed to deliver cheaper mobility.

What are the key markets for robotaxi adoption?

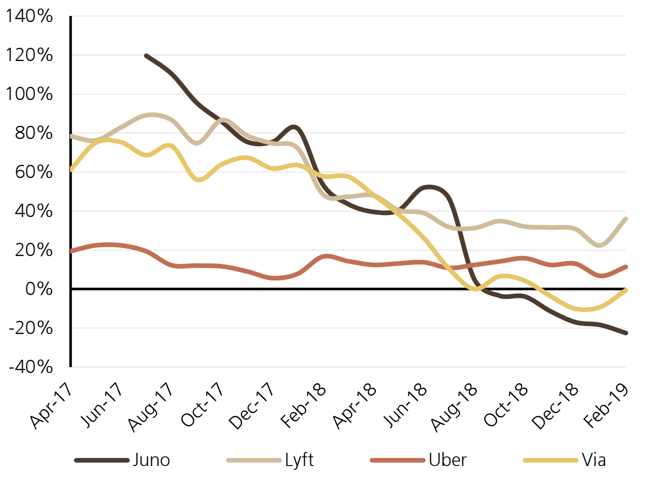
We do not see a global 'winner takes all' situation for the ride-on-demand/robotaxi markets, mainly because of regulation. Nor do we see existing leaders as the "natural winners" in a robotaxi world.

North American ride-on-demand: Lyft taking share in duopoly market

As we wrote about in our LYFT initiation, we would characterize the ridesharing market in North America as a duopoly between two major players, Lyft and Uber, and see the potential US/Canada addressable market rising to US$180bn by 2023 (c11% 2018-23E CAGR). Within this, we estimate the US/Canadian ride-on-demand market will grow bookings at a c17% 2018-23 CAGR, to $60bn by 2023. Despite rapid growth over the past decade, the ridesharing market is still early in development, accounting for just 1-2% of all vehicle miles driven in the US and a low-single-digit percentage of household spend on transportation.

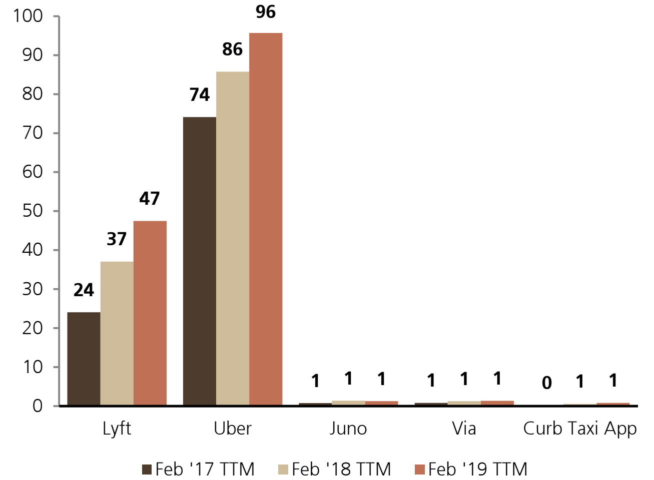
We recently introduced the UBS Evidence Lab US Ride-on-Demand Spend Tracker. While decelerating, credit and debit card spend data still shows YoY growth of around 30% for Lyft's monthly average 'brand incidence rate' (the number of customers who make at least one journey per month) vs. Uber's mid-teens YoY growth. Furthermore, after showing strong growth through most of 2018, growth in use of Juno (NYC) and Via (NYC, Chicago and Washington DC) appears to be declining YoY.

Figure 89: YoY growth in monthly average brand incidence rate (US only)



Source: UBS Evidence Lab

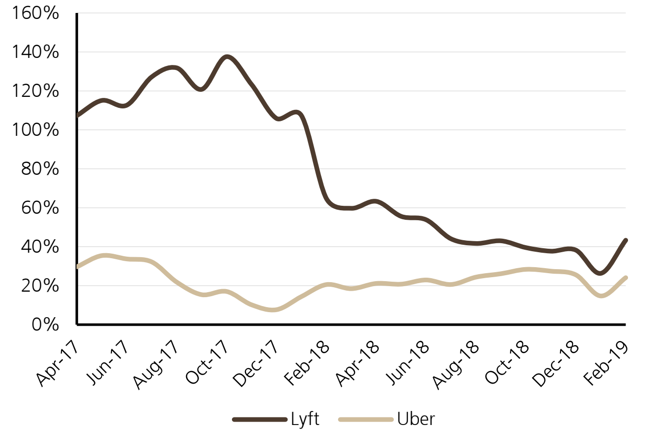
Figure 90: TTM indexed brand incidence rate (US only)



Source: UBS Evidence Lab
Note: Indexed share of consumers who make at least one purchase of any amount at the brand in the year (12-month period). Values are indexed so that the total customer share across the competitive set = 100 in the first period (Feb '17 TTM), and are chained for subsequent periods to reflect changes in the size of the customer population from period to period

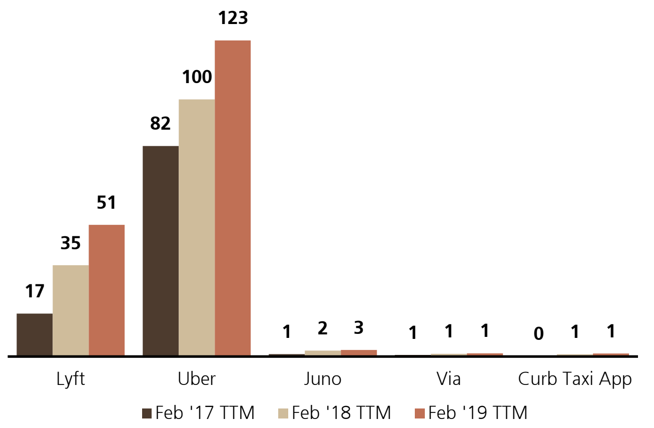
Total monthly spend has been growing 35-45% YoY for Lyft. On a trailing 12-month (TTM) basis, Lyft has narrowed the gap considerably with Uber. Specifically, for TTM ending February 2017, Uber's indexed total spend was ~4.9x Lyft's. However, Lyft narrowed the gap to ~2.4x for TTM ending February 2019.

Figure 91: YoY growth in monthly total spend (US only)



Source: UBS Evidence Lab

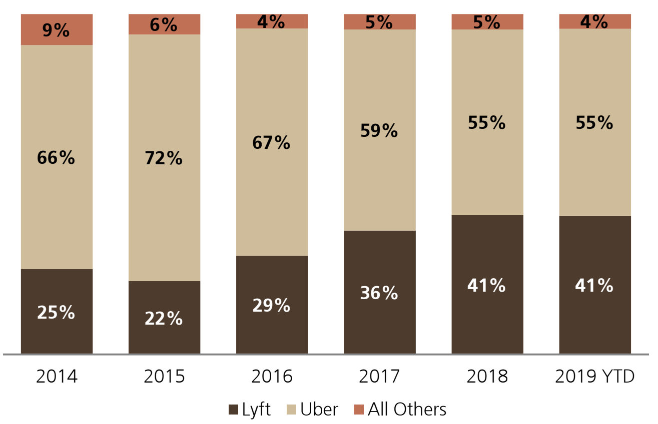
Figure 92: TTM indexed total spend (US only)



Source: UBS Evidence Lab
Note: Indexed total spend with the brand in the year (12-month period). Values are indexed so that the total spend across the competitive set = 100 in the first period (Feb '17 TTM), and are chained for subsequent periods to reflect changes in total spend from period to period.

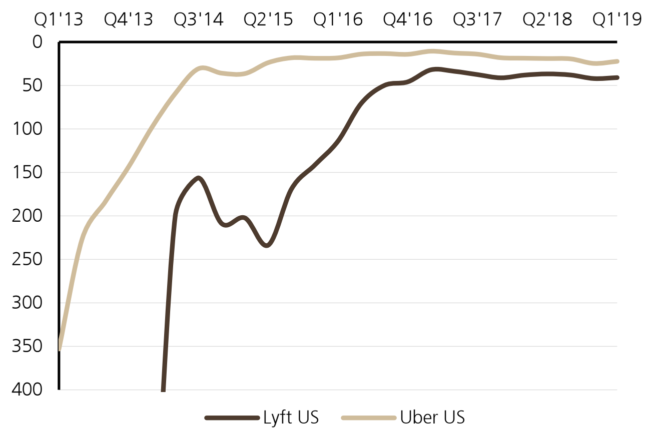
Trending similarly to survey results previously published (Link) around brand usage/awareness and perception, Uber remains number 1 in terms of app download ranking and share of app downloads on an annual basis in the US. Since the end of 2017, Lyft has had ~40% share of downloads in the US within a given period.

Figure 93: US – share of downloads by ROD service



Source: UBS Evidence Lab, Sensor Tower

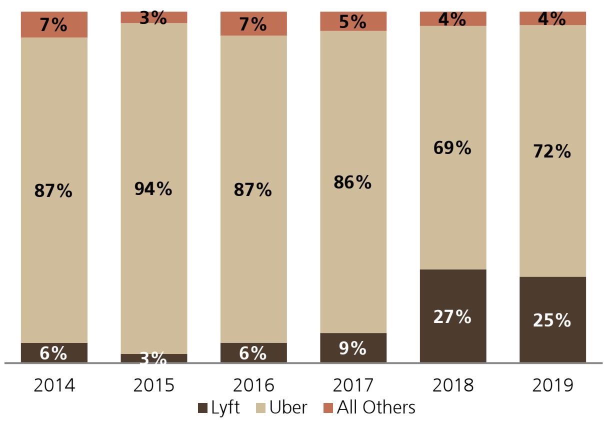
Figure 94: Lyft/Uber – US app download ranking (iPhone all category)



Source: UBS Evidence Lab, Sensor Tower

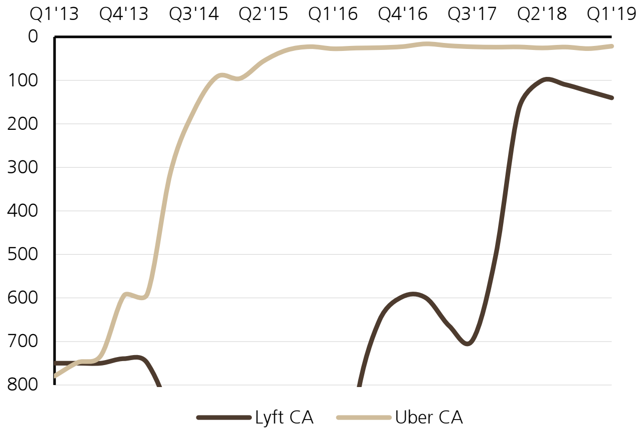
In Canada, Lyft has a 25% share of app downloads YTD in 2019 (roughly in line with the 27% in 2018) vs. Uber at 72% YTD (vs. 69% in 2018). We note that Canada represents a small segment of the overall ride-on-demand industry today, at a low-single-digit percentage of total downloads, especially relative to the US in the mid-teens.

Figure 95: Canada – share of downloads by ROD Service



Source: UBS Evidence Lab, Sensor Tower

Figure 96: Lyft/Uber – Canada app download ranking (iPhone all category)



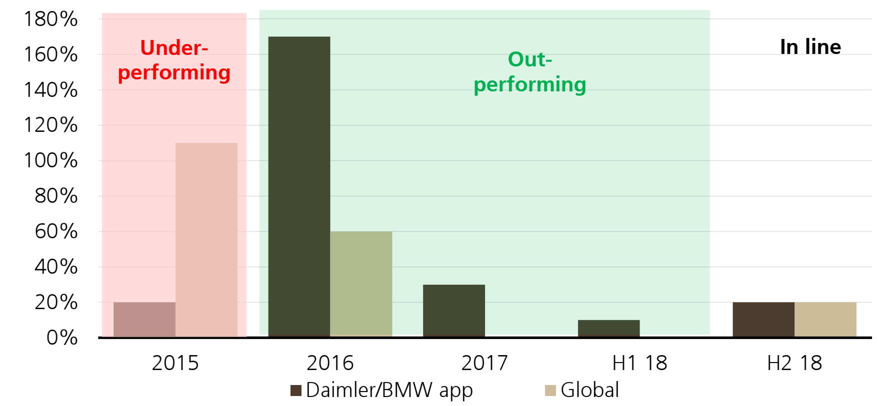
Source: UBS Evidence Lab, Sensor Tower

Europe: Daimler/BMW stable; Uber losing share

Uber losing market share in Europe

Daimler/BMW app downloads have been outperforming global market growth since 2016 and are still growing at a double-digit rate (Figure 97).

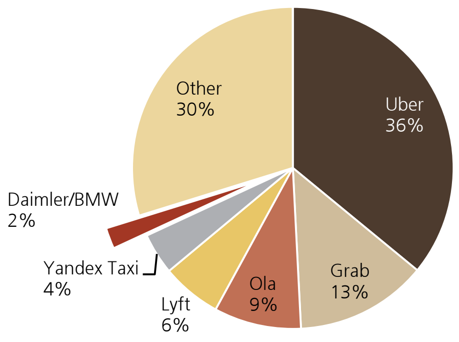
Figure 97: Daimler/BMW ride-on-demand vs global app download growth yoy



Source: UBS Evidence Lab, Sensor Tower, iOS and GooglePlay combined

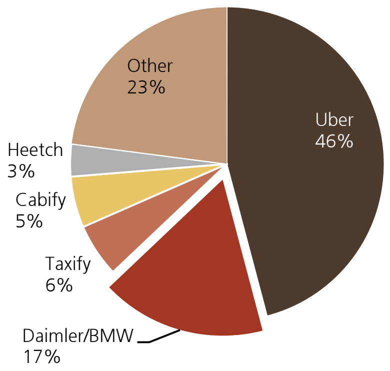
Globally, Daimler/BMW remains a small player with "only" a 2% market share (Figure 98). However, in Europe, they rank number two with a 17% market share (Figure 99). Interestingly, the market share of Uber has fallen by 4 percentage points in Europe since H1 2018.

Figure 98: Ride-on-demand – market share split globally (excluding China) (H2 18)



Source: UBS Evidence Lab, Sensor Tower, iOS and GooglePlay combined.
Note: calculated as % of app downloads

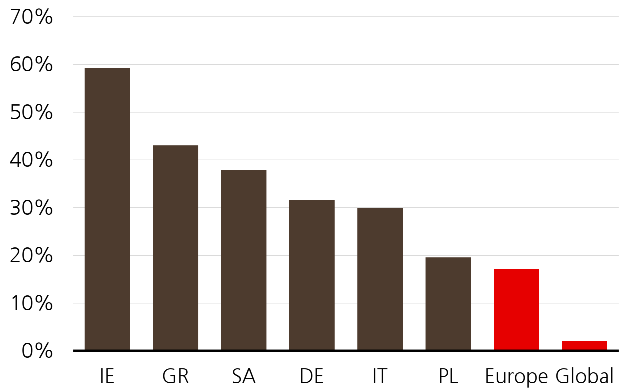
Figure 99: Ride-on-demand – market share split in Europe (H2 18)



Source: UBS Evidence Lab, Sensor Tower, iOS and GooglePlay combined
Note: calculated as % of app downloads

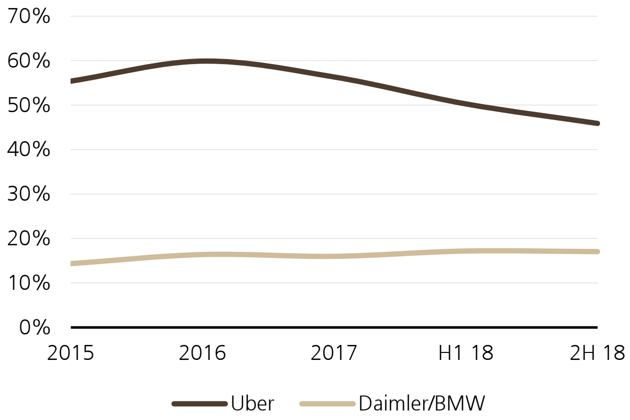
We have identified six markets where Daimler/BMW's market share is above 20%. Those are mostly markets where Uber is not present for local regulatory reasons (Figure 100). Finally, it seems that Uber's European market share peaked in 2016, at 60%, and is currently slightly below 50%. Meanwhile, Daimler/BMW's market share has improved slightly, stabilising at around 17% (Figure 101).

