AD PUNCTUM

Driverless On-Demand Mobility: Fact, Forecast And Fiction

It's cool that the possibility of widespread availability of driverless vehicles creating on-demand mobility services has caught the imagination over the past couple of years. Many exciting visions of the future have been shared and lots of amazing gadgetry has been demonstrated.

When it comes to what the future holds, two camps have emerged. On the one hand, there are the optimistic futurists who see robo-taxis for all by 2030 as a statistical certainty. On the other, the world-weary sages who say it will all be a lot later and develop in a far more boring way. Worryingly, this splits along party lines: the tech industry in the avant-garde corner whilst the car industry bides its time, muttering something about having seen it all before. Strangely there aren't that many people in the middle.

After researching the way people travel and the possibilities for on-demand mobility, it seemed appropriate to write a first principles analysis and provide more facts into the debate…

A presentation with an overview of the research is here

The full fat version is here -- it's 20,000+ words but we promise you'll learn from reading it

Firstly, beware of single point forecasts (the kind that say "for certain, by 2030 driverless cars will have X% of the market share"). These are scenarios. They are fine for headlines but dig into the detail and very little is concrete. It is more a case of *if*… driverless cars are good enough and *if*… regulators allow them free rein and *if*… people are happy to travel in them because there aren't any death-trap early experiences. No one knows exactly how this will develop or how fast. If they do, they are from the future. And if they came from the future would they really be writing about the automotive industry rather than relaxing on a beach with their lottery winnings (or maybe being Elon Musk)? This does not mean that any given forecast is certainly wrong. It means you should view them as the author's preferred scenario. It won't necessarily happen like that.

We've sorted the facts, forecast and fiction to help you develop your own scenarios.

Fact

- Using a driverless car as a taxi will become cheaper than owning a car
- You don't have to share a robo-taxi for it to be cheaper than a private car, you only have to share robo-taxis if you want it to be cheaper than public transport
- Widespread use of robo-taxis would mean far fewer cars were needed
- Robo-taxis will reduce road accidents and deaths by a massive amount
- The electronics are going to be cheaply available very soon
- Being cheap matters
- A driverless car is still a car
- Driverless car capability is already quite high
- There is a massive market out there
- Travel is going to grow, with or without on-demand mobility
- Some markets are underserved today

Forecast

- It isn't clear what the will customer think of autonomous vehicles
- We don't know how willing regulators will be to let the vehicles onto the roads in the first place
- How much regulators will let the free market rule remains an open question
- There isn't an agreed formula for how long it takes artificial intelligence to learn new roads
- We can't be sure how the legal framework will develop
- We don't know how much money is available to fund these new fleets
- It isn't clear how similar robo-taxis are to private vehicles
- We aren't sure if it matters whether or not the vehicles are electric
- We don't know how fast costs come down
- No one knows how quickly production capacity will increase
- It is unclear how much incremental travel autonomous vehicles will create
- Some say robo-taxis will clean up our streets, some that they will create nightmare traffic jams
- We don't know how much autonomy will impact freight delivery

Fiction

- Vertically integrated solutions won't last in the long term
- Operators will not get to become long term monopolies
- Long-distance commuting while sleeping in driverless cars will be niche
- Widespread use of flying cars? Come off it

There are a few certainties about driverless cars:

