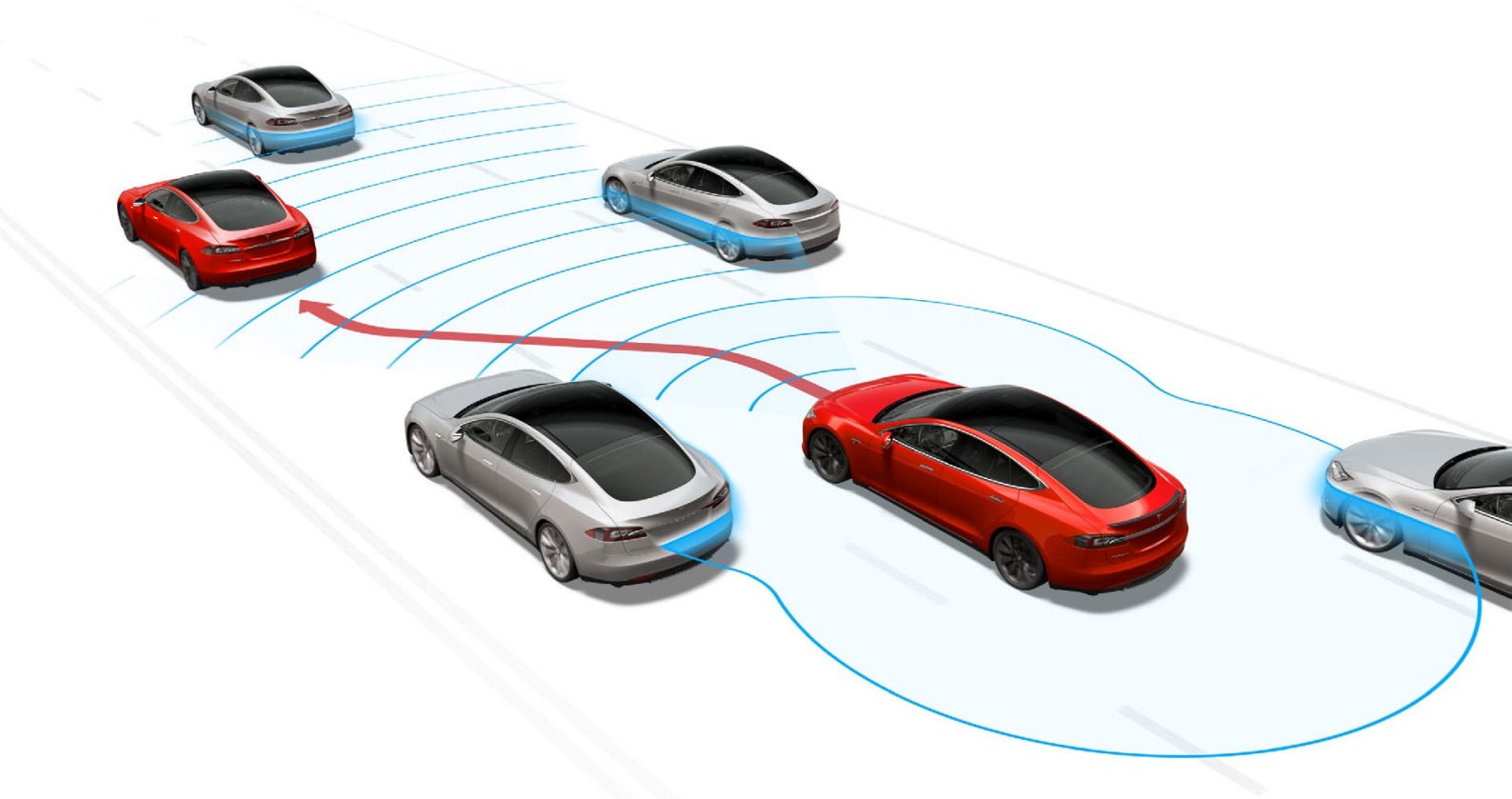
The Economist Intelligence Unit



A whitepaper from The Economist Intelligence Unit

Driving to the future

The development of connected cars

www.eiu.com

The Economist Intelligence Unit

The world leader in global business intelligence

The Economist Intelligence Unit (The EIU) is the research and analysis division of The Economist Group, the sister company to The Economist newspaper. Created in 1946, we have 70 years' experience in helping businesses, financial firms and governments to understand how the world is changing and how that creates opportunities to be seized and risks to be managed.

Given that many of the issues facing the world have an international (if not global) dimension, The EIU is ideally positioned to be commentator, interpreter and forecaster on the phenomenon of globalisation as it gathers pace and impact.

EIU subscription services

The world's leading organisations rely on our subscription service for its data, analysis and forecasts to keep them informed about what is happening around the world. We specialise in:

- **Country Analysis:** Access to regular, detailed country-specific economic and political forecasts, as well as assessments of the business and regulatory environments in different markets.
- **Risk Analysis:** Our risk services identify actual and potential threats around the world and help our clients understand the implications for their organisations.
- **Industry Analysis:** Five year forecasts, analysis of key themes and news analysis for six key industries in 60 major economies. These forecasts are based on the latest data and in-depth analysis industry trends.