Figure 100: Countries where Daimler/BMW have 20% or more of app downloads in H2 18



Source: UBS Evidence Lab, Sensor Tower, iOS and GooglePlay combined.
Note: IE (Ireland), SA (Saudi Arabia), IT (Italy), GR (Greece), DE (Germany), PL (Poland),

Figure 101: Uber vs Daimler/BMW – market share trend in Europe



Source: UBS Evidence Lab, Sensor Tower, iOS and GooglePlay combined.
Note: calculated as % of app downloads

China

New opportunities likely to emerge in China for internet companies as robotaxis develop

We believe new business opportunities will emerge in China for internet companies as robotaxis develop. First, according to the UBS Evidence Lab model, a robotaxi fleet of 4,500 vehicles in Manhattan can generate daily revenue of $3.3m with profit margin as high as 90%. China will likely have different economics but given the high population density and number of large cities, we see considerable value creation for robotaxi operators. Second, providers of technology and services supporting robotaxis could enjoy upside once the business gains scale (e.g. HD map provided by Baidu Apollo platform). Third, in-car monetization of content and other services via ads, subscriptions, tipping, etc. is another large opportunity for online media companies as passengers have more spare time in vehicles. And fourth, smart city/transportation projects to improve intra-city infrastructure and traffic management by working with government agencies could represent additional business opportunities.

Didi is running test for AV fleets

Didi Chuxing is naturally well placed to provide robotaxi services and fleet management by leveraging its current ride-on-demand expertise and data. During our visit to Didi, management presented its ambitious plans for a future robotaxi service. Didi now has test fleets in both China and the US, and says it will continue to step up investments in the R&D of its autonomous driving technology.

Not a 'winner takes all' situation

Robotaxi service and fleet management, however, is unlikely to be a Didi monopoly, as OEMs, suffering from stalled new car sales growth, are launching mobility services of their own. Among these OEM-backed mobility companies, Caocao, invested by Geely Group, is a first mover. SAIC launched Xiangdao Chuxing in November 2018 to explore the online car-hailing market as a strategic move in pursuing the auto-sharing trend. In March 2019, three major government-owned OEMs – FAW Group, Dongfeng Motor and Changan Auto – joined home appliance retailer Suning and several internet companies in forming a joint venture with a total investment of Rmb9,760mn on mobility service.

Baidu's Apollo platform has attracted over 130 partners

In addition, many OEMs are partnering with internet leaders to jointly develop autonomous vehicles and explore mass production/commercialization. For example, Baidu's Apollo platform has attracted over 130 partners, many of which are leading domestic and global OEM brands.

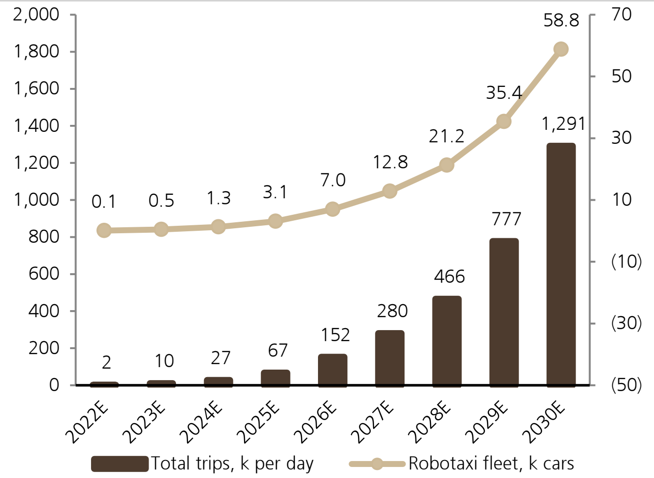
Chinese companies are at a relatively early stage but are catching up with global leaders, and we believe they have competitive advantages over global peers in terms of user acquisition, partnerships and government support in the local market. We see increasing focus and resources being invested in autonomous vehicles/robotaxis from leading internet and technology companies (e.g. BAT, Didi, Huawei, etc.) and start-ups (e.g. Pony.ai, WeRide.ai, SenseTime, etc.), and continued progress in testing and launching robotaxi services at small scale. We also see substantial government support for these initiatives. In December 2018, Pony.ai launched an app in Guangzhou that allows users to call a robotaxi for a free ride, but the app was only open to a small group of users and trips were limited to specified locations. Baidu announced plans to launch 100 robotaxis in Changshai City in 2019 managed by its own V2X system, which will be the first robotaxi fleet in China.

Russia will likely be one of the first adopters, too

Since the country's largest internet company – Yandex – is very unusual in terms of its leadership in search and navigation technologies combined with having its own taxi and car-sharing businesses, we believe Russia can become one of the early adopters of self-driving cars. The Russian government is developing a set of regulations, which is planned to be approved in 2019, while Yandex is already testing robotaxis in two regions of Russia, and is expected to have c100 Level-5 vehicles by YE19.

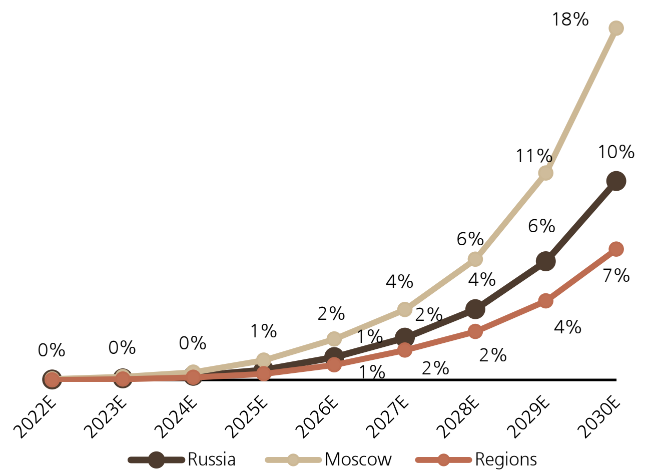
We forecast the total Russian robotaxi fleet to reach c60k cars by 2030E (7% of the total car fleet servicing ROD users in Russia; c1% share in global). We expect 10% of the Russian passenger mobility services mileage (including both taxi and car-sharing) will be driven by autonomous cars by 2030E. Although we anticipate the penetration of self-driving cars to be unevenly distributed among Russian territories (Moscow penetration will be higher than in other regions), we estimate that the Russian citizen will on average make three trips using an autonomous car out of 33 total rides (combined taxi and car-sharing) per annum.

Figure 102: Robotaxi total trips evolution, k per day



Source: UBS estimates

Figure 103: Robotaxi mileage as % of total RCD (taxi and car-sharing) in Russia



Source: UBS estimates

Korea

We see an opportunity for a local service provider to be the winner in the Korean market

We believe Korea is well positioned to embrace the robotaxi opportuniy, based on our analysis of the incumbent Internet service offerings and telecommunication infrastructure build-out schedule of a nationwide 5G network. We believe, given tough labour laws and local regulations (e.g. global map providers do not provide detailed map/navigation services in Korea), that a local champion is likely in Korea – as seen in the case of the taxi-hailing market. Our analysis of the Korean ride-on-demand taxi market shows that the addressable market for robotaxis is sizeable in Korea. For instance, our analysis of Kakao T's 2018 operational matrix, the most downloaded ROD app in Korea, shows that Kakao T's addressable market in 2018 was around USD2bn in terms of booking revenue from travel fare alone, out of a total addressable taxi and designated driver market of around USD10bn. More interestingly, we highlight that the average trip time per ride was 32.4 minutes, with an average distance driven per ride of 8.5km, as the metropolitan Seoul area is quite spread out and taxis are one of the most popular means of transportation, along with buses and subways. We also note an average of over 737,000 daily completed rides for Kakao T, while we estimate that Kakao T only accounts for less than 30% of the total addressable Korean taxi market booking revenue. We estimate that the number of taxi drivers registered with Kakao T was 79% of Korea's total taxi driver population, and the number of designated drivers registered with Kakao T was 28% of the total designated driver market in 2018. See our report on Korea ride-on-demand analysis for further details.

Figure 104: Addressable market (distance and time travelled) analysis for robotaxi opportunity in Korea – (Using Kakao T 2018E as a proxy)

Aggregate of Kakao Taxi, Kakao Black and Kakao Driver	
Number of days	365
Number of daily rides	**737,722**
Average distance driven per ride (km)	8.5
Distance driven by the fleet - daily (km)	**6,290,425**
Distance driven by the fleet - annual (km)	2,296,005,191
Average trip time per ride (min)	32.4
Distance driven by the fleet per hr (km)	29.6
Average rate per ride (Won)	8,716.4
Booking revenue of the fleet - daily (Won bn)	6.4
Booking revenue of the fleet - annual (Won bn)	2,347.1
Average net revenue per ride (Won)	154
Total net revenue of the fleet - daily (Won bn)	0.11
Total net revenue of the fleet - annual (Won bn)	41.3
Net revenue (Won bn)	41.3
As % of booking revenue	1.8%

Source: Kakao T data from Mar 2015 to Sep 2018; Kakao Driver data from June 2016 to Sep 2018.
Source: Company data, UBS estimates

Internet – Kakao offers an integrated mobility service

Korea's mobile messenger platform is well suited to leverage robotaxis opportunities

While Naver is the largest Internet company in Korea in terms of revenue, earnings, and R&D budget, we believe Kakao is best positioned to leverage the robotaxi opportunities, given its fully integrated mobility service offering. Kakao Corp is currently providing various mobile services – with top user market shares in Korea – that are linked its core mobile messenger platform, and we believe that robotaxi services and fleet management can be a natural extension of its mobility + in-vehicle infotainment + mobile messenger platform. Kakao's core platform is the mobile messenger 'Kakao Talk', with a dominant 44m monthly active user base (there are a total 52m Korean registered smartphones in Korea), which connects Kakao's various services (#1 mobility and #1 music streaming and #1 map/navigation and #1 mobile messenger by user traffic) through a single ID platform in Korea with an integrated payment system. In 2018, content (e.g. music and webtoons) accounted for over 30% of its consolidated revenue, followed by advertising (27%), games (17%), and commerce (13%). There are multiple local companies forming alliances to develop an autonomous driving eco-system, but we believe Kakao is well positioned as it has formed a partnership with Hyundai Motor Group (Korea's largest automobile manufacturer, with 7.2m global units shipped in 2018) to provide an in-vehicle entertainment system. At the 21 March unveiling of the Sonata, Hyundai Motor's flagship volume sedan model, an AI system developed by Kakao called "Kakao I" was showcased as the in-vehicle infotainment and navigation system. Kakao has also partnered with KT (Korea's largest pay-TV provider and second-largest wireless provider) to create "Mobility as a Service" to offer a real-time platform that can include a combination of transport methods (e.g. car sharing or rental or taxis), and provide services ranging from travel planning to payments.

First 5G commercialization providing an infrastructure base for Korea to be an early market mover

Korea is targeting 93% 5G population coverage by end-2019 and full roll-out by 2022

As highlighted in earlier sections, 5G is only a small part of the overall infrastructure needed for a robotaxi business to commence in Korea. However, we highlight that Korea has the potential to be one of the early market movers on robotaxis, given the fast roll-out schedule of the nationwide 5G infrastructure. The three major telecom operators and the MSIT (Ministry of Science and ICT) held a meeting on 23 April and agreed to a speedy roll-out of 5G coverage to meet the

90% population coverage target by year-end. As of 22 April, there were 54,512 5G base stations (110,751 installed equipment), and the target is to increase that installed equipment number to 230,000 by the end of 2019, which would mean 93% population coverage in 85 cities. We highlight that it is difficult to compare 4G LTE and 5G base stations on an apples-to-apples basis, given the technical differences between the two telecom communication technologies, but the full nationwide roll-out is expected to be completed by 2022. Korea's three major diversified operators all boast wireless, IPTV, media, and e-commerce businesses. While the innate technological characteristics of 5G should help the telecom operators take a greater share of the revenue opportunity than they did in the 4G LTE era (e.g. net neutrality), we believe that the bigger impediment for Korean telecom companies with regard to the robotaxi opportunity lies with its management quality versus that of the Internet companies.

Could the simulation be applied to emerging markets?

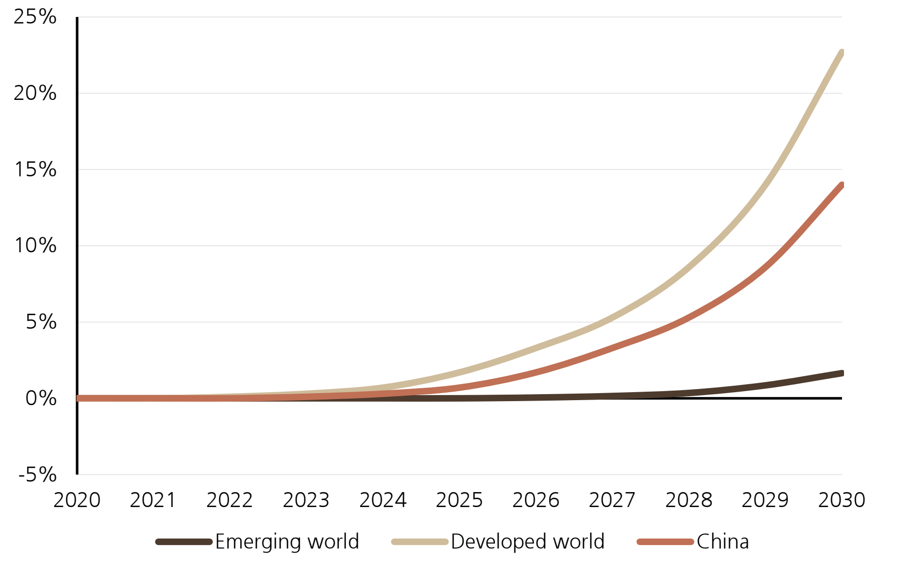
A concern one may have is that the UBS Evidence Lab robotaxi simulation could not be applied to emerging markets (EM) given the specificities in terms of income, population density, traffic etc.

As discussed earlier, we have separated the (urban) world into three zones: developed markets (DM), China and EM. For each zone, we assume different adoption rates and a sharp increase in the S-curve happening at various points in time.

We think penetration will start first in DM, while EM penetration will likely remain very low. We expect China to follow a similar pattern to DM, and we would not rule out that penetration in China could even be larger than in DM.

We expect penetration to start in DM, then China (where it could even be larger than in DM); EM penetration likely to remain low

Figure 105: Robotaxi penetration by region



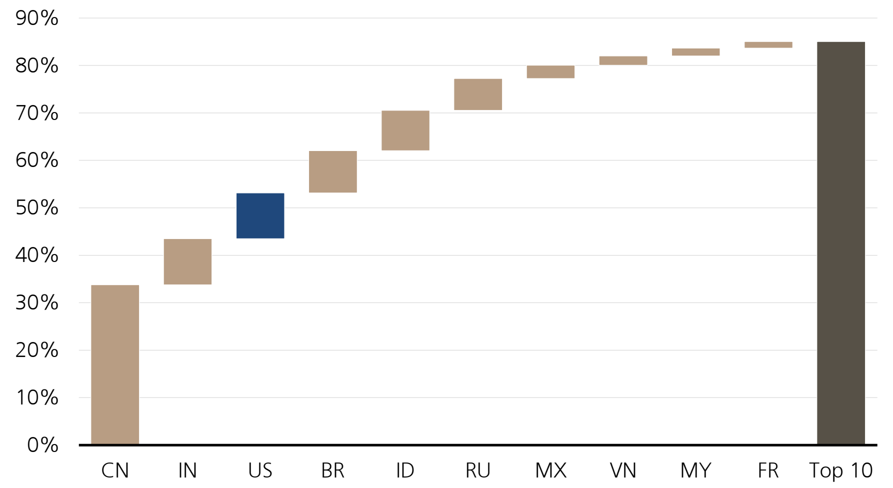
Source: UBS estimates. Note: defined as % of urban population making two trips each day

EM remains the main contributor for ride-on-demand app downloads

Our most recent "ride-on-demand" app downloads analysis, which we conducted last year, found that the top 10 largest markets accounted for 82% of app downloads globally. Nine of the top 10 were emerging markets. There is therefore a high level of interest in these new forms of mobility in EM, despite the lower level of penetration of cars, lower income, lack of infrastructure, etc.

Figure 106: Contribution to "ride-on-demand" app downloads by country in Jan-July 2018* (in millions, analysis conducted in July 2018)

Nine out of the top 10 ride-on-demand markets are EM



Source: UBS Evidence Lab (2018), Sensor Tower, iOS and GooglePlay combined

Note: We removed countries where we did not have Google Play data, except China where we assumed equal numbers of iOS and Android downloads. CN =China; US = United States; IN = India; BR = Brazil; ID = Indonesia; RU = Russia; MX = Russia; VN = Venezuela; KR = South Korea; M = Malaysia; based on the aggregation of iOS and Google Play. *Our analysis was run in July 2018.