- **Using a driverless car as a taxi will become cheaper than owning a car.** Once the artificial intelligence gets sorted out, whether that is 2020, 2030 or 2040, driverless taxis will have a clear cost advantage. The reason is that we all leave our cars parked up in the sun, rain and snow for nearly 23 hours a day on average. Driverless cars can be in use 8 to 10 times more than that (that's about the limit unless we change our travel habits). The cost doesn't drop by a factor of 10 because much of it is mileage based but there is enough of a reduction that a taxi operator can cover the overhead of running a car service, make a profit and still charge you less than your car would cost to run.
- **You don't have to share a robo-taxi for it to be cheaper than a private car, you only have to share robo-taxis if you want it to be cheaper than public transport.** Some people are put off by the notion of "shared" mobility and having to rub shoulders with strangers, but that needn't be the case. If you want to travel on your own then you can do so. You'll pay more than people who share but less than owning your own car. People who share will pay less than public transport, get a door-to-door service and travel alongside fewer strangers than if they took the bus or metro.
- **Widespread use of robo-taxis would mean far fewer cars were needed.** Since this is about stating the facts, we must choose our words carefully. A system that uses the same vehicle to serve multiple customers throughout the day needs a smaller number of vehicles than there are at present, that is a fact. This is not a cast iron guarantee that new car production is reduced -- but it is certain that older vehicles (which outnumber new ones by more than 10:1) would no longer be required (apart from for posterity purposes of course). Whilst not guaranteed, it is very likely that new car production would decline. The only scenario in which it would not involves very low vehicle lifetimes and low utilisation rates.
- **Robo-taxis will reduce road accidents and deaths by a massive amount.** The forecast is a 90% reduction. Once you start looking at the technology, it's not hard to see why. The sensors can see a phenomenal amount, in all directions, over long distances. Looking at the track record of humans, things become even more clear. The UK Department for Transport collects road accident data about how the vehicle was travelling when the accident occurred. 50% of them take place whilst the driver is going in a straight line. That's right, we're worried about whether robots can drive yet half our accidents come when all we have to do is hold the wheel steady and not crash.
- **The electronics are going to be cheaply available very soon.** Although there are questions over how quickly the artificial intelligence (decision making part of the car) will mature, the sensors (the bits that see the surroundings) will be ready for 2020 and be relatively cheap (around $5,000 or possibly even less).
- **Being cheap matters.** There is plenty of academic research about how price sensitive people are when it comes to travel and the answer is: a lot. There is a big difference in the amount that the richest and poorest groups travel on the road (far flung holidays come on top of that), even in rich countries. Only the wealthiest 40% can afford to switch

simply based on luxury (a robotic chauffeur) and the value of time and effort saved. The rest will find it appealing in concept but wait until the price is right before hopping aboard.

- **A driverless car is still a car.** The artificial intelligence bit is super cool but it only covers a narrow range of activities -- it will drive and maybe try to monitor your facial expressions; changing the music and mood lighting accordingly. That's it. The rest of the experience is all traditional car. Is it quiet inside? Is the seat comfortable? Is the ride bumpy? Was that the door handle that just came off in my hand? Technology companies can't deliver a full turnkey solution without the help of car companies (which can be expanded to include Chinese manufacturers and others such as Magna). Car making is hard. Car making is so hard that there are only two surviving new western car makers in the last three decades -- Tesla and McLaren -- and neither of them have sold over 100,000 cars a year yet or managed to profitably produce a car that costs less than $80,000 (Model 3 fanboys take note: I said "yet"). Car making is so hard that even though Elon Musk has a company that worked out how to make rockets land on ships, he still frets about getting Model 3 dashboards bolted in efficiently. Please no Fix-It-Again-Tony puns… The fact is that Fiat can sell you a Panda that carries five people at highway speeds and protects them in a crash for the same price as a couple of high end televisions. If someone does a car where the driverless part is amazing but the car bit is rubbish, customers will quickly grow weary. These products must be well executed in every way -- the first driverless cars are ambassadors for a whole new mode of transport. Successful solutions will have deep involvement from a car maker.
- **Driverless car capability is already quite high.** Most miles are travelled on the easiest road types -- the kind of journeys that Tesla's Autopilot has already gingerly ventured into. Today, more than 60% of road travel is on major roads and highways. Driverless vehicles don't have to be capable of navigating streets filled with grannies chasing ducks in order to cover most of the journeys that humans take.
- **There is a massive market out there.** Humans travel trillions of miles each year on the roads. Even if robo-taxis didn't dominate but managed to get a market share measured in the tens of percentage points then it could be hugely lucrative -- and far bigger than the taxi business is today at about 1% of miles travelled.
- **Travel is going to grow, with or without on-demand mobility.** Although it isn't directly correlated with GDP growth, miles travelled on the road have grown over time and that trend is forecast to continue even with traditional car ownership. In 30 years' time, the market will probably be somewhere between 20% and 50% larger than today, regardless of the technological changes.
- **Some markets are underserved today.** Whether you look at the UK or the US, about 10% of the population have restricted mobility (across age groups). These people travel only half as much on average than everyone else (very few people are completely house-bound). There are very real use cases where cheap, driverless services can help individuals travel more and make a big difference to their lives.