EIU Consulting

EIU Consulting is a bespoke service designed to provide solutions specific to our customers' needs. We specialise in these key sectors:

- **Consumer Markets:** Providing data-driven solutions for consumer-facing industries, we and our management consulting firm, EIU Canback, help clients to enter new markets and be successful in current markets.
- **Healthcare:** Together with our two specialised consultancies, Bazian and Clearstate, The EIU helps healthcare organisations build and maintain successful and sustainable businesses across the healthcare ecosystem.
- **Public Policy:** Trusted by the sector's most influential stakeholders, our global public policy practice provides evidence-based research for policy-makers and stakeholders seeking clear and measurable outcomes.

The Economist Corporate Network

The Economist Corporate Network (ECN) is The Economist Group's advisory service for organisational leaders seeking to better understand the economic and business environments of global markets. Delivering independent, thought-provoking content, ECN provides clients with the knowledge, insight, and interaction that support better-informed strategies and decisions.

The Network is part of The Economist Intelligence Unit and is led by experts with in-depth understanding of the geographies and markets they oversee. The Network's membership-based operations cover Asia-Pacific, the Middle East, and Africa. Through a distinctive blend of interactive conferences, specially designed events, C-suite discussions, member briefings, and high-calibre research, The Economist Corporate Network delivers a range of macro (global, regional, national, and territorial) as well as industry-focused analysis on prevailing conditions and forecast trends.

Contents

Introduction

The term "connected car" conjures up images of futuristic self-driving vehicles, buzzing around towns and cities without the need for human control. Yet the concept of connectedness in cars is far from new. Basic in-car connectedness has been a part of auto technology for more than five years, introduced via in-car entertainment and mapping systems in around 2010. Since then, however, cars have started to absorb ever-greater levels of technology.

The modern car is not only a feat of engineering, it is also a mobile supercomputer. Hidden beneath the steel or aluminium body is the computing power of 20 personal computers, dealing with around 100m lines of code and holding more processing power than any of NASA's early spacecraft, including the original Apollo lunar module.

A truly connected car, in the modern sense, still gives drivers the ability to connect to music applications and use global positioning system (GPS) equipment. In addition, however, it is also slowly beginning to reflect the internal ecosystem of the car, using connectivity to provide users with feedback on the car's performance, monitoring of the car's components and mechanisms to ensure the comfort and convenience of a passenger's journey. In future, these same systems could be used for future applications, including self-driving, car-sharing or communicating with the internet of things (for example, in connected homes).

It has taken some time for automakers to realise the potential of connected cars, and to devote time and resources to exploring the applications of such a technology. Yet the world of connected cars is moving fast, putting carmakers in a difficult position. Traditionally the auto industry relies on months, if not years, of research and development (R&D), leading to new car models that then require investment in complex and expensive manufacturing plants and machinery to launch onto the market. The sunk start-up costs are high, as is the cost of failure. So car companies carry out exhaustive testing when it comes to issues such as safety, driveability and fuel economy, while also taking the time to ensure a car has the kind of marketability needed to appeal to consumers.

The technology sector, on the other hand, develops and evolves at a far faster pace, with innovation driven by far lower costs and less sunk capital. With a short time to market and far less safety testing, the tech sector is able to innovate in a much more flexible and dynamic way, and without much fear. This allows for a far quicker response to changes in consumer demand, and a far easier process of trial and error with new launches. Given its lack of experience in this field, one of the auto industry's biggest fears is being unaware of consumers' preferences and how to go about meeting their needs.

The divergent nature of these two industries therefore makes them somewhat uncomfortable bedfellows when it comes to establishing a means of collaboration and partnership in the connected car field. Where do auto manufacturers and their suppliers invest their R&D spending, and how do they ensure that they keep the benefits of their innovation? Do they rely on collaboration with technology partners, or try to develop their own? In short, to what extent do they abandon the old ways and embrace the new? And while they are deliberating, are they in danger of being overtaken by technology companies such as Google, which are moving in the opposite direction, into auto?

This report will go some way to answering those questions, which will determine how investment in connected cars progresses in future. First, we will describe both current and future uses of connectedness in the auto sector, in order to identify what a fully connected car would look like. We will then analyse how companies are tackling the connected car space, looking not just at traditional auto and technology companies, but also industry "disruptors", such as Uber and Lyft, which are slowly changing the nature of urban mobility. Finally, the report will determine what kind of infrastructure and support is needed to make all these innovations a reality, bringing fully connected cars to the market.

The uses of "connectedness"

At its most basic level, a connected car is simply a vehicle that has internet access. In most current models, consumers encounter this through a dashboard-mounted screen that controls a vast array of functions, from onboard audio and video, GPS mapping technology and web access, to the monitoring of car diagnostics, such as tyre pressure, oil level and wiper blade efficiency.