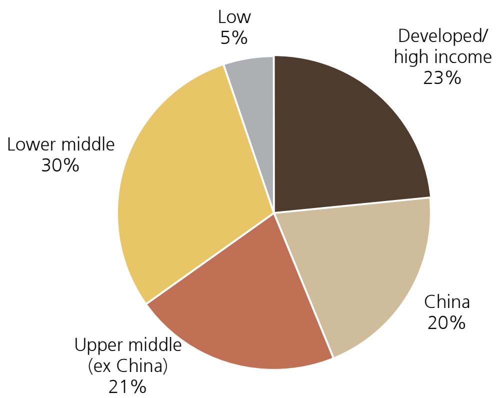
EM likely to lag DM adoption

While megacities in EM could represent an attractive opportunity for robotaxi fleets given high population densities, we believe penetration in EM is likely to significantly lag DM, given lower income, pricing, cheaper infrastructure and other challenges. As a consequence, we model only a 2% penetration by 2030 in our base case (vs 23% assumed for developed markets).

Average income not enough to afford robotaxi fares in EM

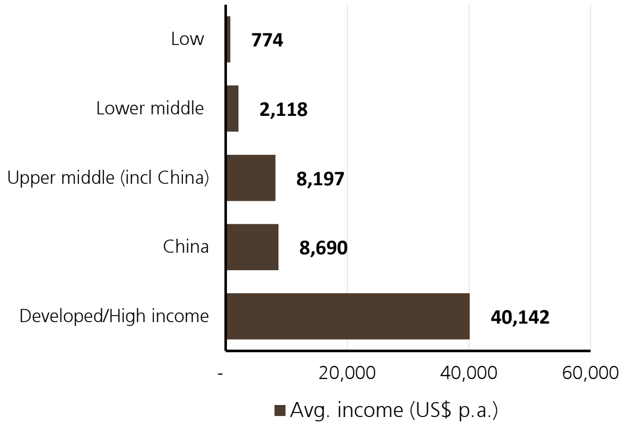
According to UN data, high-income (GNI +$12,235) and upper-middle income (GNI $3,956-12,235) segments represented 23% and 41% of the total urban population in 2017, respectively. If we assume that the cost of one trip is $3 (based on Uber pricing in India (see below)) and two trips per working day (as per the simulation), the annual total cost would be around $1,500 (or about 20% of global average GNI), which seems unaffordable. Therefore, the vast majority of the urban population in EM will not be in a position to afford the average fare of $10 that the simulation shows (assuming no reduction in the fee).

Figure 107: World urban population by country income category (2017)



Source: World Bank

Figure 108: Average per capita for countries included in the income category



Source: World Bank

Figure 109: Income segments – gross national income per capita (US$)

Threshold	GNI/Capita (current US$)
Low-income	< 1,005
Lower-middle income	1,006 - 3,955
Upper-middle income	3,956 - 12,235
High-income	> 12,235

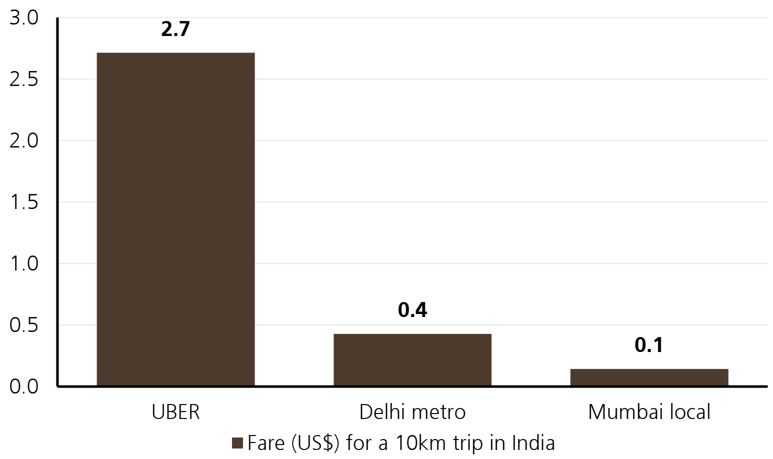
Source: World Bank

Robotaxi pricing remains not competitive enough for EM

Current Uber pricing in India is materially cheaper than in the simulation: the average fare is c$3 for a 10 km (40-min) ride, compared to the simulation showing c$10 per trip (or c$3/km on average).

Overall, pricing is likely to remain a fraction of DM pricing. Therefore, we assume initial adoption in EM (excluding China) will remain low.

Figure 110: Uber versus urban public transport fares in India



Source: UBS

Robotaxis unlikely to compete with public transport and two-wheelers in EM

Competition from two-wheelers

In India, the cost of public transport remains materially lower than that of Uber. Figure 110 shows that Uber is 7x more expensive than the metro in Delhi. On that basis, it is very difficult to imagine that robotaxi fleets could price-compete with public transport (unlike in DM).

In addition, in India and other low/mid-income EM countries, two-wheelers represent an important part of individual mass mobility. The cost of two-wheelers is similar to public transport (~US$0.35 for 10 kms).

China's market potential likely to resemble DM

In terms of robotaxi adoption, we think China could be more like DM than other EM countries

We discuss China separately from other emerging markets as we believe that in terms of robotaxi adoption, China could demonstrate greater similarity with DM than other EM.

Firstly, on income, by 2030, Chinese GDP per capita could be close to US$20,000 (assuming a mid-single-digit growth rate similar to what we can see today), which is close to the low end of some developed markets like Portugal.

Then, on technology, China shows more similarities with DM. Among the top 20 tech firm market caps in 2018, China ranks second only to the US. On auto-related technologies, China represents 52% of global electric vehicle sales in 2018. On ride-on-demand service, Didi processes more orders on a daily basis than Uber globally combined. On autonomous driving tests, as per the California DMV 2018 report, Chinese companies Pony.AI, Baidu, Roadstar.AI, WeRide and SF Motors all rank in the top 20 as measured by kilometres per disengagement.

We argued in our May 2018 report Where are Chinese companies in the race for autonomous vehicles? that China enjoys some advantages in robotaxi deployment, including a technology-adaptive and open-minded public attitude, strong government initiatives, efficient infrastructure deployment, and so on. Even though the cost of a driver in China is not as high as in DM, its aging and large non-driving population, high road accident rate, and congested and polluted megacities, are all pushing a shift toward robotaxis and autonomous driving.

A key challenge in China is the heavy and complex nature of traffic. This could be solved by limiting the operating areas of robotaxis to relatively traffic-light areas (at least initially), while training the algorithm to handle greater complexity in the long run.

China is well positioned to scale up robotaxi fleets

For example, Uber was first to create the business model of ride-on-demand, but Didi has achieved higher daily orders than Uber within just a few years. Spreading from Beijing or Shenzhen to the rest of China usually happens a lot faster than from Silicon Valley to the rest of the DM world, which as a whole has similar population to China but is fragmented across different countries with different regulatory environments and different languages.

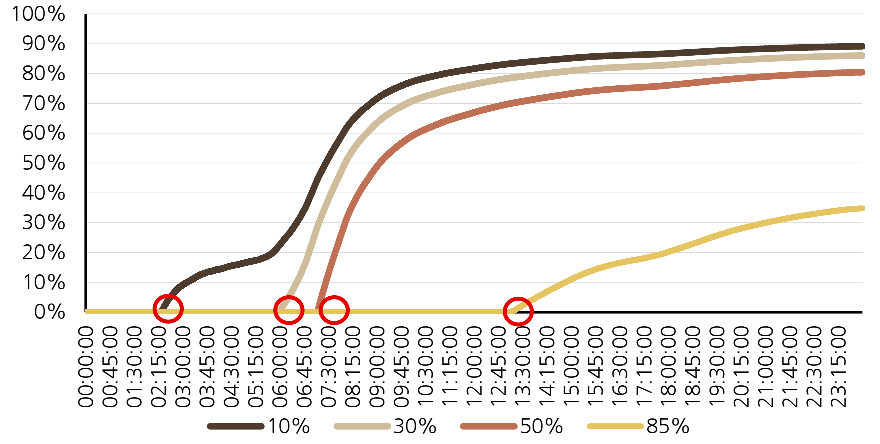
We do not rule out the possibility that China might eventually have a higher robotaxi penetration than DM, just as China currently has a bigger high-speed rail network than DM countries combined, even though the first Chinese high-speed train only departed the platform more than four decades after the first such DM train.

What is required for the economics to potentially work in EM?

As discussed above, the simulation shows that the average cost of a trip is c$10, and we see potential for a reduction of 80% or more. In other words, the average cost of a trip could over time decline to less than $2. If a trip is shared by at least five people, robotaxis would be able to price-compete with the metro cost in Delhi, for instance.

Furthermore, market entry costs are extremely low, with daily running costs (excluding depreciation) estimated at only $40 per vehicle. Therefore, the scope of a robotaxi fleet could be much larger than in highly dense areas in DM, and there could be a strong rationale in EM as well.

Figure 111: Profitability margin sensitivity at different levels of price reduction over the course of 24 hours



Source: UBS Evidence Lab. Note: Red circles indicate when the profitability breakeven is reached

At a glance: Sector Thesis Maps

Global OEMs

Robotaxis – impact on sector… Growth: → Margins: → ROIC: ↘ Valuation: →

PIVOTAL QUESTIONS

Q: What are the implications of the shift towards robotaxis?

Carmakers will likely have to reinvent their business model and expand into new areas. Given the high level of profitability of robotaxi fleet management and the lower cyclicality of the revenue stream, OEMs should no doubt consider entering this field. The penetration of electric cars should be boosted.

Q: Does the shift in the OEMs' business model represent an opportunity or a threat?

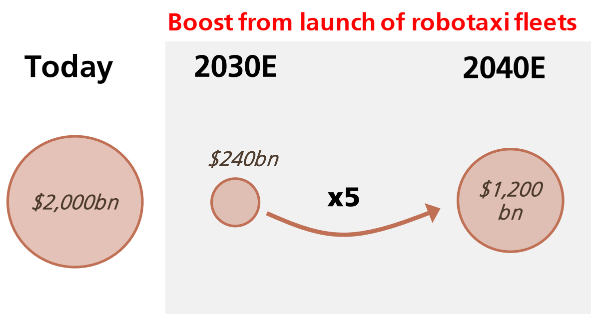
Mixed. A few winners, many losers. Positives: Less cyclical revenue streams, and a more asset-light business model. Negatives: Sharp reduction in the penetration rate of private cars, OEMs with low brand equity potentially becoming irrelevant, lower barriers to entry and more competition.

FINANCIAL IMPACT

Q: What will be the financial impact on the industry?

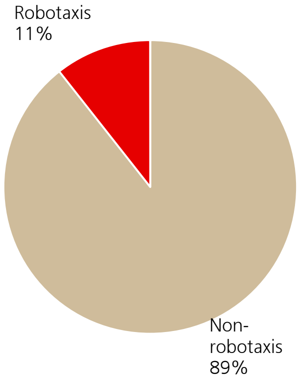
We estimate that the revenue pool of producing robotaxis could represent >$200bn in 2030, or >10% of producing new cars today. In other words, c11% of EVs sold in 2030 could relate to robotaxis.

Robotaxi vehicle production, today vs 2030E vs 2040E



Source: UBS estimates

Robotaxis as % of new EV sales, 2030E



Source: UBS estimates

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from robotaxis?

No. Managing the transition could be a challenge. OEMs would need to accelerate investments in EVs and autonomous vehicles. Only a few have developed partnerships with shared mobility platforms. The mindset needs to change from 'selling a car every four years' to 'selling a minute or a kilometre'.

SECTOR VALUATION

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

Yes. Current valuations are running c30% below through-the-cycle multiples. Less cyclical revenue streams and slightly higher returns could merit a higher multiple. OEMs would likely need to write off their asset base first.

STOCK IMPACT

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

MOST FAVOURED	Stock	UBS rating	2020E PE	Comment
	GM	Buy	5.1x	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.
	VW	Buy	5.2x	Best ability to benefit from economies of scale, but not a leader in AV technology today

LEAST FAVOURED	Stock	UBS rating	2020E PE	Comment
	PSA	Neutral	6.7x	PSA for now is not among the leaders in AV technology, and it lacks scale compared with the largest mass-market OEMs.
	FCA	Neutral	5.5x	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.

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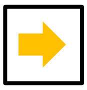
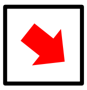
Robotaxis – impact on sector… **Growth:**  **Margins:**  **ROIC:**  **Valuation:** 

PIVOTAL QUESTIONS

Q: What are the implications of the shift towards robotaxis?

Competition should be intense and auto suppliers do not screen as best positioned to bring the highest added value. The manufacturing process would be more standardised. There should be very strong content growth, but price deflation would likely be extremely high. Highly profitable aftermarket revenues would collapse. The interior of the car should become a key differentiating factor for OEMs.

Q: Does the shift represent an opportunity or a threat?

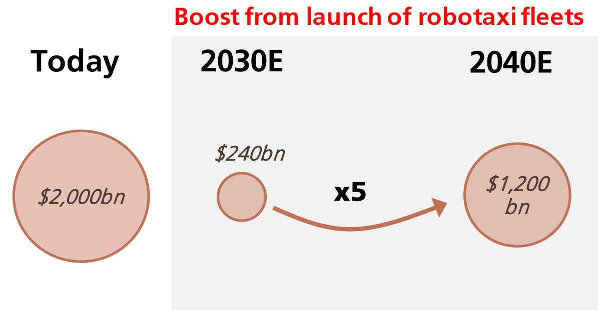
Mixed. Positives: Higher content value per vehicle. Negatives: Lower new car sales; lower barriers to entry with new entrants competing; lower aftermarket revenues despite higher utilisation rates, driven by: (1) car parc size shrinking; and (2) fewer moving parts in electric cars; more pricing pressure on traditional products.

FINANCIAL IMPACT

Q: What will be the financial impact on the industry?

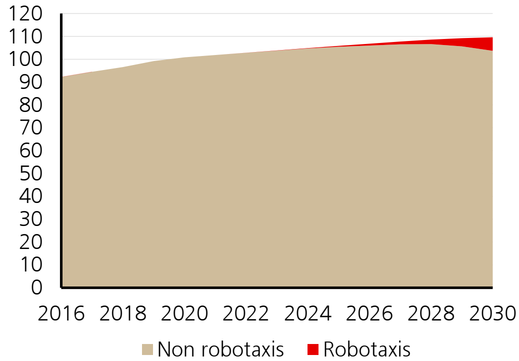
The strong growth will likely continue in the medium term, but it is unclear whether any players will be able to make attractive enough margins. In the long run, some suppliers might have to write down some assets as the technology they have invested in becomes irrelevant.

Robotaxi vehicle production, today vs 2030E vs 2040E



Source: UBS estimates

Trend in global car production (m)



Source: UBS estimates

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from robotaxis?

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

SECTOR VALUATION

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

Unlikely in the near term.

STOCK IMPACT

Q: What stocks should 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	2020E PE	Comment
Hella	Buy	11x	Positively exposed via sensor hardware (global leader in radar) and lighting (robotaxis likely to require more lighting content versus conventional cars).
Valeo	Buy	13x	Valeo generated an order intake worth €1bn for robotaxis last year. Valeo has a clear competitive edge thanks to its leadership in lighting and wiping systems.
Aptiv	Neutral	13x	By far most advanced in AV among our global supplier coverage, thanks to Nutonomy acquisition.

LEAST FAVOURED	Stock	UBS rating	2020E PE	Comment
	Veoneer	Sell	-	Pure auto tech play. At risk of disappointing on organic growth, profitability margin and cash.
	Leoni	Sell	3.9x	Moderately positively exposed to AVs, given higher wiring content (5-10% versus conventional car).

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Tyre makers

Robotaxis – impact on sector… **Growth:** ↗ **Margins:** ↗ **ROIC:** ↗ **Valuation:** ↗

PIVOTAL QUESTIONS

Q: What are the implications of the shift towards robotaxis?

Tyre makers will benefit from the higher number of kilometres driven. The simulation shows that a robotaxi would drive, on average, around 250km daily, which translates into more than 90,000km on an annual basis. This is 6x more than a private car today. Therefore, even if we estimate that the fleet size could be reduced by two-thirds with the introduction of autonomous vehicles, the kilometres driven would still increase on a like-for-like basis.

Q: Does the shift in the OEMs' business model represent an opportunity or a threat?

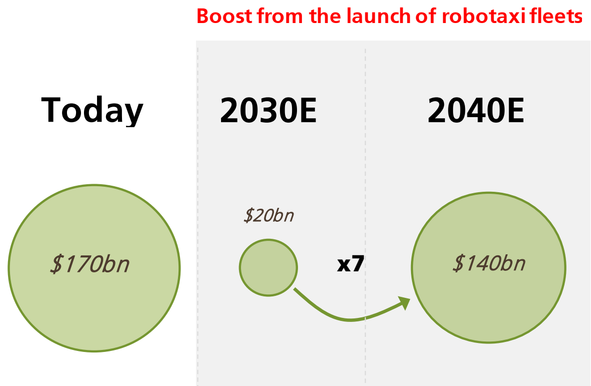
Opportunity. We estimate the number of kilometres driven will increase. The robotaxi simulation shows that the number of km driven per hour in Manhattan should increase by a factor of 20x.