Erm, that's it for the hard facts. **Notice how little that tells us about the timeline.** It is solid evidence of driverless mobility being amazing at some point, but not when we can expect it.

Here is what we don't know, and until we know it we won't know the timing and when we know it, it will be because it already happened:

- **What will the customer think?** Widespread usage of robo-taxi services requires two changes in customer behaviour. The first is to be okay with being driven around by a machine. The second is to be okay with subscribing to a service that provides a taxi whenever you need it instead of owning a car. We don't yet know how receptive people will be to either, certainly in the mainstream. Surveys at the moment say many are wary of driverless cars (but they haven't actually experienced them) and in the year 2000, 4% of Americans believed Elvis was still alive, so what does any of that tell us?
- **How willing will regulators be to let the vehicles onto the roads in the first place?** It will probably vary across the globe. Some will be encouraging, whilst others will be more conservative, perhaps even hostile. Currently, there isn't even widespread agreement to free running of test fleets -- despite the presence of "safety drivers" hovering over the steering wheel. Optimistic forecasts assume that the regulators are compelled by the safety and business case. That may or may not be true, as Saudi Arabia's ban on women driving and places where you can ride a motorcycle without a helmet attest. The counter argument? These are outliers. The counter-counter argument? These are outliers more than 100 years after the introduction of private cars. When cars were first allowed on the roads in Britain they famously had to be preceded by a man with a flag. Some regulators will take inspiration from that.
- **How much will regulators let the free market rule?** The implicit assumption by many today is that driverless mobility will be a no-holds-barred battle of technology and business nous. The victor will be bequeathed an unparalleled monopoly over travel. This vastly misjudges how most regulators -- and the governments that appoint them -- think and work. Driverless vehicles are a matter of safety and public transport. How many regulators will allow a situation where your chances of death are significantly higher if you use the RobGo service rather than RobDrive? Will they demand that transparent standards are set, followed and available to all for a nominal royalty payment or will they be comfortable with safety-critical technology being proprietary IP? Why would they allow travel monopolies to develop when the markets in energy, media and telecommunications are heavily policed for anti-competitive measures? Approaches will vary, and with them, growth rates. We simply don't know whether the biggest markets will have the best or worst conditions for growth. In case you doubt the capability of regulators to enact whimsical solutions, just remember that there are cities where you can only drive in on a given day if you have the correct digits on your registration plate.
- **How long does it take artificial intelligence to learn new roads?** There are two parts to this question: the first is how long it takes before the artificial intelligence thinks it knows the road, the second is how long it takes for regulators to trust it to use those roads. Elon Musk thinks six billion miles will be sufficient to convince regulators (Toyota think 8.8 billion, including simulation). If Musk is right, then that is less than 0.2% of road travel in the USA each year. It's high compared to the number of driverless cars on the roads at present but a figure that would be

quickly achieved with the right size of fleet in future. There's an implicit assumption in those statements that approval is a one-time event: will regulators then allow companies to decide for themselves that they are capable on a new road or will they want more oversight?