One aspect of this is the vehicle's information and entertainment (or "infotainment") system. Google and Apple (both of the US) are the biggest suppliers of infotainment connectivity, with Android Auto and Apple CarPlay allowing drivers to connect their smartphones to their car's entertainment system. At present, this is used mainly for music, phone calls and mapping, but this system could expand to movies, games and other online offerings in the near future, at least for non-drivers.

As for the diagnostics side, by incorporating this into an internet-enabled system, the data can be streamed back to the manufacturer's service department, which can tell drivers when their car needs a service or replacement parts. This is particularly useful in the commercial vehicle industry, which also uses connected technology to improve logistics. Meanwhile some manufacturers also use diagnostics to provide roadside assistance or anti-theft applications, as pioneered by General Motors (GM) with the introduction of its OnStar system in 1996.

Since 2009, GM has been equipping many of its vehicles with remote ignition blocks, which stop the engine from starting, or stolen vehicle slowdown capability, which sends a signal that prevents the vehicle from travelling at high speeds. The latest GM models with OnStar technology also provide crash response services, in which sensors detect impact and connect with an advisor to evaluate the extent of a driver's injuries, while a red emergency button can alert the emergency services if assistance is needed.

Another use of diagnostics data is to monitor driver performance, including

the steering, braking, throttle control and speed, via telematics and black-box recording technology. This information can then be relayed to insurers so they can tailor their insurance premiums accordingly. According to Ptolemus, a geo-connected mobility consultancy, the telematics-based (or "usage-based") insurance market had around 12m drivers on its books worldwide in 2015. The company estimates this will rise to 93m by 2020, and that by 2030 around one-half of the world's vehicles will be insured under a telematics policy.

Currently, the three biggest markets for the telematics insurance industry are the US, Italy and the UK, in order of take-up. The speed at which the technology costs fall will be a factor in how fast the market develops, as will the effect on premiums and insurers' profitability. Reticence on the part of drivers to be monitored will also play a role. Those who allow themselves to be monitored, and whose data show that they are a careful driver, can get a big discount on their insurance premium, but not many will want to see their habits placed under such close scrutiny. The advantages of being able to use real-time telematics with connected-car technology will not only help insurance companies develop more tailored premiums, but coupled with contextual information such as weather and road conditions, this can also be a vital tool in analysing road-traffic accidents and establishing fault.

It is not just insurance companies that are likely to show an interest in the powerful data created by a connected vehicle. With connected cars capable of shedding light on all kinds of driver habits, the potential for cross-marketing is significant. Peter Wells, professor of business and sustainability at Cardiff University, believes that big data will "allow systems to pre-emptively offer exclusive and highly customised information", similar to the kind of algorithm used by Amazon when recommending similar products to its customers. "We are scraping the surface of what can be done with big data in vehicles at the moment", he says, adding that there is potential to generate "massive revenue outside of vehicles". A time when the vehicle we drive can provide us with restaurant recommendations based on location and preferences may therefore not be far away.

The one major sticking point towards this kind of marketing "free-for-all" is privacy. The most obvious comparison is with Facebook, which has had to deal with all kinds of privacy-related tussles, including years of reports that users are obliged to divulge personal identification information or risk having their accounts suspended. Many argue that it is virtually impossible to have a "private" Facebook account, given that a user's "likes" are treated as publicly available information, used by a host of companies for marketing purposes. Connected cars could well come up against similar concerns, but given that Facebook has largely weathered the privacy storm, so may connected cars.

As Mr Wells says: "We will get used to it, as long as there is enough benefit,

and 99% of people won't be worried because of those benefits". Consumers are generally receptive to technological developments and innovations that are user-friendly enough to become ubiquitous and indispensable, regardless of the downsides. Consumers are also responsive to marketing that caters to their needs and preferences. Provided that carmakers are careful about just how much consumer information is gathered and disseminated, cross-marketing may be one of the biggest revenue opportunities in the connected car segment over the coming years. Nonetheless, the issues of both privacy and security are a hot topic in the industry currently.

Another area with potential is pairing connectivity in the car with the evolution of smart-home technology. At the Consumer Electronics Show (CES) held in Las Vegas in January of this year, Control4, a company that builds automation systems, debuted a smart-home app for use in the connected car, allowing drivers to control a host of home applications, including thermostats, lights, locks and garage doors. Several other companies are developing similar applications. In July of this year, Volkswagen announced that it would be teaming up with electronics manufacturer LG to help further blur the lines around vehicle and home connectivity. The two companies debuted a connected car smart-home platform at this year's CES, although a launch date remains a few years away.