FINANCIAL IMPACT

Q: What will be the financial impact on the industry?

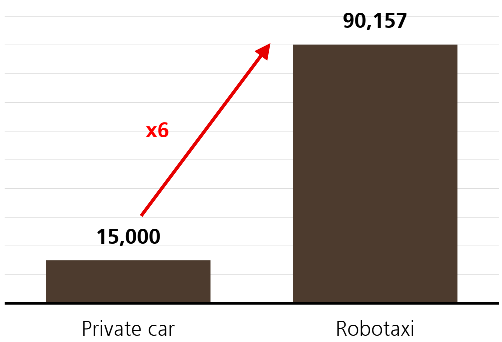
The shift towards robotaxis should support the industry volume with an annual growth rate of close to 1% between today and 2030E (with most of the impact felt post 2025E). We see a net revenue uplift of 50% by 2040E as the number of kilometres driven per vehicle increases.

Revenue pool for tyres, today vs 2030E vs 2040E



Source: UBS estimates

Yearly km driven comparison – private car vs robotaxi



Source: UBS estimates

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from robotaxis?

Yes. Premium players have started to invest in developing tyres dedicated for electric vehicles. The installed capacity should be enough to meet the incremental demand.

SECTOR VALUATION

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

Yes. Tyre makers trade at only a small premium to some auto component suppliers, despite generating higher profitability margins and better cash conversion.

STOCK IMPACT

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

MOST FAVOURED

Stock	UBS rating	2020E PE	Comment
Michelin	Buy	9x	Benefits from large scale capabilities, a strong brand, experience in working with fleets and high-performance tyres dedicated to electric cars (that can last longer).
Pirelli	Buy	9x	Clear focus on high-value tyres.

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US internet

Robotaxis – impact on sector… **Growth:** **Margins:** **ROIC:** **Valuation:**

PIVOTAL QUESTIONS

Q: What are the implications of the shift towards robotaxis?

We see a number of different scenarios in which US internet companies could operate within the autonomous ride-sharing ecosystem, depending on when/how this technology is deployed. Since AV technology is still in its early stages, we believe most companies are trying to be as flexible as possible with their current strategies in order to give themselves optionality in how they ultimately fit into the broader landscape. That said, in addition to a large attractive pool of revenue, autonomous vehicle technology also has the potential to reduce certain costs of operating ride-sharing networks and ultimately boost profitability for some companies.

Q: Does the shift in the OEMs' business model represent an opportunity or a threat?

It depends on how potential business models within the industry play out. If the industry continues down the path of partnering, this could present an opportunity to US internet companies, which may look toward OEMs either as a supply chain partner for their own fleets and/or a partner to supply their networks with vehicles in an asset-light model.

FINANCIAL IMPACT

Q: What will be the financial impact on the industry?

We have seen an increase in R&D spend from internet companies as a result of their efforts to develop autonomous vehicle platforms. This spend could increase as they implement robotaxis near term, which could further pressure margins. That said, we are positive on the long-term revenue and margin potential from robotaxi operations and related services, though our positivity depends on whether the operations are asset-light or heavy.

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from robotaxis?

Yes. Companies such as Waymo and Lyft are all preparing for a world of autonomous ride-sharing. 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 robotaxis lead to a change in sector valuation multiples?

Yes. We do not believe US internet stocks are currently pricing in these call options, which could result in long-term value creation for shareholders. For example, we would argue that investors are currently ascribing little-to-no value to Alphabet's cash balance, emerging businesses (cloud and hardware) or long-term call options (including Waymo and life sciences efforts). As to Lyft, we believe investors are taking a conservative approach to valuation and embedding all of the costs related to AV investments, but none of the long-term revenue opportunity.

STOCK IMPACT

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

We believe Alphabet and Lyft will be most positively impacted.

MOST FAVOURED

Stock	UBS rating	2020E PE	Comment
Alphabet	Buy	23x	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
Lyft	Buy	NA	We believe Lyft is attractively positioned within the autonomous vehicle industry in order to have flexibility and take advantage as opportunities arise and business models play out.

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Robotaxis – impact on sector…	Growth:	↗	Margins:	→	ROIC:	→	Valuation:	↗

PIVOTAL QUESTIONS

Q: What are the implications of the shift towards robotaxis?

We believe new business opportunities will emerge in China for internet companies as robotaxis develop. (1) According to UBS Evidence Lab, a robotaxi fleet of 4,500 vehicles in Manhattan could generate daily revenue of US$3.3m with profit margins as high as 90%. China will likely have different economics, but given the high population density and number of large cities, we see considerable value creation for robotaxi operators. (2) Providers of technology and services supporting robotaxis could enjoy upside once the business gains scale (eg, HD map provided by Baidu Apollo platform). (3) In-car monetisation of content and other services via ads, subscriptions, tipping, etc, is another large opportunity for online media companies as passengers have more spare time in vehicles. (4) Smart city/transportation projects to improve intra-city infrastructure and traffic management by working with government agencies could represent additional business opportunities.

Q: Does the shift in the OEMs' business model represent an opportunity or a threat?

We believe it presents opportunities for China internet. Many OEMs partner with internet leaders to jointly develop autonomous vehicles and explore mass production/commercialisation. For example, Baidu's Apollo platform has attracted more than 130 partners, many of which are leading domestic and global OEM brands.

FINANCIAL IMPACT

Q: What will be the financial impact on the industry?

We have seen R&D spend from internet companies as a result of their efforts to develop autonomous vehicle platforms. This spend could increase as they implement robotaxis near term, which could put further pressure on margins. We are positive on long-term revenue and margin potential from robotaxi operations and related services, though our positivity depends on whether the operations are asset-light or heavy.

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from robotaxis?

Chinese companies are at a relatively early stage but are catching up with global leaders, and we believe they enjoy competitive advantages in user acquisition, partnerships and government support in the local market versus global peers. We see an increasing focus and resources invested in autonomous vehicles/robotaxis from top internet and technology companies (eg, BAT, Didi, Huawei) and start-ups (eg, Pony.ai, WeRide.ai, SenseTime), and continued progress to test or launch robotaxi services at small scale. We also see substantial government support for these initiatives. In December 2018, Pony.ai launched an app in Guangzhou that allows users to call for a robotaxi for free rides, but the app was only open to a small group of users and the trip was limited to specified locations. Didi, the dominant ride-hailing platform in China with significant passenger and traffic data, is reportedly working on building an electric robotaxi fleet. Baidu announced plans to launch 100 robotaxis in Changsha City in 2019 managed by its own V2X system, which will be the first robotaxi fleet in China.

SECTOR VALUATION

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

Yes. Currently, we do not think investors have assigned much value to internet companies' investments in robotaxis or autonomous driving in general. In fact, some are penalising companies for their spending so far. For instance, we do not include Apollo in Baidu's sum-of-the-parts valuation framework due to its limited financial contribution at this stage.

STOCK IMPACT

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

We believe Baidu is best positioned in China internet. Baidu is the frontrunner in autonomous driving in China with its open-sourced Apollo platform, large partner base and policy support. We saw significant development in 2018 in regard to both its technology and business model. We think Baidu can maintain its leadership with continued investments and expanding partnerships, and we expect 2019 to be the beginning of an inflection point, with autonomous vehicles running Apollo potentially increasing from ~100 in 2018 to thousands this year.

MOST FAVOURED

Stock	UBS rating	2020E PE	Comment
Baidu	Neutral	22x	We view Baidu as a local leader in China in autonomous driving technology, and it is launching robotaxis among other autonomous programmes in 2019. We believe the long-term financial implications related to this area are not priced in yet.

Jerry Liu, Analyst jerry.liu@ubs.com

Robotaxis-impact on sector … **Growth:** ↗ **Margins:** → **ROIC:** → **Valuation:** ↗

KEY PIVOTAL QUESTIONS

Q: What are the implications of the shift towards self-driving cars?

We believe the commercialization of AV technology presents a number of new opportunities for Yandex (the largest Russian internet company). We assume the following new revenue streams for the company: 1) robotaxis (fleet of c100 by YE19); 2) commercial cargo transportation (it remains uncertain whether the company will operate vehicles itself in a similar way to robotaxis or will partner with transportation companies in exchange for a revenue share); 3) in-car time monetization (through advertising and media consumption); and 4) selling licences to private car owners.

Q: Does the shift in the OEMs' business model represent an opportunity or a threat?

We think the shift represents an opportunity for the Russian internet sector. We also see an opportunity for partnerships between OEMs and the Russian internet companies (for example, the partnership signed by Yandex and Hyundai Mobis in March 2019).

FINANCIAL IMPACT

Q: What will be the financial impact on the industry?

On our estimates, the Russian robotaxi market size may reach cRUB190bn (c$4bn), or 11% of total ROD (including taxi and car-sharing) GMV in 2030E.

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from robotaxis?

Launched in 2017, Yandex's autonomous cars development programme has already achieved a number of milestones. Yandex is already testing its robotaxi service (with an engineer in a car so far) in Moscow and Innopolis (Republic of Tatarstan) and demonstrated the service in Las Vegas (CES 2019). Although there are a number of issues to address in the near future (including the insufficient detail of road maps, an absence of clear traffic regulation on autonomous cars, no proof from the state that the technology is safe enough to use), we think that a full-scale robotaxi rollout is likely to begin in 2022E.

SECTOR VALUATION

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

Yes, we expect a positive impact. We believe investors do not currently attribute any value to autonomous driving technology development in Russia.

STOCK IMPACT

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

Yandex is the only internet company in Russia which is working on autonomous driving technology, so we think it it is the most exposed to the shift to robotaxis. The current Yandex market price is not reflective of a potential robotaxi rollout, we think.

MOST FAVOURED

Stock	UBS rating	2020E PE	Comment
Yandex	Buy	16x	Yandex is the leader in Russia in autonomous cars development, we think. It began the programme in early 2017 and will be able to conduct first steps in commercializing self-driving cars in 2022E, in our view. The potential upside from autonomous cars has not yet been reflected in the current market price, in our view.

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Utilities

Robotaxis – impact on sector… **Growth:** ➡ **Margins:** ➡ **ROIC:** ➡ **Valuation:** ➡

PIVOTAL QUESTIONS

Q: Should we expect robotaxis to impact power consumption significantly?

The impact will be limited, in our view. With Manhattan currently consuming around 11GWh of electricity on a daily basis, robotaxis would increase demand by only ~0.6% by 2030E. Moreover, if we assume that the density of robotaxis across the rest of the country versus Manhattan will likely be lower, we believe robotaxis would have a limited impact in terms of power demand.

Q: Could robotaxis impact the daily curve for power companies?

Not in a meaningful way. In other words, we believe the charging needs from robotaxis would likely not impact peak demand. As opposed to household EVs (UBS Evidence Lab: How will the growth in EVs impact global utilities?), which could indeed increase peak demand, robotaxis are likely to charge during off-peak demand periods, thus slightly smoothing the daily load curve for individual utilities, and therefore without stressing the existing system or requiring further power production and network capacity. Even though the scenarios presented in this note assume that robotaxis would charge homogeneously during the day, the reality is that this could take a different pattern. As robotaxis would operate towards revenue maximisation, charging is likely to take place during off-peak hours. This coincides with off-peak times for power demand itself, thus with limited impact on peak demand.

Q: Could robotaxis impact the daily curve for power companies?

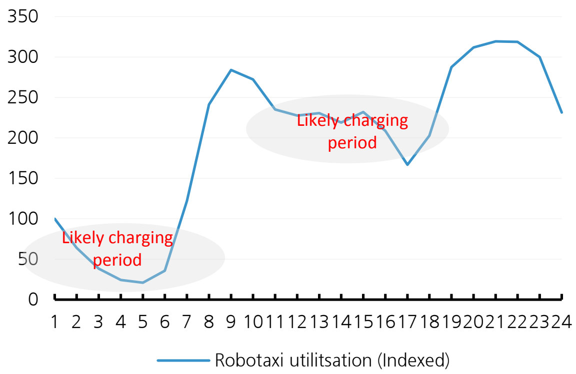
Difficult to forecast, but overall we believe the impact on networks' capex for the utilities would be equally limited. As we explain in this note, we forecast that the overall investment in the charging infrastructure, solely dedicated to robotaxis, in Manhattan, would hardly surpass the US$1.0bn mark (this being an extremely high level, in our view). If we assume that the same type of infrastructure is developed across 100 similar cities in the US (which would cover half of the US population), the overall total cost would stand at significantly less than US$100bn by 2030E. With total capex of US$60-80bn being spent annually by the US utilities across the power networks of the country, the robotaxi infrastructure would, in our view, hardly represent 10% of the total capex to be spent by these companies over the next 10 years.

FINANCIAL IMPACT

Q: What will be the financial impact on the industry?

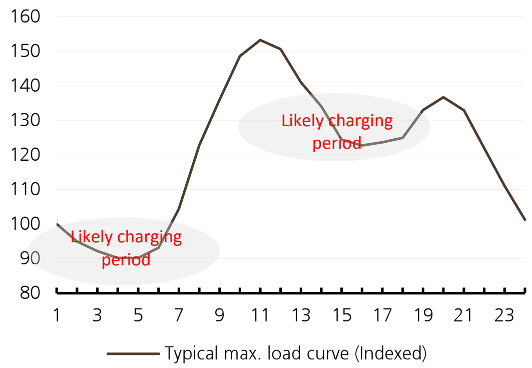
Positive, but rather limited.

Robotaxi potential utilisation curve over a typical 24-hour period: charging could be concentrated during off-peak periods…



Source: UBS estimates

…which would coincide with off-peak hours for power demand (example of a daily load curve during high-demand periods)



Source: UBS estimates

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from robotaxis?

As mentioned above, investments in infrastructure are required, but across the sector the impact would be rather limited, and therefore we do not expect the power infrastructure to be a potential bottleneck for roll-out of robotaxis.

SECTOR VALUATION

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

In our view, the impact would be limited.

STOCK IMPACT

Q: What stocks should be impacted most positively?

MOST FAVOURED

Stock	UBS rating	2020E PE	Comment
Enel	Buy	11x	Positively impacted by higher capex on power distribution networks, and slight power demand increase.
Iberdrola	Neutral	15x	Positively impacted by higher capex on power distribution networks, and slight power demand increase.

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Telecoms

Robotaxis-impact on sector … **Growth:** ↗ **Margins:** → **ROIC:** → **Valuation:** →

KEY PIVOTAL QUESTIONS

Q: What are the implications of the shift towards robotaxis?

The rising usage of Robotaxis and autonomous vehicles should increase demand for connectivity, which could open up new revenue opportunity for telcos. While it is not clear whether 5G is an essential prerequisite and how much of the data usage of a connected car (as much as 4TB/day as per Intel) will need real-time mobile networks, we do expect telcos to benefit from either a subscription or a data-usage based revenue model.

Q: Does the shift in the OEMs' business model represent an opportunity or a threat?

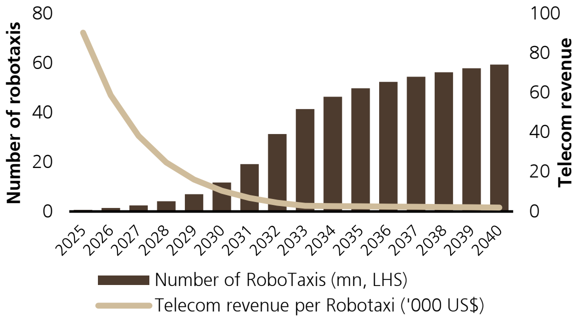
There is no immediate impact on telcos' connectivity-based business model from the changes in OEM business models around connected cars.

FINANCIAL IMPACT

Q: What will be the financial impact on the industry?

Using this simulation on robotaxis, we estimate a potential revenue opportunity of US$100-120bn for telcos by 2030, adding 7-9% to the sector revenue pool, which we estimate would reach US$1.6-1.7trn by that time. This is based on assumed annual revenue per car of cUS$10k in 2030, although declining rapidly to US$1,200-1,500 by 2040E, given declining unit cost of data and increased commoditization of access.

Commoditization of access in Telecoms



Source: UBS estimates

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from robotaxis?

No. Aside from the direct connectivity / access business, telcos have not been visibly involved in standard setting or collaborating with OEMs.

SECTOR VALUATION

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

Unlikely, as the revenue opportunity, while not immaterial, is not substantial and requirement for ubiquitous coverage may negate the revenue upside, with higher capex. As of now, we see limited reason for sector multiples to change unless telcos can sustainably build a subscription model, with access as one element of the service.