- **How will the legal framework develop?** The fear is this: robo-taxis inevitably crash, the victims sue the faceless corporation that operates them for negligence and win big, bankrupting them. The truth may be more complex. When the manufacturer is hauled before the courts, they will apologise for the outcome but point to the accident rate of their technology being one-tenth that of a human taxi driver. Lawyers will demand that their client be treated as if they are an exceptional driver who made a mistake rather than a wilfully negligent industrial behemoth. Judgements will be completely inconsistent across the globe. In some countries, lawmakers will develop frameworks that can be followed, others will rely on case law. The less coherent the legal conditions, the fewer robo-taxis on the road, but there will likely always be some prepared to test the "guilty but normally better at driving, Your Honour" argument. Even with a 90% better accident rate than humans, thousands may perish in robo-taxi crashes each year. Plenty of court appearances await.
- **How much money is there out there to fund these new fleets?** Our analysis is that a fleet of vehicles covering the needs of the US population would cost up to $2.5 trillion to build from scratch. Then there will be an on-going bill to renew the fleet. This means that to have rapid growth, one or more of the following conditions must be met: (1) Hundreds of billions of upfront funding to buy the fleets or; (2) massive customer demand, unchecked by the inevitable accidents, means that robo-taxis operators make massive profits before the inevitable price war or; (3) someone has created an upgrade kit that means conventional cars can be converted into driverless taxis quickly and cheaply and the initial fleet can be created from a motley crew of purpose built and re-purposed cars.
- **What type of vehicle will robo-taxis be?** Is it the same as the cars private consumers buy with a few extra parts bolted on to make it autonomous or is it purpose-built an industrial owner wanting to sweat the asset? Some say the former because it gives car makers more flexibility, some say the latter because it optimises the business case. There is a trade-off. If a retail-esque vehicle is used, then they will be wearing out after less than two years. That seems like a lot of money to send to the scrapheap. If they are purpose-built then they will have separate designs, components and assembly machinery (advances in manufacturing engineering and platform commonality notwithstanding).
- **The cars are probably electric but does that even matter?** Many researchers are coming to the same conclusion -- it makes sense for driverless vehicles operating a taxi service to be electric. It offers the following advantages: longer vehicle life; quieter and smoother customer experience and; regulatory blessing (look how clean I can make your city). What isn't so clear is whether this is a differentiating factor versus private cars.
- **How fast do costs come down?** Suppliers are already talking about a technology cost of around $5,000 in 2020. This means that the vehicle manufacturer will likely want to charge the end customer somewhere in the $7,500 to $10,000 range. But how quickly does the cost come down? Some forecast $1,000 by the late 2020s. The outcome will be heavily based on technology and volume development. Cost reductions probably don't make or break the business case. If a car lasts for 500,000 miles (as a New York taxi does today) then the difference between a $1,000 and $10,000 technology cost is under $0.02 per mile.
- **How quickly does production capacity increase?** If there is demand for driverless vehicles then production capacity will rise but that doesn't ensure production capacity rises in line with growth in demand from operators. Some forecasts assume driverless vehicles arrive in 2020, quickly prove their worth and then usage takes off. Whilst possible, this doesn't seem to be the industry's planning assumption. Although vehicles will be available around 2020, no manufacturer aside from Tesla is saying that these will be in mass production quantities. It takes manufacturers the best part of five years to bring a new product from a blank sheet of paper to production at scale. Ignore their PR teams telling you otherwise. Even if the initial test fleets show great promise for driverless mobility therefore, manufacturers may struggle to deliver volume before mid-decade.
- **Will there be an explosion in travel as road movement becomes cheaper and more relaxing?** The advent of on-demand driverless transport will mean big gains for the individuals with restricted mobility (see facts), but at a population level, the effect is less significant -- probably around 5% growth in total travel. Explosive growth of new markets (some talk of 40%+ increases in miles travelled) requires a fundamental change in behaviour. Quite possibly those forecasting huge growth will end up being right for the wrong reasons: organic transport growth will mean a rise in miles travelled that would have happened even if we were still using "dumb" cars.