As the number of internet-enabled apps and functions multiplies, however, carmakers are struggling to determine what kind of driver experience consumers want. Many carmakers are seizing on the idea of "cocooning" drivers and passengers in their vehicles, to deliver an ambience that insulates users from the outside world. Ford calls this idea "dynamic sanctuary" and is devoting time and resources to ensuring that the in-car experience recreates the creature comforts of home. Others are keen for cars to become potential workplaces, allowing busy executives to conduct their business while on their way to a meeting or even the supermarket.

Perhaps the end-game for connected vehicles, however, is self-driving cars. The idea being that these vehicles would use their connectedness to monitor outside conditions, including everything from the road direction to the distance to the car in front, or the presence of street signs and pedestrians, and the risk of a traffic jam up the road. All this information could then be fed to the vehicle systems, which would operate on their own, leaving the driver free to sleep, play games or work until the car reaches its destination.

It is a fine idea, and if it ever comes to full fruition, it would not only save drivers time and effort but could also free up road space, reduce fuel usage, and cut accident rates. However, the reality so far is less sophisticated. Plenty of carmakers and technology companies are working on self-driving vehicles, as a natural extension from the kind of driver aids – parking sensors, self-parking systems, assisted braking – that are now becoming commonplace.

Distracted driving

In-car video and audio is enjoyable, but distracted driving, already a huge problem in many countries worldwide, will only get worse as more immersive in-car technology develops. Back in 2013, the AAA Foundation for Traffic Safety in the US found that using speech-to-text technology in a vehicle can severely diminish driver responsiveness, delaying reaction times by up to 25%.

The results can be disastrous. According to the US government website for distracted driving, in 2014 more than 3,000 people died and 431,000 were injured in crashes that involved distracted drivers. And in the UK, an August 2016 survey by Fleet News, a publication covering the commercial vehicle sector, found that more than one-half of businesses surveyed said they were concerned about their drivers being distracted by in-car technology, rising to 55% for small businesses.

Proper guidelines on the safety of in-car applications are needed, but as yet decision-makers and national authorities lack the appetite to address the problem. The use of mobile phones is banned in many countries, for example, but enforcement is patchy and hands-free phones remain distracting. Devising and imposing firmer rules will be incredibly difficult, but carmakers, tech companies and governments need to collaborate to ensure the adverse impact of distracted driving is minimised over the short and medium term. Otherwise a backlash will be inevitable.

Add in a plethora of more sophisticated sensors and cameras, as well as additional safety features, and it may be possible for drivers to take their hands off the steering wheel. Furthest along this road, perhaps, is Google, whose fleet of driverless passenger cars is capable of manoeuvring around streets unaided. Yet the final goal, where connected cars can communicate seamlessly with each other and the world around them to get to their destination without accident, while passengers sit back and relax, is still a long way off.

If the technology is right, however, then it may eventually become better than human judgement and the gains would be huge. In the US, for example, car crashes kill 30,000 people per year and driver error is said to account for around 90% of those deaths. Combine self-driving with car sharing (see page 14) and there could be huge benefits in terms of congestion, use of resources such as fuel, and the urban environment, not to mention the added convenience for the people who use those cars.

Connected car developments

Faced with the huge potential of connected vehicles, companies have to make choices about which technologies might catch on with consumers, and how best to cater for that demand. Several players within the automotive and the tech sectors are already well-placed to take advantage of the opportunities. Others are drawing up strategies that involve extensive R&D, alliances with other carmakers or technology firms, or even outright acquisitions in order to obtain a headstart.

Carmakers are perhaps the most apprehensive about what a connected car future holds. Not only does the technology have the power to disrupt their core business, but they also have to deal with deep cultural differences between the ways the automotive and tech industries operate. This is at least partly driven by the differing dynamics in both sectors—the tech industry can generally put products out to market with minimal lead time, whereas vehicle manufacturing, as Mr Wells attests, "remains a difficult and complex product to bring to market, incorporating a huge range of materials and performance attributes". He adds that an "Armageddon scenario" for the car industry would be one where a car becomes a commodity product that is adapted and used by other businesses.

It seems clear, therefore, that auto manufacturers will have to tread carefully, both in their willingness to incorporate connected car technology into their vehicles, but also in how they choose to develop it. The auto sector is fairly risk-averse, owing to the extensive and rigorous testing that has to be carried out in the name of safety, as well as the threat of regulation and litigation. So vehicle-makers will be looking closely at the potential advantages and disadvantages of the three main choices they face: developing their own systems; striking alliances with technology companies; and acquiring such companies outright.

Developing their own technology, either in-house or conjunction with suppliers, does have distinct advantages in that it fits best with the way the auto industry currently operates, as well as allowing manufacturers to keep tight

control over both the intellectual property (IP) and the supply chain. However, as the fitful development of auto mapping systems showed, such technology may be less suited to customer needs and could soon become obsolete unless it allows for regular software updates and (even more importantly) a lot of future-proofing.