STOCK IMPACT

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

MOST FAVOURED

Stock	UBS rating	2020E PE	Comment
AT&T / Verizon/ China Mobile	Buy	9x/12x/ 11x	Upside to revenue growth as 5G use cases are monetized
AMT	Buy	20x AFFO	Sustainable carrier activity to support MSD organic growth for several years

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Batteries

Robotaxis – impact on sector… **Growth:** **Margins:** **ROIC:** **Valuation:**

PIVOTAL QUESTIONS

Q: What are the implications of the shift towards robotaxis?

The introduction of robotaxis should accelerate EV penetration as the running cost is about a third cheaper than for an ICE taxi fleet. This means total cost of ownership parity for robotaxis can be achieved in a number of markets.

Q: Does the shift in the OEMs' business model represent an opportunity or a threat?

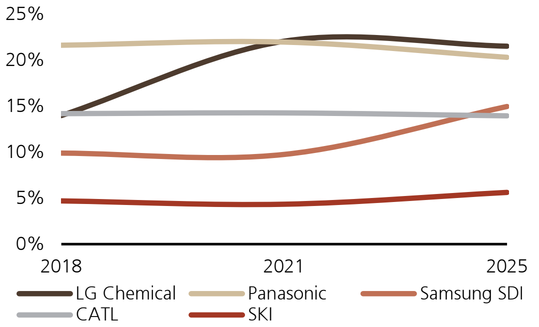
As robotaxis make on-demand riding safer and more economic and convenient, more consumers (particularly in urban areas) may forgo new car purchases.

FINANCIAL IMPACT

Q: What will be the financial impact on the industry?

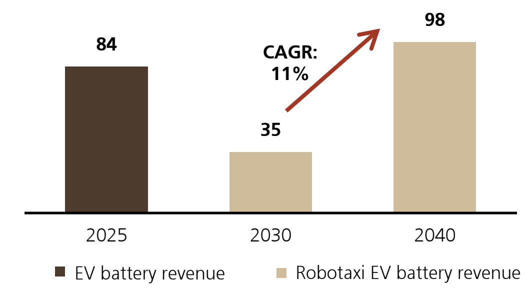
Initially, robotaxis should boost sales and earnings for EV battery makers. In the long term, robotaxis may cause margin dilution if standardised battery cells become an industry standard. If robotaxis drive commoditisation of EV batteries, this could have a negative long-term impact on industry profits.

Market share trend for top 5 EV battery makers



Source: UBS estimates

2025E passenger vehicle vs 2030-40E robotaxi EV battery revenue pool (US$bn)



Source: UBS estimates

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from robotaxis?

If robotaxis use a more or less identical battery pack compared to EV vehicles on a dedicated platform, the industry should be able to cope with upside to battery demand growth.

SECTOR VALUATION

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

The uncertainties around margins and potential commoditisation of EV batteries do not make a near-term re-rating likely. Additionally, visibility on battery technology is low beyond 2025. Visibility on the dominant cell format and chemistry is currently low.

STOCK IMPACT

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

MOST FAVOURED

Stock	UBS rating	2020E PE	Comment
LG Chem	Buy	10x	Top 3 EV battery maker
Samsung SDI	Buy	13x	Top 5 EV battery maker

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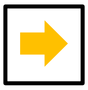
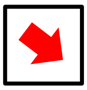
Chemicals

Robotaxis – impact on sector… **Growth:**  **Margins:**  **ROIC:**  **Valuation:** 

PIVOTAL QUESTIONS

Q: What are the implications of the shift towards robotaxis?

Automotive is one of the main end markets for the chemicals industry and production volume trends and technology shifts matter to a large number of companies under coverage. To the extent that robotaxis would accelerate the shift towards EVs, robotaxis may further accentuate the challenges in the long term for chemicals companies with exposure to the combustion engine power train while providing opportunities for EV pioneers and battery materials. For specialty polymers, a greater focus on interior design may create additional business opportunities in the medium term, although this would be offset by lower long-term new car sales. We have discussed the implications of EVs on the chemical industry here as well as in our Innovation Q-Series.

Q: Does the shift in the OEMs' business model represent an opportunity or a threat?

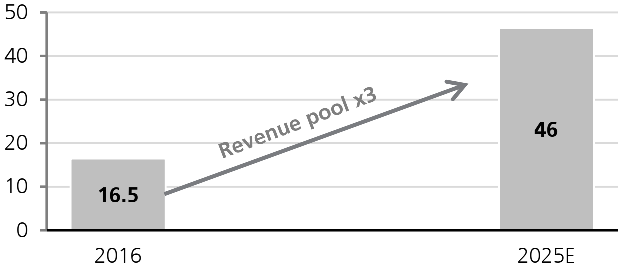
As robotaxis could support new car production in the medium term, this shift could prove a small positive overall for the next five years, but we would regard a drop in new car production in the longer term as a major threat for the broader chemicals space.

FINANCIAL IMPACT

Q: What will be the financial impact on the industry?

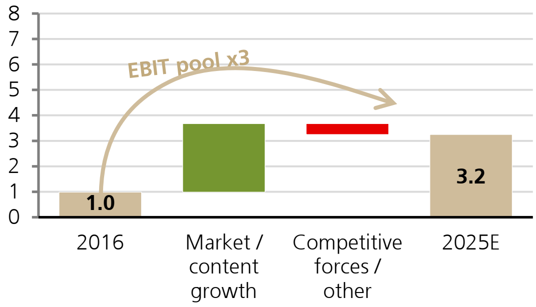
The impact should vary greatly, depending on the specific chemicals exposed and types of applications within automotive. We see the greatest risk of a negative impact with auto catalysts (Johnson Matthey, BASF, Umicore) where the shift towards EVs and ultimately lower volumes could lead to substantial revenue losses. We see upside in terms of content growth for adhesives and polymers in interior design applications for Sika, EMS-Chemie and Lanxess. Umicore would have the greatest leverage to battery materials growth related to EVs.

Revenue pool for EV (€bn): Beneficial for battery materials producers



Source: UBS estimates

EBIT pool (€bn): Opportunity at the cost of diesel and gasoline exposure



Source: UBS estimates

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from robotaxis?

Not sufficiently. While EVs have become a theme for all chemicals companies with auto exposure, the pace of penetration (1 in 3 by 2025E in Europe) remains non-consensual with, eg, Lanxess and EMS-Chemie assuming a slower adoption, which is contrary to the view that robotaxis could speed up the shift.

SECTOR VALUATION

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

While the valuation impact could prove material for a few names, such as Johnson Matthey (diesel exposure in autocatalysts) or EMS-Chemie (>60% automotive exposure), we think the sector as a whole is too diversified across products and verticals to witness a significant change in valuation. Supply dynamics (regulatory crackdown in China), energy and feedstock cost curves, and construction and consumer end markets are likely to be more topical in the debates than robotaxis for the foreseeable future.

STOCK IMPACT

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

As far as robotaxis would accelerate the migration to EV powertrains, this shift could impact a number of key stocks in our sector, both positively (Sika, Umicore) as well as negatively (BASF, EMS-Chemie, Johnson Matthey). Other companies that would be impacted include Clariant (through its refining exposure), Lanxess (polymers and through a rubber JV for tyres) and Covestro (polycarbonates).

MOST FAVOURED	Stock	UBS rating	2019E PE	Comment
	Umicore	Neutral	21x	Net beneficiary from leading position in cathode materials, outweighing diesel exposure in catalysts and risk of metal price volatility in recycling operations.
	LG Chemicals	Buy	12x	We expect LG Chemicals will have 22% of global battery capacity by 2025 and the business will grow almost 4x 2018-22.
	Asahi Kasei	Buy	10x	We assume an EBIT increase of ¥30-50bn for LIB separators by 2025 (2018 base).
	Toray	Buy	14x	We assume an EBIT increase of ¥30-50bn for LIB separators by 2025 (2018 base).
	Sika	Neutral	21x	Some 8% of group exposed to high-growth adhesives and sealants in EV market.
	Albemarle	Buy	13.1x	We estimate c30% of 2019 EBITDA is battery-grade lithium, and we model that growing to c60% by 2025, with batteries for EVs being the largest market by then.

LEAST FAVOURED	Stock	UBS rating	2019E PE	Comment
	Johnson Matthey	Sell	15x	The biggest net negative impact due to size of light-duty diesel (16% of EBIT) and currently modest position in battery materials.
	EMS-Chemie	Sell	26x	Over 60% of sales exposed to transport end markets, largely specialty polymers.
	BASF	Neutral	12x	We assume a loss of c€150m of EBIT in auto catalysts and PGMs by 2025 compared with 2017, but a growing franchise in battery materials (Toda JV and organic capex in Finland and other regions should provide significant capacity in time).

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Semiconductors

Robotaxis – impact on sector… **Growth:** **Margins:** **ROIC:** **Valuation:**

PIVOTAL QUESTIONS

Q: What are the implications of the shift towards robotaxis?

The shift towards robotaxis should be positive for the content growth of the semiconductor suppliers as it accelerates the two key content drivers. The trend towards EVs, we believe, will increase the drivetrain semiconductor content by US$550 compared with an ICE car, with the main beneficiaries being power semiconductor suppliers. An acceleration in the adoption of L4/5 autonomous features would boost the ADAS content opportunity, which we believe could drive a content uplift of a further >US$2,000 per car (depending on the architecture).

Q: Does the shift in the OEMs' business model represent an opportunity or a threat?

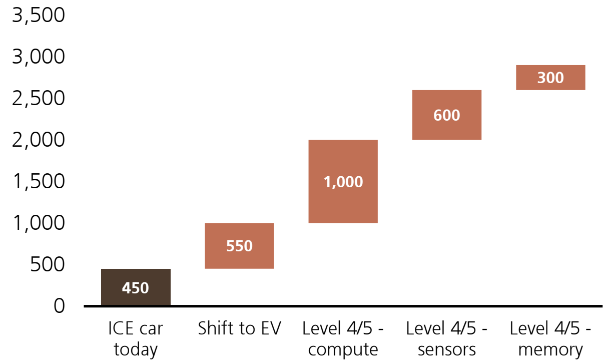
Opportunity. Positives: Supports the content growth acceleration we expect from EV/ADAS; greater use of infotainment/advertising could also drive up content; OEMs likely to increasingly work directly/closely with semi content suppliers. Negatives: 5-10% lower new car sales in the medium term could dampen growth.

FINANCIAL IMPACT

Q: What will be the financial impact on the industry?

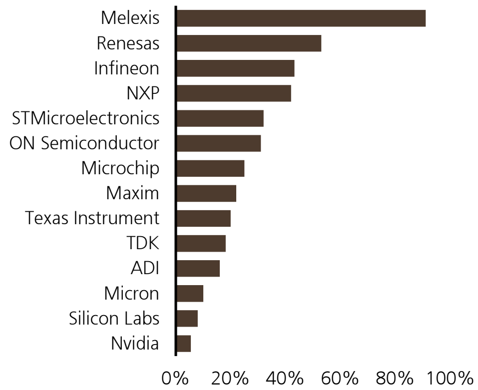
The content uplift in electric-autonomous cars for semiconductor suppliers is significant and, we believe, could be as much as 6-7x higher than the content in an ICE car today – significantly outweighing any reduced volume.

Semiconductor content steps to EV/autonomous cars (US$)



Source: UBS estimates

Autos exposure by semi company (% of sales)



Source: UBS estimates

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from robotaxis?

Yes, the industry is investing heavily today both in R&D and capex as semis are critical to make the trend happen.

SECTOR VALUATION

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

Yes, from current levels, a refocusing on the structural growth opportunities could drive up multiples, in our view.

STOCK IMPACT

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

Most stocks should be positively impacted by the trend – we highlight our preferred names below.

MOST FAVOURED

Stock	UBS rating	2020E PE	Comment
Infineon	Buy	17x	Greatest beneficiary of rising EV penetration.
NVIDIA	Buy	30x	Key supplier of compute content for autonomous.
TSMC	Buy	16x	Leading foundry – benefiting from rising logic compute content for ADAS.

LEAST FAVOURED	Stock	UBS rating	2020E PE	Comment
	Melexis	Neutral	23x	Not a beneficiary of shift to electrification and highly valued.
	Texas Instruments	Sell	21x	Growing in autos but not as geared as others to the shift to EV or autonomous driving at this point.

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Robotaxis – impact on sector… **Growth:** ➡ **Margins:** ➡ **ROIC:** ➡ **Valuation:** ➡

PIVOTAL QUESTIONS

Q: What are the implications of the shift towards robotaxis?

For the insurance sector, we would envisage a manageable impact from robotaxis. While traditional motor fleet premiums could fall, this is a small part of the market. In addition, there would likely be some offset from increased liability insurance.

Q: Does the shift in the OEMs' business model represent an opportunity or a threat?

Perhaps the OEM would retain the liability of the vehicle, meaning the OEM is responsible for insurance. This could lead to a shift away from retail insurance towards commercial insurance. This was one of the reasons why AXA bought XL Group in 2018; AXA believes commercial insurance will start to insure more of the risk pool in the future.

FINANCIAL IMPACT

Q: What will be the financial impact on the industry?

From an insurance perspective, the main question we would have on a rising penetration of robotaxis would be the impact this has on commercial insurance premiums. Taxis typically fall under motor fleet commercial insurance, which would have a property and liability component. As it stands, insurance premiums (ie, revenue) from taxi/executive car services represent a small component of overall commercial premiums globally.

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from robotaxis?

We expect a modest impact only, and the sector looks well positioned to absorb any impacts.

SECTOR VALUATION

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

No.

STOCK IMPACT

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

MOST FAVOURED

Stock	UBS rating	2020E PE	Comment
Zurich	Neutral	11x	Large commercial insurers would be well placed to pick up increased commercial premiums, albeit this is small for the sector overall.
AXA	Neutral	8x	Large commercial insurers would be well placed to pick up increased commercial premiums, albeit this is small for the sector overall.

LEAST FAVOURED

Stock	UBS rating	2020E PE	Comment
Hastings	Neutral	9x	Smaller specialist motor players would be less well placed if the OEM kept the liability, and premiums shifted away from retail to commercial.

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Car rental

Robotaxis – impact on sector… Growth: Margins: ROIC: Valuation:

PIVOTAL QUESTIONS

Q: What are the implications of the shift towards robotaxis?

Car rental companies will likely have to continue to reinvent their business model and expand further into new mobility services, such as ride hailing.

Q: Does the shift in the car rental business model represent an opportunity or a threat?

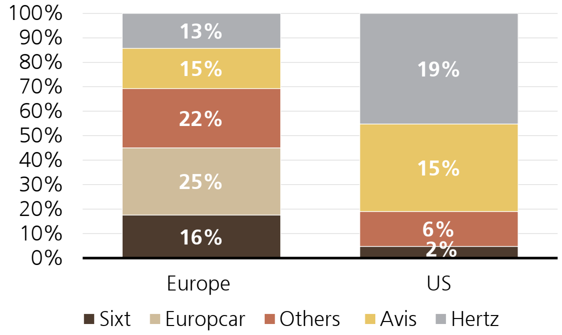
At this stage, it would still represent a threat, in our view, as the car rental industry is still at the beginning of adapting to this trend. If partnerships with robotaxi platforms are entered into or expanded, rental car companies could benefit from their expertise in fleet management and with their years' worth of customer data.

FINANCIAL IMPACT

Q: What will be the financial impact on the industry?

Negative for players only exposed to the traditional car rental business. Less negative for players that are already involved in shared mobility concepts and focus on further developing these. It clearly depends on how involved the car rental industry decides to get in the robotaxi shift.

Market shares of major car rental companies in the US and Europe



Source: Euromonitor, Sixt

Most car rental companies are involved in ride hailing and only few in robotaxi development

Car-rental	Partnerships / own platform	Comment
Avis	Lyft	Rents cars to Lyft drivers
	Waymo	Co-operates in testing self-driving cars
Europcar	Brunel	Acquired ride hailing platfrom Brunel
Enterprise	Rideshare and Zimride	Van pooling and online ride matching
	Voyage	Co-operates in testing self-driving cars
Hertz	Uber	Rents cars to Uber drivers
	Apple	Co-operates in testing self-driving cars
Sixt	myDriver (Sixt One)	Own ride hailing and own platform solution

Source: Company data, UBS

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from robotaxis?

No. The listed car rental companies (Sixt, Europcar, Avis and Hertz) all have developed partnerships with shared mobility platforms but are less exposed to the robotaxi trend. We do not think the car rental companies are taking the trend too seriously, and we are under the impression it could take another 5-10 years until the technology matures. Smaller more local players that only offer traditional car rental are even more at risk. In our view, the mindset still needs to change from 'renting a car' to offering 'mobility solutions'.