- **Will robo-taxis clean up our streets or create nightmare traffic jams?** There seem to be two opposite opinions here. The first is that with fewer cars, which are on the move more of the time, there will be less need for parking (true) and that space will given over to the public and filled with (developers may have other ideas). The second is that autonomous cars will cause an explosion of miles travelled, resulting in a gridlocked hellscape beyond our worst fears (Malthus would applaud but given how much travel has increased in the last century, it seems that cities and humans can cope).
- **How will autonomy impact freight delivery?** Presently, about 50% of freight volume travels on the road (as opposed to rail and pipeline). Removing the driver of a heavy goods vehicle will yield savings, but at a $/tonne level (it will be cents per package). Removing the driver of local delivery vehicles would have a more significant impact on the customer's wallet. This is dependent on new solutions for getting the package safely into the home without a delivery person involved.

Each of the points above have variability which would prove positive or negative for robo-taxi growth. Divining a single timeline is a challenge. Steady growth is about various forces (operators, customers, regulators, investors and manufacturers) finding a favourable equilibrium -- likely to be easier in some locations than others.

Here is what we won't see -- or if we do it's because on-demand mobility becomes a business that defies known laws of commerce in new and special ways.

- **Vertically integrated solutions won't last in the long term.** Almost everyone seems to be planning on doing everything (except perhaps for Google, Lyft and FCA). The vertically integrated narrative is this: Companies will design and manufacture driverless vehicles. They will sell them to a subsidiary that owns and operates a fleet for rental on a per-ride basis. This fleet subsidiary will be twinned with a wholly-owned customer transport business that will take care of all travel needs, using the fleet vehicles to conduct all travel except long-distance journeys (which might involve air travel or high speed rail). Whilst the mobility business is immature, companies might find themselves trying to offer a complete service to fully stimulate demand but if they continue operating this way as the market nears maturity then they will find themselves operating far more broadly than other industries. It would be like the same company making an aeroplane, having an airline and running a travel agent. Corporations that can do this will be the best companies in the world; they will have mastered the challenge of running a conglomerate. The list of possibilities is endless: where will they go next: ice cream or diamonds? The business reality will be far different, and for good reason: Google knows artificial intelligence but not much about complex mechanical machinery and high volume production; GM knows about designing and building cars but doesn't have much experience of e-commerce and customer-facing services; Uber knows about linking customers with taxis and taking payment but it doesn't know the nitty-gritty of owning, servicing and cleaning thousands of vehicles per day. Companies that try to do it all will lose out to well-balanced partnerships.
- **Operators will not get to become long term monopolies.** If they do manage then they will have succeeded where mobile phone operators, media companies, airlines and hosts of others have failed. Any monopolies won't last long. The assumption of monopoly potential is based dominance of Google and Facebook in their respective markets but this ignores that those segments operate in conditions which make it hard for regulators to judge what is in the consumer's best interest: the service is free at point of use. If someone has this model for operating robo-taxis, we are yet to see it. If, as we suspect, they intend to charge money and make a profit then expect competition authorities to come after monopolistic activities. They have plenty of tools at their disposal, ranging from crude break-ups to licencing granted via auction in traches where any single bidder can only win a fraction of the total amount.
- **Long-distance commuting while sleeping in driverless cars will be niche.** Some dream of a non-stop world where we virtually live in vehicles always on the move. Multi-millionaires provide a clear counterpoint though: they could choose to do this now, a customised van with driver wouldn't set them back very much ($350,000 for something with an interior befitting a corporate jet) and yet few of them do so. For centuries, humans have commuted for about an hour a day. A trend that has seen off the train, coach and car is likely to have the measure of robo-taxis too.

- **Widespread use of flying cars? Come off it.** There are plenty of obstacles that driverless cars must overcome (not least of which is price) and yet technological and logistical issues surrounding quadcopters-for-all can be resolved in a short time frame? Wake us up once air traffic control has been automated and can handle exponential increases in traffic.

The End Result

It will be exciting, lots of money will be lost, lots of money might be made. People who got lucky will, after the event, say that they had it figured out all along. Whenever you see an apparently definitive forecast, tell yourself that it's a best-guess and ask yourself how it might be affected by the variables listed here. If you want to tear our points to shreds then please read the comprehensive report first. Reading the detail will help you prepare an even more compelling counter-argument!