Striking alliances with tech companies is perhaps the strategy most likely to

A mapping alliance

A prime example of carmakers joining forces to acquire connective technology was the purchase of Nokia's mapping technology, Here, by a consortium of German carmakers in December 2015. The companies in question—Audi, BMW and Daimler—paid around €2.8bn to acquire Here, fending off rumoured interest from Uber, Amazon and Apple. The acquisition price alone demonstrated the carmakers' willingness to cast market rivalry aside in order to team up and combat the threat posed by technology companies. The deal also showed that carmakers are capable of collaborating and, as Mr Wells states, "operating a shared back-office function while still delivering individuality".

The deal was certainly a significant one as far as mapping is concerned. As at December 2015 Nokia's mapping technology provided location-based map data to 80% of all in-car navigation systems worldwide, while also providing that same data to major companies such as Amazon, Yahoo! and Microsoft. In future, Here has the potential to collect data from the vehicles of all three manufacturers to deliver more accurate real-time maps. This kind of capability will prove crucial in a connected car future.

More recently, at the Paris Motor Show in September 2016, the trio of carmakers unveiled plans to collate data from car sensors, which would be shared with other vehicles in order to inform drivers of traffic conditions. Specifically, a forward-facing sensor will focus on detecting traffic sign information, accidents, road closures and other incidents, while sensors embedded in other areas of the car will amass data on speed, direction, vehicle location and weather conditions.

Finally, the Open Location Platform, due to be made available in the group's cars as of the first half of next year, will also use an ultrasonic parking sensor to detect areas in the vicinity that have free parking spaces. The platform will initially only be available on cars from one of the three manufacturers, but there are plans to open it up to other marques, which shows how seriously carmakers are considering collaboration in an industry that is otherwise tight-lipped about technical innovation. As such, the German trio's capture of Here represents somewhat of a coup, albeit for now these are spoils accrued from a skirmish in an otherwise long-term battle.

fit with carmakers' overall goals, therefore. By using tech companies to develop the kind of sophisticated driving experience consumers will expect, carmakers can then use their marketing and brand prowess in auto circles to leverage their offering. The gains may be more marginal than for in-house technology, but the cost of investment will be spread. However, carmakers do have to be careful about relying on IP they do not own outright, particularly if an alliance breaks down. That could entail considerable costs, particularly if it involves extensive changes to the vehicles themselves.

Outright acquisitions are also risky, in that they may turn out to be a bad fit or to lead down a dead end in technology terms. But if the choice of acquisition target is good, and its integration is approached in the right way, acquisitions can allow vehicle-makers to bring in the kind of knowledge and flexible innovation they need, while retaining full ownership of the resulting IP. In some cases carmakers have been able to club together to share both the costs and risks of such an approach.

The problem for car companies is that technology companies in many ways have the upper hand, as they approached the issue of connected cars from the opposite end of the business spectrum. They can focus solely on developing and refining the technology that goes into connected cars, without having to worry about actually producing the cars that house it.

Google and Apple have both made inroads into the connected car space with their in-car infotainment and mapping applications. Google's Android Auto, a smartphone-driven application that allows mobile devices to connect to the car's dashboard, was released in March 2015. It has since been incorporated into the Open Automotive Alliance, a joint venture formed with mobile tech supplier Nvidia and 28 car manufacturers, including General Motors (GM), Ford, Volkswagen and Nissan, which is focused on embedding Android Auto into vehicles.

Android Auto's biggest advantage is its Google Maps functionality, which much like Google's search engine, has become accepted as the consumer standard in mapping software. While that is the main draw of Google's app platform, Android Auto also offers audio streaming and hands-free calls, as well as web access, among other functionality. Apple's CarPlay system works along similar lines, although it swaps Google's proprietary Android capability for its own, relying on its own mapping software and entertainment platform. Around 100 models of car – from Ferraris to Skodas - now incorporate CarPlay.

However, both Apple and Google have ambitions beyond simply bridging the connectivity gap between a driver's smartphone and their in-car navigation and entertainment system. At Google's I/O conference in May of this year, the company demonstrated a much more integrated Android Auto platform, called Android N. This incorporates a 15-inch touchscreen that serves not only as a way of managing audio and navigation functionality, but essentially acts as the car's

Steering the future

Tesla changed the way people drive when it launched luxury electric sedans in a market that was still heavily sceptical about cars that didn't run on petrol. Today, its vehicles – which sell for over US$60,000 – are coveted across the world. Now, the carmaker is again aiming to revolutionise the auto industry with its self-driving technology.

The Silicon Valley-based carmaker launched its autonomous driving system in October 2015 to great fanfare. The technology was dubbed "autopilot", in reference to an aeroplane system that helps pilots navigate. Released through a software update, the system had enabled some of Tesla's Model S sedans to steer and park themselves under certain conditions.

Early versions of the software established the foundation of the technology, which used a combination of cameras, radar, ultrasonic and GPS to allow cars to control speed, change lanes and brake on their own. Over the next few months, the company added a 'summon' feature: the cars could open garage doors, park themselves and switch off. Once only a remote possibility, Tesla had appeared to make self-driving a reality.