SECTOR VALUATION

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

If car rental companies remain late adopters, this could have a negative impact on valuation multiples. If the trend is adopted, this could translate into less cyclical revenue streams (higher share of private/leisure customers).

MOST FAVOURED

Stock	UBS rating	2020E PE	Comment
Sixt pref.	Buy	12x	Premium car rental company; recently launched its own integrated mobility platform, with the aim of no longer differentiating between car rental and car sharing.

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Robotaxis – impact on sector… Growth: → Margins: ↗ ROIC: ↗ Valuation: →

PIVOTAL QUESTIONS

Q: What are the implications of the shift towards robotaxis?

In the long run, wide-scale adoption of robotaxis could have a profound impact on the real estate sector, although the theme competes and interacts with a number of other mega-trends (urbanisation, other technological advances including e-commerce), making the ultimate impact difficult to predict. The two key findings from the UBS Evidence Lab-backed study that we consider for the real estate impact are: (1) the potential for a 67% reduction in taxi fleet; and (2) the potential 80%-plus reduction in fare costs.

At the margins, a reduction in car ownership stemming from the increased use of robotaxis, and the potential for a much smaller taxi fleet, is likely to impact demand for parking and petrol stations, impacting short-term cash flows, but freeing up land for alternate (and possibly higher-value) use. This includes parking lots around shopping malls and apartment buildings as well as standalone parking spaces and facilities.

More fundamentally, location desirability may shift if commuters and shoppers rethink their journey times, given our finding that average fares could fall by more than 80%. This could have a profound impact on land values, particularly given the conventional wisdom that real estate is about 'location, location, location'. Marchetti's constant holds that average commute times are 30 minutes one-way. If those 30 minutes can be spent productively (eg, being driven by a robotaxi in comfortable surroundings directly to your destination), it is conceivable that commuters will tolerate longer drive times. A recent Cushman & Wakefield survey on the subject suggested that 70% of respondents would use 'saved' commute time for work activities. The increased tolerance for longer commutes could contribute to suburban sprawl, and would run against the global current trend of urbanisation. It could lead to a flattening of real estate prices as the location premium of being close to a transport node diminishes.

However, if individuals do start to live further apart, the social need for community and in-person contact could strengthen. Thus, centralised offices, retail and leisure facilities may increase in importance and their location premiums could increase. Thus, we are sceptical on the prospect of a threat to central business districts (CBDs) from the rise of robotaxis. Indeed, a report by Deloitte noted that 'experts have underestimated the role of location before'. The report cites predictions from 15 years ago that, as the internet reduced the cost of communicating over distances, the importance of location would disappear. In the intervening period, the opposite has occurred. The report goes on to cite Glaeser's *The Triumph of the City* (2011), which concluded that 'the declining cost of connecting over long distances has only increased the returns to clustering close together'.

As an aside, it is interesting to note that the trend of urbanisation has seen car ownership decline, given the higher cost of parking and the growth in ride sharing. Thus, urbanisation is a driving factor in ride sharing and ultimately leading to the prospect of robotaxis, which may circle back to impact the urbanisation trend.

Q: Does the shift in the OEMs' business model represent an opportunity or a threat?

In general, we think wide-scale adoption of robotaxis and the associated material reduction in car ownership represents an opportunity for the real estate sector, although we can see some areas that are threatened. We discuss these opportunities and threats in the following paragraph.

FINANCIAL IMPACT

Q: What will be the financial impact on the industry?

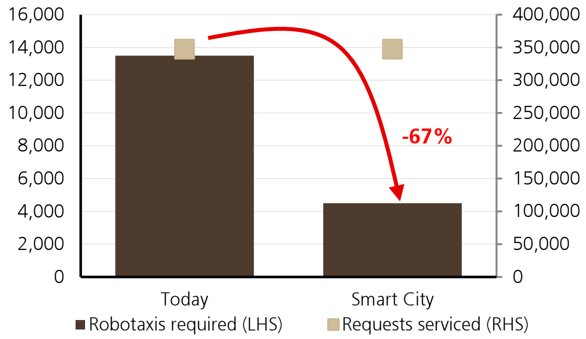
The opportunity lies in the potential for change to higher and better use, particularly for space currently used for car parking. Our study suggests the fleet of robotaxis could be just one-third of the current fleet, dramatically reducing the need for parking facilities, particularly in high-value locations.

Our literature review found estimates for total car parking spaces in the US ranging from 105m to 2bn[1]. The low end of this wide range covers just pay-for parking spaces, with on-street, commercial and home spaces making the balance. Assuming an average parking space size of 17 sq m, these estimates equate to 0.03-0.50% of the total surface area of the US. Of course, a narrow fraction of this space would be in consolidated structures (estimated range 6-15%). Thus, we think the potential for change of use is an opportunity for those real estate owners with material parking facilities, but we do not see a wave of supply arising from this change of use that could flood any of the major real estate markets and suppress values.

The opportunity may come as a welcome break for the embattled retail sector, albeit still some way in the future, with e-commerce to contend with in the meantime. Support from local planning authorities will be a prerequisite, but the theme may catalyse them to take a more flexible approach.

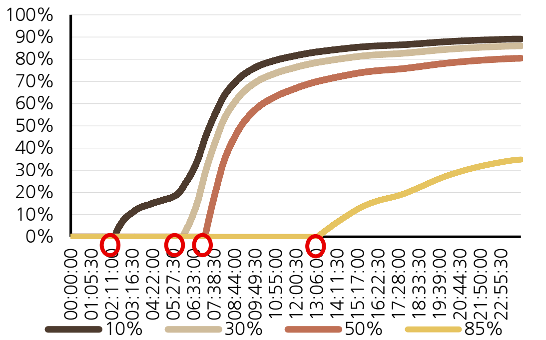
We see potential for a threat to the industrial/logistics sector, although somewhat minor, mitigated and a long way in the future. While robotaxis themselves pose a limited threat, autonomous trucks used to transport freight may have an impact on the location premium of some big-box distribution facilities, allowing the logistics providers more flexibility in their business model. The counter to this is that, typically, even big-box logistics locations are based on an optimization of cost and time-to-end-destination. As time is a critical factor, this suggests that there cannot be a wholesale move of big-box distribution to remote (i.e. low-value) land. Potentially high-value last-mile distribution facilities are threatened if the change of use of car parking facilities is to distribution facilities, creating excess supply in a market that is generally supply-constrained as of now. The broader and more current theme of e-commerce, driving demand for logistics, may supersede this threat, though, particularly if AVs lead to another leg up in the online penetration of retail sales (eg, driverless delivery vans). Demand for data centres is likely to rise, given the volume of data that will be generated by the AVs.

By how much could the (robo)-taxi fleet be reduced in a smart city?



Source: UBS estimates

Profitability margin sensitivity at different levels of price reduction



Source: UBS estimates

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from robotaxis?

Preparing, but not prepared. We are not aware of any companies materially altering their strategy for the specific disruption from robotaxis, but we do know a number are setting up broader working groups to focus on the various threats and opportunities arising from changes in technology. On balance, we think robotaxis present more of an opportunity than a risk for real estate, and time lines are quite long term, hence 'preparing' seems a sensible stage to us.

[1] Mikhail Chester *et al.*, 2010, *Environmental Research Letters*, 5 034001

SECTOR VALUATION

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

At the aggregate level, we think this possibility is remote. However, at the subsector level, we do see various opportunities and a few threats. Clearly, **alternate real estate** providers of car parking spaces are threatened in the short term, but the longer-term change-of-use potential could be lucrative, with any change to local planning laws arising from this theme a catalyst. **Retail**, particularly those assets with large-scale surface-level car parks may be a beneficiary, particularly if there is additional pressure on planning authorities to accept change-of-use proposals, accelerating a trend that is already occurring, given the structural pressures retail property is facing due to e-commerce. However, this may not be enough to offset the ongoing and strong e-commerce headwinds facing the retail real estate sector globally, and AVs (eg, driverless delivery vans) may exacerbate this issue, if they allowed last-mile delivery costs to fall. **Residential developers** may benefit from lower requirements for car parking, and therefore potential for higher site densities. **Industrial** (ie, logistics) is likely most threatened, but as discussed above, this is likely mitigated by a number of factors, and subordinate to other mega-trends (eg, e-commerce and the associated need for warehousing). **Data centres** may benefit from increased data storage requirements.

STOCK IMPACT

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

With c500 stocks in the main global listed real estate index and 2,000-plus listed real estate stocks globally, we think it is premature to pick stock-level winners and losers from this theme. Rather, we would look on a subsector basis, as discussed above and illustrated below.

Positively impacted

Subsector	UBS view	Comment
Retail	Cautious	Car parks could be replaced with higher-value uses. Planning authorities may relax rules in response. Unlikely this will be enough to stem the ongoing e-commerce issues, however.
Residential	Neutral	Potential for infill of existing car parking and lower/zero requirements on new development allowing higher densities.

Negatively impacted

Subsector	UBS view	Comment
Industrial	Positive	Driverless trucks (not robotaxis) may allow broader (and cheaper) location of logistics facilities. However, many mitigating factors.

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Robotaxis – impact on sector… **Growth:** **Margins:** **ROIC:** **Valuation:**

PIVOTAL QUESTIONS

Q: What are the implications of the shift towards robotaxis?

With a reduced number of cars on the road, we see an adverse impact on overall auto capex and automotive consumables spend, which accounts for about 10% of sector revenues. For instance, in terms of consumables, an EV could have up to 75% fewer moving parts and about 50-75% fewer bearings versus a traditional ICE vehicle. On the other hand, a shift to EVs would also imply incremental capex from factory upgrades, given the higher number of platforms and the grid upgrade implications from the proliferation of an EV charging infrastructure.

Q: Does the shift in the OEMs' business model represent an opportunity or a threat?

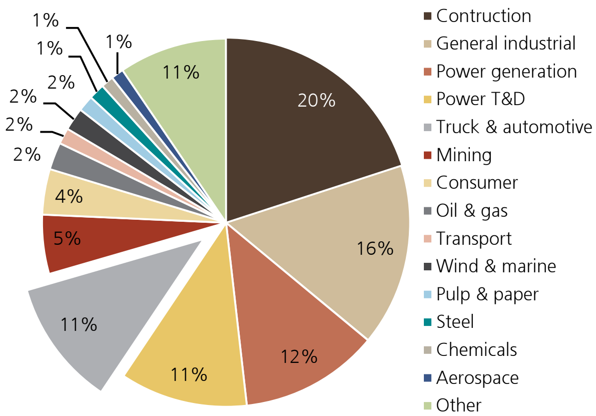
Both an opportunity and a threat. The shift to EVs would be an opportunity for automation companies, such as ABB and Siemens, over the next few years as they build out additional platforms. However, the 5-10% lower new car sales long term could dampen auto capex growth as well as consumables revenues, and thereby revenue growth for the capital goods companies, especially for the direct component suppliers, such as SKF and Sandvik.

FINANCIAL IMPACT

Q: What will be the financial impact on the industry?

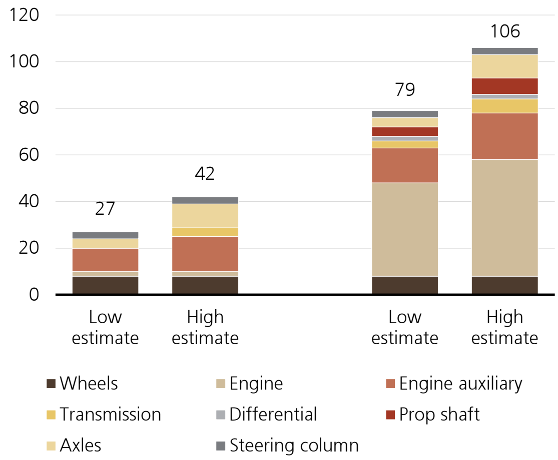
Given the breadth of our coverage, the impact would vary from company to company. With fewer cars, and these requiring up to 75% less bearings, we see a potential for over 10% impact on SKF's auto division earnings.

Auto sector forms c10% of sector revenues



Source: Company data, UBS

Bearings in a BEV (left-hand bars) vs an ICE car powertrain (right-hand bars)



Source: UBS analysis and estimates

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from robotaxis?

We see automation players prepared to serve incremental demand from any platform switches or incremental capex in the space (the product is there). Assuming that robotaxis will largely be electric and autonomous, this should support the penetration of EVs, which, in turn, has implications for the sector. For instance, German car OEMs are planning to upgrade existing lines and we estimate VW, BMW and Daimler to spend €30bn, €10bn and €8bn, respectively, over the next five years on EV, much of which will be on platform, plant and products. It has not been disclosed how much of this will go towards tooling, but we expect upgrades to existing lines. We believe the industry is ready for this transition and will give companies such as Siemens, ABB, Hexagon and Kuka the opportunity for holistic discussions around production set-up. We see Siemens as particularly well positioned, given its front-to-back offering from design software to motion control and factory automation. Component suppliers (such as SKF) would need to adapt their products, but we believe this is a core topic for management teams at the moment.

SECTOR VALUATION

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

Not materially. While the valuation impact could prove meaningful for a few names, such as SKF, we think the sector as a whole is too diversified across end markets to witness a significant change in valuation.

STOCK IMPACT

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

As far as robotaxis would accelerate the migration to EV powertrains, this shift could impact a number of key stocks in our sector, both positively (Siemens, ABB), as well as negatively (SKF, Sandvik).

MOST FAVOURED

Stock	UBS rating	2020E PE	Comment
Siemens	Buy	13x	Incremental auto capex good for Digital Factory (PLM, factory automation, motion control, an estimated c30% of sales driven by autos). Charging infrastructure positive for Energy Management; ePowertrain pick-up positive for 50/50 JV with Valeo.

LEAST FAVOURED

Stock	UBS rating	2020E PE	Comment
SKF	Sell	13x	Some 20% of SKF's automotive sales relates to drive-train components for cars and light trucks (largely cars). With lower volumes and those too EVs, about 5-10% of SKF's top line today would disappear.
Sandvik	Sell	14x	Decreased steel and parts content combined with the transition to the electric motor from the combustion engine should impact Sandvik Machining Solutions.

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Real estate brokers

Robotaxis – impact on sector… **Growth:** → **Margins:** → **ROIC:** → **Valuation:** →

PIVOTAL QUESTIONS

Q: What are the implications of the shift towards robotaxis?

Based on New York City filings, we estimate there could be an additional 13.5m sq ft that could shift from parking to commercial/residential realty, assuming the decline in spaces reflects a similar decline to the taxi fleet. For context, there is 401m sq ft of commercial real estate (CRE) alone in Manhattan south of Central Park, and 13.5m would equate to only a ~3% additional increase in available space. In 2018, the Manhattan market was able to absorb 10.4m in additional CRE that came to market, which leads us to believe that the dilutive impact to real estate values would be *de minimis*.

Q: Does the shift towards robotaxis represent an opportunity or a threat?

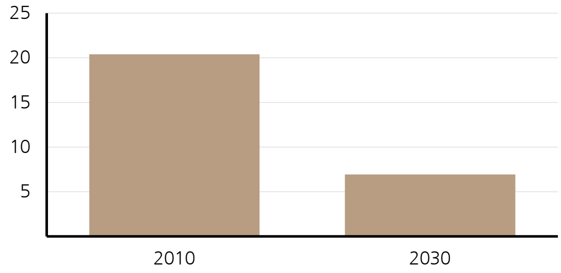
The shift towards robotaxis represents an opportunity for the industry, given that parking spaces are generally not as lucrative on a per sq ft basis as CRE. In fact, monthly parking in the targeted area can range from US$350 to US$550 per month, or US$1.75-2.75 a sq ft. This is in contrast to a blended US$78.83 rent per sq ft (per CWK's Q4 18 market report for CRE). We believe this dynamic is similar to other markets where parking is cheaper/free.

FINANCIAL IMPACT

Q: What will be the financial impact on the industry?

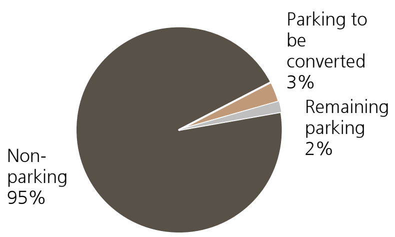
We estimate that a 3% increase in commercial inventory could increase possible CRE sales by US$1bn in NYC, which may be worth only US$10-11m in revenue. Therefore, it is not a meaningful driver of future opportunity.

Square feet (m) for public parking, NYC, 2010 vs 2030E



Source: UBS estimates

Share of NYC CRE used for parking, 2030E



Source: UBS estimates

SECTOR HEALTH CHECK

Q: Is the industry prepared for disruption from robotaxis?

Somewhat. CBRE in particular has written about disruption from autonomous driving and actively considers the impact when advising clients on how to best position their real estate portfolios.

SECTOR VALUATION

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

No, the impact from robotaxis would be *de minimis* to the overall addressable market for the US CRE brokers.

STOCK IMPACT

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

MOST FAVOURED

Stock	UBS rating	2020E PE	Comment
CWK	Buy	12x	One of the largest CRE brokers in the US, could likely capture some of these sales and/or facility services in the new space.

LEAST FAVOURED

Stock	UBS rating	2020E PE	Comment
CBRE	Neutral	14x	Largest CRE broker in the US, could likely capture some of these sales and/or facility services in the new space.
JLL	Neutral	14x	One of the largest CRE brokers in the US, could likely capture some of these sales and/or facility services in the new space.

Alex Kramm, CFA, Analyst alex.kramm@ubs.com **John Goode**, Associate Analyst john.goode@ubs.com

'Prices, valuations and ratings as at close of 22 May 2019.

How does the robotaxi simulation work?

In this section, we discuss in detail the methodology behind the robotaxi simulation discussed in this report. UBS Evidence Lab has developed a complex algorithm that performs dynamic optimal route generation and passenger-vehicle assignment considering vehicle capacity and rider demand.

We have built two scenarios into the simulation:

- **Scenario 1 – non-commuter,** with the goal of minimising the robotaxi fleet size; and
- **Scenario 2 – commuter,** with the goal of maximising the number of commuters carried, with a robotaxi fleet approximately equal in size to the current NYC taxi fleet.

Figure 112: UBS robotaxi scenarios

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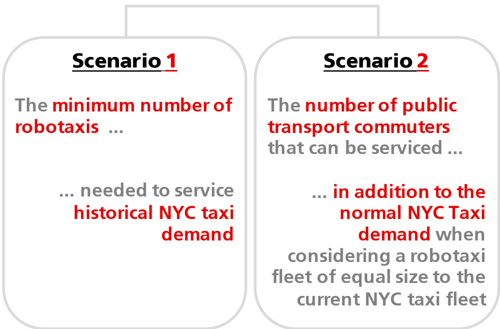


Source: UBS Evidence Lab

At this stage, the simulation assumes one passenger per vehicle. However, we believe the dispatching algorithm could be further improved to reflect pooling the use of the vehicle by several passengers, which should lead to even greater efficiencies.

Simulation software

The simulation is a real-time algorithm that responds to online taxi demand and availability. It was built in-house by UBS Evidence Lab using Python together with a suite of related open-source technologies. The simulation operates over a specific time-frame, at a provided time resolution. For the production runs, UBS Evidence Lab used a resolution of 15 seconds (i.e., 15 seconds is one epoch). The following steps are executed at each epoch:

Figure 113: How does the algorithm work?

1. **Collect passengers from pool** and combine with outstanding request
2. **Create subgraphs representing feasible taxi-trip** assignments and filter unfeasible
3. **Generate optimal routes and assignments using a mathematical model** that minimizes the sum of all trip delays
4. **Drive assigned taxis along optimal routes** within the 15 second time window
5. **Remove passengers from the pool** of outstanding requests whose maximum waiting time is sooner than the next epoch time
6. **Rebalance unassigned vehicles to unassigned passengers** using a mathematical model that minimizes the sum of travel times from rebalancing vehicles to unassigned passengers
7. **Drive rebalancing taxis along optimal routes** within the 15 second time window

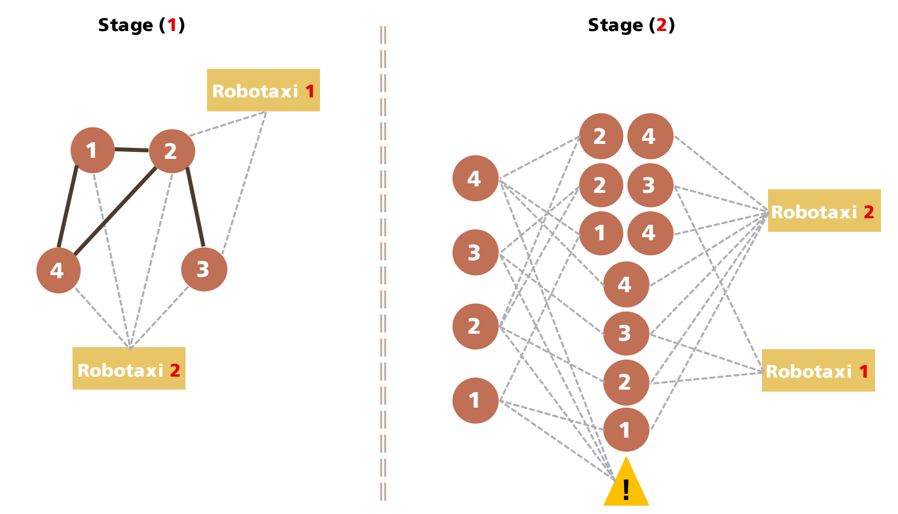
Source: UBS Evidence Lab

The simulation performs dynamic optimal route generation and passenger-vehicle assignment considering online vehicle capacity and rider demand. It does this using a multi-stage dispatching and rebalancing algorithm computed at every epoch.

Subgraph generation

The creation of feasible taxi-trip assignment subgraphs is an iterative algorithm, occurring in two stages. The first stage generates a subgraph of feasible vehicle-single-passenger-trips. The second stage uses this subgraph to iteratively build feasible trips of size N for each vehicle, using the edges of the first stage as the initial building blocks.

Figure 114: Two-stage taxi assignment generation



Source: MIT, UBS Evidence Lab

First stage (1) and second stage (2)

Filtering candidate assignments using these subgraphs is needed to reduce the number of variables put into the solver (below), which is by far the most acute computational bottleneck in the simulation.

Dispatching algorithm

For every taxi-trip assignment, an optimal route is generated. Each route has a "penalty" assigned to it, which is equal to the sum of travel delays for each passenger along that route. Travel delays include the time a passenger needs to wait for the taxi. Assignments are determined by minimizing a cost function global to the entire simulation, defined as the sum of travel delays, and the sum of penalties incurred by ignoring passengers.

Figure 115: Compute optimal assignments

$$C(S) := \sum_{i,j \in RV} c_{i,j}\epsilon_{i,j} + \sum_{k \in \{0,\ldots,n\}} c_{ko}X_k$$

Cost over all variables

Cost of assigning passenger *i* to vehicle *j*.
Equal to the travel delay: wait time + delay from possible rerouting

Binary activation variable, indicating assignment from passenger *i* to vehicle *j*

Cost of ignoring passenger *k*.
Large enough to incentivize pickups

Binary activation variable, indicating that request *k* is unassigned in this epoch

Source: MIT, UBS Evidence Lab

Note: Cost function for optimal assignments is based on high-capacity vehicle pooling and ride assignment

In the formula above, *i* and *j* are enumerated for all feasible trip-vehicle assignments. $c_{i,j}$ is the sum of delays for all passengers when trip *i* is completed by vehicle *j*. $e_{i,j}$ is a binary activation variable for trip *i* and vehicle *j*. It is 1 when the trip is assigned to the vehicle, and 0 otherwise. *k* enumerates all individual passengers. c_{ko} is the cost for ignoring passenger *k*, and X_k is a binary activation variable for ignoring request *k*. It is 1 when the passenger is ignored, and 0 otherwise. The function conforms to the constraint that assigned passengers within a trip must fit within the seat capacity of the corresponding taxi, throughout the execution of the optimal route. It also conforms to some obvious constraints (e.g., a passenger cannot be assigned within a trip and ignored at the same time).

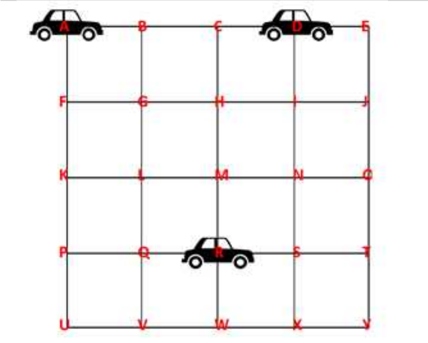
Rebalancing algorithm

After optimal assignments are generated, unassigned taxis are paired to outstanding requests by minimizing a cost function defined as the sum of travel times from unassigned taxi to outstanding request. The function conforms to the constraint that a taxi is assigned to at most one outstanding request, and an outstanding request receives at most one rebalancing taxi. The algorithm encourages taxis to quickly swarm and cover areas that were not addressed during the optimal assignment phase. It builds on the assumptions that: (1) taxis are likely to be dispatched to aging requests due to the cost function defined above; and (2) requests collocate: the locations of new requests are likely indicators of more to come.

How are trips simulated?

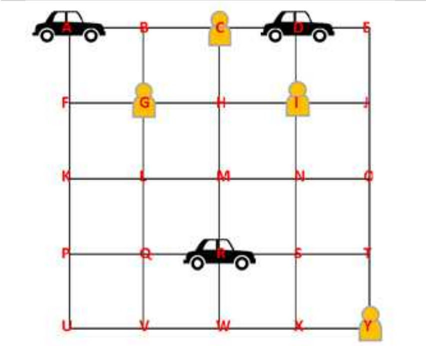
A trip is simply defined as a vehicle route that will pick up and drop off any group of pending requests or in-transit passengers. The trip must conform to an adequate number of passenger seats in the vehicle at each segment along the trip. Further, it must contain pick-up and drop-off times for each passenger which are valid for every passenger in the trip. Our simulation currently assumes one passenger. This in turn means that each passenger's wait and delay time tolerances are respected within the methodology. The following graphics represent one simulation cycle.

Figure 116: Vehicles at random nodes



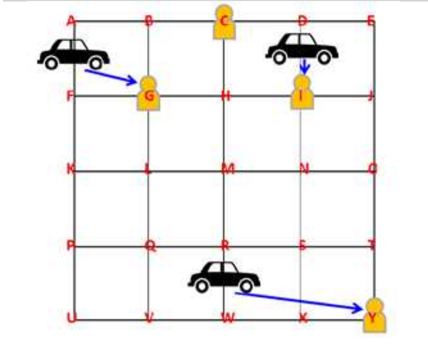
Source: UBS Evidence Lab

Figure 117: Add passengers



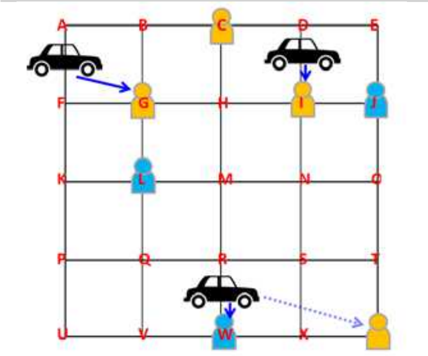
Source: UBS Evidence Lab

Figure 118: Drive vehicles



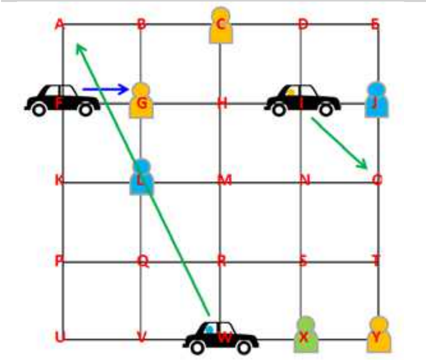
Source: UBS Evidence Lab

Figure 119: Add passengers



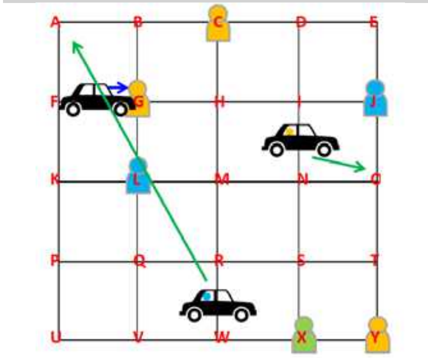
Source: UBS Evidence Lab

Figure 120: Drive vehicle



Source: UBS Evidence Lab

Figure 121: Add passengers



Source: UBS Evidence Lab

Vehicles

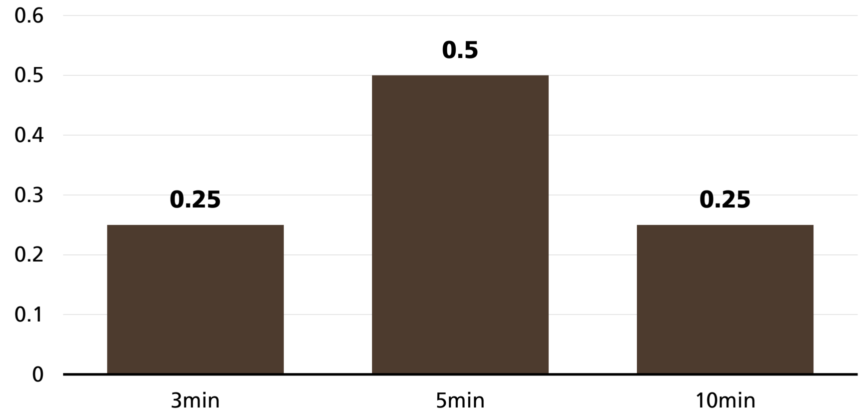
At the beginning of every simulation run, all vehicles are initialized at random nodes on the street network. The number of vehicles for each scenario is determined through calibration on a testing set of time windows, to minimise the number of vehicles needed to maintain a greater than 97% service rate. For **Scenario 1,** running only on TLC trip data, a total of 4,500 vehicles were used, which represents roughly 33% of the current NYC taxi fleet. For **Scenario 2,** running on both TLC trip data and 15% of commuters, the current NYC taxi fleet size of 13,500 vehicles was used.

Waiting time distribution

Passengers are represented by two cohorts: historical NYC Taxi trips provided by the NYC Taxi & Limousine Commission (TLC), which represent the existing taxi demand, as well as mocked-up commuters from home and commute locations provided by the US Census. The robotaxi fleet has the tolerance to operate within a maximum wait time and a maximum delay time. The maximum wait time is defined as the maximum time a passenger is willing to wait to get picked up by a taxi, which is determined by the below weighted distribution.

Within the analysis, we assume one passenger per robotaxi vehicle, with a maximum waiting time distribution of 3 minutes for 25% of the passengers, 5 minutes for 50% and 10 minutes for the last quarter. Moreover, we assume a maximum delay time per passenger excluding the waiting time of 10 minutes and base our analysis on the first Wednesdays and Saturdays of each quarter.

Figure 122: Sample distribution of maximum wait time from request to pick-up



Source: UBS Evidence Lab

The maximum delay time is defined as the additional delay time a passenger is willing to incur, after being picked up by a taxi, due to any rerouting a taxi might need to do in order to pick up or drop off another passenger in the vehicle. It is declared as a fixed value of 10 minutes for all passengers.

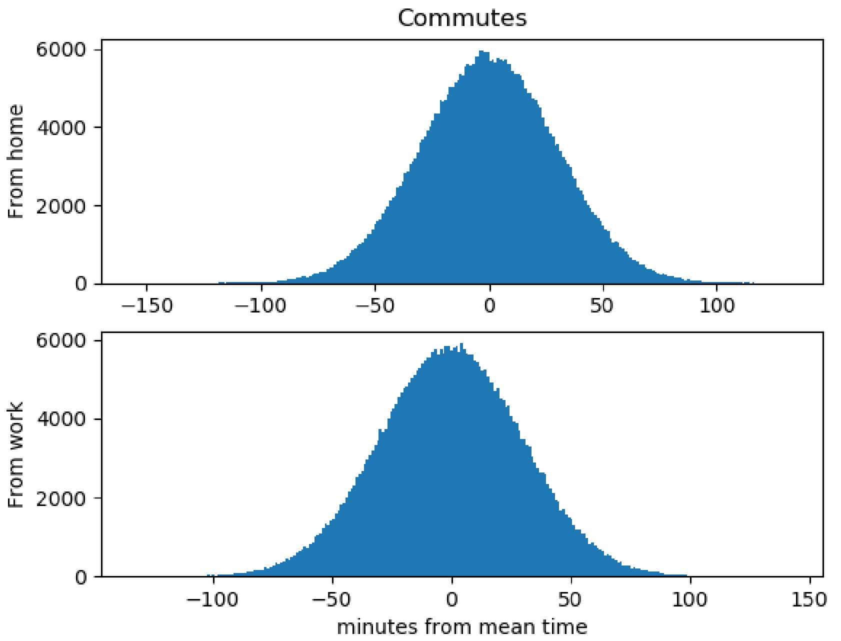
TLC taxi data

TLC trip records include fields capturing pick-up and drop-off dates and times (minute resolution), as well as pick-up and drop-off locations (6-digit latitude and longitude resolution). We take these trips unsampled within a given simulation's time window. Filtering is then performed to remove trips whose origin or destination falls outside of the street network. The request time for a TLC passenger is equal to the TLC-provided pick-up time.