That said, the technology still only allows for semi-autonomous rather than fully autonomous driving. Tesla's chief executive, Elon Musk, has emphasised that the technology in still in its beta or test phase. The system is disabled by default in all new cars and requires drivers to acknowledge that it is currently merely an assist system. It also requires drivers to keep their hands on the steering wheel at all times; otherwise the car slowly comes to a halt.

Although the technology has been extremely popular with buyers, it has raised questions about the safety of allowing computer systems to take over even partial control of steering and braking. There is also concern about the legal implications, including who takes responsibility for any accidents.

The system had its first brush with controversy earlier this year, when a Model S sedan operating in autopilot mode collided with a truck in May, killing the driver of the electric vehicle. That was the first known fatality involving the system and prompted US regulators to launch a preliminary investigation into the matter.

About two months later, authorities said that they were looking into a crash involving the company's Model S sports utility vehicle, to determine whether the car's autopilot system was engaged at the time of the accident. Barely a month later, one of its cars crashed in Beijing while running in autopilot mode.

While the outcome of the investigation is pending, Tesla has moved quickly to try and rectify the situation. In September, the company upgraded the software to set new limits on its features, including using more comprehensive radar technology to judge the nature of the obstacles around the car and brake more effectively. Mr Musk has said that these features would have prevented the crash in Florida in May.

Other automakers have signalled investment that reflects their confidence in the future of self-driving technology. In August 2016 Volvo, a Swedish carmaker owned by China's Zhejiang Geely Holding Group, partnered with Uber, a US-based ride-sharing company, to introduce driverless taxis. Some of these have already been deployed in the US city of Pittsburgh.

German carmaker Mercedes Benz, US automakers General Motors (GM) and Ford, and Japan's Toyota and Honda are among global automakers that have announced plans to launch self-driving cars over the next few years.

control centre, used by a driver to manage infotainment, lighting, heating, speed and general measures relating to the car's performance. This more ingrained platform will also be open source and allow either CarPlay or Android Auto functionality, with either applications essentially sitting on top of the Android N framework.

But the end-game for both these tech giants could stretch even further, perhaps even encroaching on carmakers' territory by building the car itself. Google has already flirted with the self-driving car, and has now racked up around seven years of testing. In the process, the company has built around 100 prototype self-driving cars, and in August 2015 it established its own car company, Google Auto LLC, ostensibly as a way to test its fleet of self-driving vehicles. If and when the Google self-driving car does succeed, we could see a vehicle that will be manufactured under Google's own brand.

Meanwhile, Apple is working on its much rumoured "Project Titan" initiative, reportedly signed off by company CEO Tim Cook sometime in 2014, but never actually confirmed. A spate of hires from the car industry, perhaps numbering in the thousands, and a rumoured visit by Apple executives to a BMW plant in Germany, have fuelled rumours that Apple is working on an electric car that could surface over the next four or five years. Elon Musk, the founder and CEO of Tesla, has called Apple's electric car aspirations an "open secret", although detail remains scant. Indeed, in September 2016 the *New York Times* reported that Apple had closed part of the project and now intends to focus on the self-driving mechanisms, rather than building an actual car. The much-discussed iCar may already be dead.

Mr Musk's own venture poses the most obvious threat to both Google and Apple's aspirations. Tesla Auto, which was founded back in 2003, brings what Mr Wells calls a "tech company mindset" to the automotive sector. Tesla's car production, focused entirely on electric vehicles, was just over 50,000 units in 2015, but there are ambitious plans to scale it up to around 500,000 units as of 2018, after the slightly cheaper Model S is launched. The end-goal, according to Mr Musk, is to become a mass-market electric vehicle brand.

While some tech companies are preoccupied with the deep-dive wiring and interfaces involved in connected cars, other tech companies are choosing to focus on mobility itself and the means by which many of us choose to get around the world's towns and cities. In the case of Uber and Lyft, two popular taxi-hailing apps, they have managed to leverage basic smartphone and internet connectivity to offer a service that has had a tremendous impact on the way we move around urban environments in a very short space of time.

Car-sharing in a connected world

Both Lyft and Uber offer an on-demand taxi service that operates via a mobile app, into which users tap their location and their destination. This alerts an Uber driver to the customer's location, and an approximate cost is provided, which is later deducted electronically from a user's bank account. Because these on-demand services employ independent drivers using their own cars, both Uber and Lyft have been able to introduce a flexible pricing model that matches fares to the demand for vehicles. As a result, Lyft and Uber prices are usually far below those of more traditional regulated taxi services, although occasionally (at peak times) they can be more expensive.

Wedded to the convenience of being able to request a taxi directly from a user's phone, rather than having to scour streets for a passing cab, its pricing model has given Lyft and Uber a significant advantage over regulated taxis. That has drawn the ire of the taxi trade in many cities, with regulated drivers arguing that on-demand services (where drivers are essentially independently hired contractors) provide unfair competition. Some cities, too, complain that on-demand services have caused a surge in the number of cars on their roads, exacerbating already challenging congestion and pollution problems.