Commuters

The US Census provides home and work locations at the census block resolution, e.g. every block has workplace blocks enumerated for every resident of that block. The origin of every commuter is determined by sampling from a normal distribution with a mean equal to the home Census block centroid, and a standard deviation equal to 100 metres (~one NYC city block). Destinations are generated in the same way, but using the enumerated workplace Census block centroids. The morning departure time of every commuter is determined by sampling from a normal distribution with a mean equal to 8.00am, and a standard deviation of 30 minutes. Work departure times are also determined by sampling from this distribution, but with a mean equal to 6.00pm. Here are example distributions generated by this method, representing one day of commuters within NYC.

Figure 123: Example distribution of commuters



Source: UBS Evidence Lab

From a full day worth of commuters, only a percentage are actually used in Scenario 2. This percentage is determined through calibration on a testing set of time windows in order to maximize the number of commuters that can be considered while maintaining a greater than 97% service rate using a fleet equal in size to the current NYC taxi fleet. The simulation has been able to cover 15% of the Manhattan commuters using the same number of taxis as of today.

Street network

The simulation operates on a street network covering Manhattan, from Central Park North to the Financial District. This network is composed of 3,241 nodes and 6,676 edges.

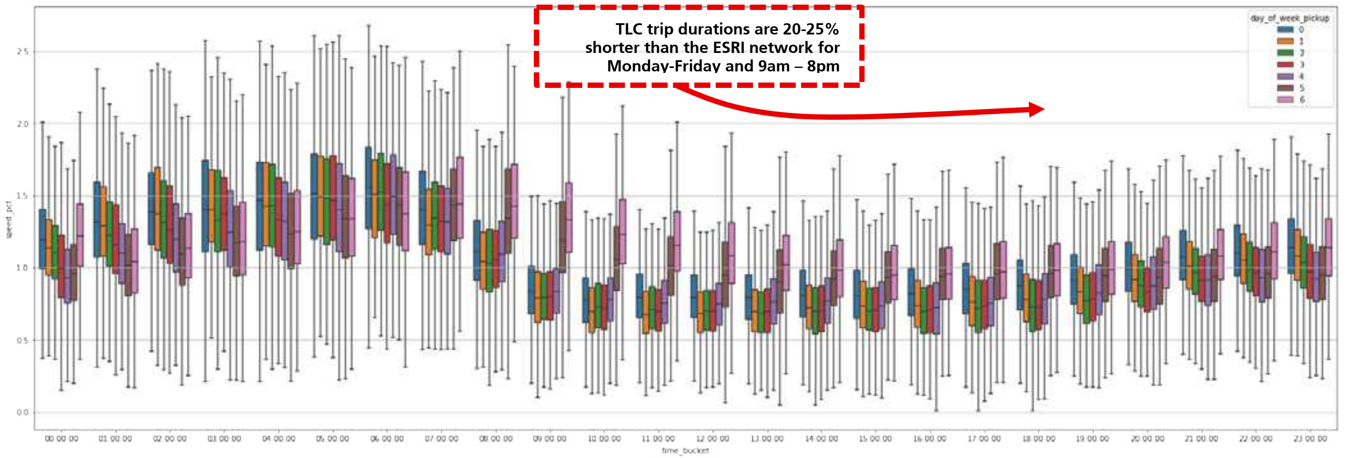
Figure 124: UBS Evidence lab simulation corridor in New York City

Source: UBS Evidence Lab

Drive times

In the first iteration, UBS Evidence Lab is using daily-average drive times for every street network edge, provided by ESRI. This is the same data used for every UBS Evidence Lab geospatial analysis that leverages drive-times. In reality, the drive-time of a given edge will change throughout the day, depending on traffic due to rush hour or other circumstances. To gauge the accuracy of this initial street network, 300k NYC taxi rides were sampled from the TLC dataset from the month of August 2015. For each sample trip UBS Evidence Lab computed $\frac{s_{TLC}}{s_{ESRI}}$, where s_{TLC} is the TLC reported trip mean speed (duration divided by distance), and s_{ESRI} is the trip mean speed calculated with the street network. These ratios were bucketed by day of week and time of day, and plotted as a box-plot time series. At a high level, reported TLC trip mean speeds are consistently 20-25% slower than the ESRI street network trip mean speeds for Monday-Friday and 9.00am-8.00pm. For 8.00pm to midnight they are comparable, and for midnight to 2.00am they are ~25% faster. Saturday and Sunday TLC trip mean speeds are more consistent with the ESRI network, but can be considerably faster depending on the time bucket.

Figure 125: Box-plot time series



Source: UBS Evidence Lab
Note: Day of week = 0 indicates Monday, 6 indicates Sunday

At a high level, reported TLC trip durations are consistently 20-25% shorter than the ESRI street network durations for Monday-Friday and 9.00am-8.00pm. For 8.00pm to midnight they are comparable, and for midnight to 2.00am they are ~25% longer. Saturday and Sunday TLC trips are more consistent with the [ESRI] network, but can be considerably faster depending on the time bucket.

Time windows

The simulation runs over a 24-hour shift from midnight to midnight. UBS Evidence Lab has conducted production runs for the following dates: 1 April 2015, 4 April 2015, 7 October 2015 and 10 October 2015. The year 2015 is chosen for the spatial resolution of trip data provided by TLC. In later years, TLC drops latitude and longitude resolution for pick-up and drop-off points, replacing them with general "zones" (about 1km radius on average). The Wednesday and Saturday runs are used for the scenario where UBS Evidence Lab leverages the minimum number of robotaxis to service existing NYC taxi demand. Only Wednesday dates are used for the commuter scenario.

Routing

Shortest path routing (Dijkstra) uses the average daily drive time along each edge. For a single-passenger trip, this is straightforward. For multi-passenger trips, every valid combination of pick-up and drop-off points is computed, and the route with the smallest sum of travel delays is chosen. Once routes are determined and optimal assignment is performed, vehicles are moved along the assigned route iteratively over the simulation according to the epoch resolution. For example, if the resolution is 15 seconds, then during a single epoch the model can only advance vehicles as far as they can travel in 15 seconds.

Robotaxi P&L

Revenue is tracked at the vehicle level for both commuters and historical taxi trips and is modelled based on the price strategy of UberX in New York City. Operating costs are determined for both gas and electric vehicles. We present our detailed cost assumptions in Figure 126 below.

Figure 126: Robotaxi simulation's underlying cost assumptions

		EV			ICE
Mileage of robotaxi fleet	**km**	**1,104,859**	**Mileage of robotaxi**	**km**	**1,104,859**
Number of robotaxis		**4,500**	**Number of robotaxi**		**4,500**
Number of km driven per robotaxi	**km**	**246**	**Number of km driven per robotaxi**	**km**	**246**
Simulation time	**hours**	**24**	**Simulation time**	**hours**	**24**
Charging			**Fuel consumption**		
Average battery size	kWh	60	Average fuel consumption	l/100km	6
Average range	km	500	Average cost of a liter	$/L	1.59
Power consumption	kWh/100km	12			
Number of charges		2,210			
Price per kWh	$	0.3			
Total charging price		45,304	Total fuel consumption		105,708
Fee charged by charging operator	%	10%	Surcharge to fuel operator		10%
Total charging costs	**$**	**49,834**	**Total fueling costs**	**$**	**116,279**
Maintenance			**Maintenance**		
Regular service, fluid change, repairs - per km	$/km	0.0155	Regular service, fluid change, repairs - per km	$/km	0.04
Regular service, fluid change, repairs - annual	$	17,115	Regular service, fluid change, repairs - annual	$	42,787
Tires	$/km	0.02	Tires	$/km	0.02
Tires annual	$	20,279	Tires annual	$	16,899
Daily cleaning	$/robotaxi	3.4	Daily cleaning	$/robotaxi	3.4
Annual cleaning	$	1,247	Annual cleaning	$	1,247
Maintenance costs	**$**	**52,770**	**Annual maintenance**	**$**	**75,062**
Other daily costs					
Vehicle registration	$/robotaxi	0.7534	Same as EV		
TLC and DMV vehicle inspection	$/robotaxi	0.3562			
DMV new plates	$/robotaxi	0.0137			
DMV vehicle license and plate renewal	$/robotaxi	1.0959			
DMV vehicle use tax	$/robotaxi	0.1096			
DMV commercial motor vehicle tax	$/robotaxi	1.0959			
Commercial insurance	$/robotaxi	13			
Total daily cost	**$/robotaxi**	**17**	**Total daily cost**	**$/robotaxi**	**17**
Total daily cost		**74,703**	**Total daily cost**		**74,703**
Total running costs	**$**	**177,307**	**Total running costs**	**$**	**266,045**
Depreciation					
Price per unit	$	40,000	**Same as EV**		
... in 2020	$	100,000			
... in 2025	$	58,500			
... in 2030	$	40,000			
Residual value (in % of original selling price)	%	10%			
Lifetime (in years)	Years	3			
Depreciation per year	$	12,000			
Depreciation per day	$	33			
Depreciation per hour	$	1.4			1.4
Depreciation per minute	$	0.02			
Depreciation per time of simulation	**$**	**147,945**	**Depreciation per time of simulation**	**$**	**147,945**
Total operating costs	**$**	**325,252**	**Total operating costs**	**$**	**413,990**

Source: UBS estimates

Sustainable Investing is an active approach to investment decision-making that takes relevant environmental, social and governance (ESG) issues into account. UBS's ESG research team believes that ESG issues are inevitably embedded in any firm's business model, and are therefore no different than the many other issues taken into consideration in investment research.

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UBS Evidence Lab has developed a real-time simulation to model the effectiveness of an autonomous vehicle NYC Taxi fleet, leveraging an integer program-based mathematical model. At every 15-second frame in the simulation, the algorithm performs dynamic optimal route generation and passenger-vehicle assignment considering online vehicle capacity and rider demand. Vehicles that are not assigned in a given frame are subsequently rebalanced according to the outstanding rider demand. The simulation covers two scenarios: first, the minimum number of autonomous vehicles needed to service historical NYC Taxi demand; and second, the number of public transport commuters that can be serviced in addition to the normal NYC Taxi demand when considering an autonomous fleet of size equal to the current NYC Taxi fleet. Metrics for each scenario are collected for every passenger and every vehicle, including seconds in vehicle, metres driven, revenue, and operating and maintenance costs.

The UBS Evidence Lab Visualization Framework visualizes / communicates the underlying data in the most attractive way by utilizing specialized techniques to create sophisticated maps, images, diagrams and animations. This report leverages the following UBS Evidence Lab assets: Autonomous Cars Visualization - Network Simulation.

Valuation Method and Risk Statement

The automobile sector has in the past exhibited high levels of volatility in terms of profitability and valuation. Sector earnings and performance are highly sensitive to variations in volume, pricing, raw material costs and currency, all of which have been volatile recently. Interest rates are also a key driver of sector earnings as they affect demand and mix as well as the earnings of the OEMs' financial services arms.

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Buy	FSR is > 6% above the MRA.	47%	25%
Neutral	FSR is between -6% and 6% of the MRA.	39%	22%
Sell	FSR is > 6% below the MRA.	14%	19%
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 2019.
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2:Percentage of companies within the 12-month rating category for which investment banking (IB) services were provided within the past 12 months.
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Company Name	Reuters	12-month rating	Short-term rating	Price	Price date
Albemarle Corp[13, 16b]	ALB.N	Buy	N/A	US$68.50	21 May 2019
Alphabet Inc.[6b, 7, 16b, 22, 26b]	GOOG.O	Buy	N/A	US$1,149.63	21 May 2019
American Tower Corporation[16b, 26c]	AMT.N	Buy	N/A	US$198.17	21 May 2019
Aptiv PLC[16b]	APTV.N	Neutral	N/A	US$72.38	21 May 2019
Asahi Kasei	3407.T	Buy	N/A	¥1,160.5	22 May 2019
AT&T Inc.[2, 4, 5, 6a, 7, 16b, 26a]	T.N	Buy	N/A	US$32.41	21 May 2019
AXA[7, 13]	AXAF.PA	Neutral	N/A	€22.58	21 May 2019
Baidu, Inc.[4, 6a, 16b]	BIDU.O	Neutral	N/A	US$118.14	22 May 2019
BASF SE[7, 14]	BASFn.DE	Neutral	N/A	€62.22	21 May 2019
CBRE Group Inc[7, 16b]	CBRE.N	Neutral	N/A	US$47.30	21 May 2019
China Mobile (HK) Ltd[16a, 16b]	0941.HK	Buy	N/A	HK$72.55	22 May 2019
Clariant[2, 3b, 4, 5, 6b, 6c, 7]	CLN.S	Neutral	N/A	CHF19.09	21 May 2019
Covestro AG[13]	1COV.DE	Neutral	N/A	€43.60	21 May 2019
Cushman & Wakefield plc[2, 4, 5, 16b]	CWK.N	Buy	N/A	US$18.37	21 May 2019
E.ON[7]	EONGn.DE	Neutral	N/A	€9.38	21 May 2019
Ems-Chemie[5]	EMSN.S	Sell	N/A	CHF606.50	21 May 2019
Enel[4, 7]	ENEI.MI	Buy	N/A	€5.77	21 May 2019
FCA[7, 13, 16b]	FCHA.MI	Neutral	N/A	€11.88	21 May 2019
Ford Motor Co.[7, 16b]	F.N	Buy	N/A	US$10.24	21 May 2019
General Motors Company[6b, 7, 16b]	GM.N	Buy	N/A	US$37.13	21 May 2019
Hastings Group[13]	HSTG.L	Neutral	N/A	189p	21 May 2019
Hella	HLE.DE	Buy	N/A	€44.08	21 May 2019
Iberdrola[2, 4, 7]	IBE.MC	Neutral	N/A	€8.16	21 May 2019
Infineon Technologies AG	IFXGn.DE	Buy	N/A	€17.28	21 May 2019
Johnson Matthey	JMAT.L	Sell	N/A	3,143p	21 May 2019
Jones Lang LaSalle Inc[16b]	JLL.N	Neutral	N/A	US$132.26	21 May 2019
Lanxess AG	LXSG.DE	Neutral	N/A	€49.45	21 May 2019
Leoni	LEOGn.DE	Sell	N/A	€14.18	21 May 2019
LG Chemical	051910.KS	Buy	N/A	Won332,000	22 May 2019
Lyft Inc[2, 4, 5, 6a, 16b]	LYFT.O	Buy	N/A	US$55.51	21 May 2019
Melexis NV	MLXS.BR	Neutral	N/A	€64.25	21 May 2019
Michelin[7, 13]	MICP.PA	Buy	N/A	€105.85	21 May 2019
NVIDIA Corp[16b, 22]	NVDA.O	Buy	N/A	US$155.06	21 May 2019
Pirelli	PIRC.MI	Buy	N/A	€5.58	21 May 2019
PSA Group[1, 2, 5]	PEUP.PA	Neutral	N/A	€21.29	21 May 2019
Samsung SDI	006400.KS	Buy	N/A	Won213,000	22 May 2019
Sandvik[4]	SAND.ST	Sell	N/A	SKr161.65	21 May 2019
Siemens[4, 5, 7, 22]	SIEGn.DE	Buy	N/A	€107.22	21 May 2019
Sika[2, 3a, 4, 5, 6b, 6c, 7]	SIKA.S	Neutral	N/A	CHF155.85	21 May 2019
Sixt SE	SIXG_p.DE	Buy	N/A	€65.20	21 May 2019
SKF B	SKFb.ST	Sell	N/A	SKr158.20	21 May 2019

Company Name	Reuters	12-month rating	Short-term rating	Price	Price date
Taiwan Semiconductor Manufacturing[16b]	2330.TW	Buy	N/A	NT$238.00	22 May 2019
Tesla, Inc.[13, 16b]	TSLA.O	Sell	N/A	US$205.08	21 May 2019
Texas Instruments Inc[16b, 26d]	TXN.O	Sell	N/A	US$107.00	21 May 2019
Toray	3402.T	Buy	N/A	¥738.7	22 May 2019
Umicore	UMI.BR	Neutral	N/A	€27.93	21 May 2019
Valeo[13]	VLOF.PA	Buy	N/A	€26.85	21 May 2019
Veoneer[16b]	VNE.N	Sell	N/A	US$18.51	21 May 2019
Verizon Communications[7, 16b]	VZ.N	Buy (UR)	N/A	US$59.50	21 May 2019
Volkswagen[7, 13]	VOWG_p.DE	Buy	N/A	€144.70	21 May 2019
Yandex N.V.[16b]	YNDX.O	Buy	N/A	US$37.42	21 May 2019
Zurich Insurance Group[2, 4, 5, 7, 13]	ZURN.S	Neutral	N/A	CHF327.90	21 May 2019

Source: UBS. All prices as of local market close.
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