None of this has stopped on-demand services from growing. Uber is growing particularly strongly, due mainly to its global expansion since it was launched in the US in 2009. Gross global bookings totalled US$3.63bn in the first half of 2015, up from US$2.93bn in the whole of 2014. Net revenue came in at US$663.2m in the first half of 2015, up from US$495.3m in 2014 as a whole. That said, Uber continues to make enormous losses. Net revenue minus the cost of revenue, operating expenses and other costs totalled US$617.4m in 2014, but this skyrocketed to US$987.2m in the first half of 2015. Fortunately, however, Uber's backers have deep pockets, and the surging popularity of the service ensures that the company can continue to run at a loss as it continues to grow.

Exactly what Uber plans to do with considerable influence and market

penetration worldwide is a fair question. Far from resting on its laurels, Uber seems to want to help reshape the definition of mass mobility, as well as the development of urban design. Back in 2015, Uber's CEO, Travis Kalanick, said that the company's intention was to make Uber "so efficient [and] highly utilised, that for most people it is cheaper than owning a car".

Just by popularising car-sharing, Uber is highly likely to drive a wedge into the future market for car ownership. However, its potential could be even greater if self-driving cars become a reality. In future, such a car could become a marketable asset, with people paying for it to drive itself to their house for a journey. Alternatively, the vehicle could be used to carry out errands when its owner is asleep or at work. With the prospects for self-driving truck fleets even more promising, Uber has also partnered with a self-driving truck start-up, Otto, to develop autonomous commercial vehicles. Uber is even said to be working on developing self-flying drones in an attempt to beat city traffic.

Aside from these projects, Uber's current trajectory has implications for the future of urban planning in many of the world's cities. Congestion and pollution mean that the current car-dominated cities are unsustainable, and a future where cities are designed more purposefully around the needs of pedestrians, cyclists and public transport users is inevitable. Uber will have its place in the transport mix, as will the private car, but these are likely to be two choices among an array of options, with people increasingly taking multi-modal trips – perhaps involving Uber, then a train and finishing with a cycle trip, for example. If such journeys proliferate, and car ownership falls, a reallocation of urban space will result. This will result in fewer parking spaces, and new routes connecting neighbourhoods that were otherwise blighted by poor transport links, prompting a more strategic consideration of what kind of infrastructure towns and cities need.

The future for techno-trucks

Connected cars get most of the attention, but arguably connected trucks have a far more lucrative future. It is certainly easier to see why companies would want to buy internet-enabled commercial vehicles in order to help them manage their businesses, as well as easing the lives of their drivers. Indeed, in-truck technology is already being used to help with logistics, mapping out routes, tracking truck progress and ensuring that deliveries are on time.

Connected trucks can also use telemetry, and related technology, to help fleet operators monitor the running costs, fuel costs and performance of their vehicles. Mercedes-Benz Uptime, for example, uses the FleetBoard Connectivity Platform to monitor the vehicle, predicting problems as or even before they arise, and then scheduling maintenance and repair slots.

As for drivers, connectedness can help ensure that they are taking any legally required rest breaks or allow them to call for emergency assistance if needed, with the vehicle location relayed automatically. At Volvo Trucks, drivers can use My Truck to connect to their vehicle remotely via a smartphone app to check if it is ready to go. And once the journey is underway, connectivity also helps to provide the infotainment and internet systems that ease the boredom of a long-distance route.

This kind of application will no doubt get more sophisticated in future as current investment efforts bear fruit. Daimler of Germany, for one, is investing around €0.5bn (US$0.6bn) into connectivity for its trucks, and already has 400,000 trucks on the road connected via the FleetBoard and Detroit Connect systems. This is all part of a plan to overhaul trucking and make it far more efficient, benefiting hauliers, the companies they work for, the economy and potentially the environment.

Faster turnarounds at warehouses and better logistics planning, for example, may be able to reduce the 25% of trucks that are currently driving around empty.

That would not only lower haulage costs, but also reduce traffic jams and traffic pollution. Internet-enabled sensors and automatic braking systems can also improve vehicle safety, not only saving lives and injuries but also reducing the tailbacks caused by accidents.

The biggest focus, however, is on platooning, which enables connected groups of trucks to move in sync along motorways, reducing braking distances and fuel consumption. Daimler estimates that a platoon of three trucks can achieve a fuel saving of around 7%. Daimler is one of seven truckmakers – the others being DAF, Iveco, MAN, Scania and Volvo Group – who took part in the European Truck Platooning Challenge, launched by the Dutch government under its EU Presidency in early 2016.

Once platooning is well-established, with systems and sensors all working well, it will feed into the eventual move towards self-driving trucks. Some progress has already been made. Mercedes-Benz, for example, has built a prototype truck – dubbed Future Truck 2025 – that can kick into autopilot mode once the driver reaches the motorway.

Using a combination of dual cameras, radar sensors and blind-spot technology, it can keep to lanes and maintain a steady speed, braking if it hits congestion. However, the truck driver needs to take over again when the truck comes off the motorway, particularly in towns, or if there is a traffic incident. Although this is still a prototype, it may go into production some time after 2025.

Given how long most truck drivers spend driving, and the dangers of overtiredness, that could be a boon to road safety. According to the National Highway Traffic Safety Administration, 3,921 people were killed in crashes in the US involving large trucks in 2012. At present, governments try to reduce this problem through legislation. In the US, drivers are not allowed to drive for more than 70 hours a week, or 11 hours a day (including a 30 minute break). In the EU, even stricter rules put the weekly limit at 56 hours or nine hours a day.

Such rules (although they help to reduce accidents) are expensive and cumbersome for employers to implement, and they may well welcome the move towards self-driving. In its initial stages, with drivers still present in each truck to override the system if necessary, self-driving trucks could help to deal with issues of driver fatigue, as well as freeing up drivers to help with logistics and planning. The next step could then be for groups of trucks to be overseen by a single driver, essentially turning platoons into a train engine with carriages. Eventually it may be possibly for platoons to be driven remotely from headquarters, doing away with the need for dedicated drivers altogether.

Self-driving in safety

If connectivity leads to cars or trucks that drive themselves and talk to each other wirelessly in urban spaces, then disruptors such as Uber, tech companies and carmakers are going to have to deliver cars that are capable of making all manner of complex, split-second decisions in the name of safety. The challenge of dealing with unforeseen pedestrian movements was made apparent in May of this year, when it was revealed that Google had filed a patent for "sticky" technology that would grab hold of any pedestrian unlucky enough to get hit by a car, preventing them from bouncing off on impact.

The news was greeted as an implicit admission that self-driving cars will find it hard to avoid striking pedestrians. Indeed, early experiments with the technology have already resulted in several incidents (see box). Safety will become ever more important as the first self-driving cars start to join the normal ones on the road, even when self-driving cars are in the majority. It may take many years before the technology becomes sophisticated enough to react swiftly to street furniture, pedestrians, cyclists and a whole host of other objects that make up the urban environment.

Part of the problem is that much of the way drivers, pedestrians and cyclists interact with each other involves non-verbal communication. At present, a driver uses his or her judgement to decide if a pedestrian walking down the pavement is just about to step into the road. The pedestrian does the same, often peering at the car driver's face to check their intentions. At present most self-driving cars can only see movement after the fact, which (good brakes notwithstanding) may be too late.

Carmakers are aware of this, and have started to address the problem. Mercedes' F015 concept car will reportedly be able to project a pedestrian crossing to allow people to cross safely, while Google patented an audible pedestrian notification system in November 2015.

Pioneering pitfalls

As both tech companies and auto companies venture into new territory, they are forced to experiment with – or even bring to market - products that are not necessarily watertight. While Tesla has won considerable plaudits for the design and comfort of its electric vehicles, it suffered a dent in its reputation on May 7th, after a driver died at the wheel of a Tesla car.

In what was reported to be a first death in a self-driving car, the driver, Joshua Brown, was killed in Florida when, having put his Tesla vehicle into autopilot mode, the car's sensors failed to detect a truck crossing the highway further ahead. A similar incident took place in northern Germany, when a Tesla reportedly travelling on autopilot crashed into a tourist bus. The driver was injured, but all 29 people on board the bus were unhurt. Tesla cars have also suffered from engine fires that have done little to dent their popularity.

Tesla is not alone. Google's self-driving car programme has resulted in several high-profile incidents, the latest of which has involved three accidents on US streets in the month of September 2016 alone. Such incidents are sure to be repeated as Google and other companies continue to try and develop a car that is truly responsive to its environment. However, there are wider concerns over connected vehicle technology.

In August last year, for example, two researchers claimed they were able to hack into a Tesla's infotainment system. A more recent hacking attack, deliberately perpetrated by an online security firm in September 2016, after several months of research, found that it was able to remotely control a Tesla vehicle in both parking and driving modes.

Perhaps the incident that really captured the security issues inherent to connected cars was the hacking of a Jeep in July of last year. Two security researchers, using the diagnostics system, were able to switch off the engine, slam on the brakes and cause the car to crash into a ditch. Fiat Chrysler eventually issued a patch update to fix the problem, but the incident only served to highlight the unease among consumers regarding the robustness of self-driving software, their flaws and their resilience to external attacks.

To counter the problem, since 2015 carmakers have manufactured vehicles that disable diagnostic mode when the car is moving beyond 5mph. Unfortunately, that same duo of hackers has since discovered that this safety feature can itself be disabled. In Fiat-Chrysler's defence, they maintain that hacking the vehicle can only be made possible with physical access to a car, so a remote hack remains a distant possibility. That may be true, for the time being at least.

More recently, in September 2016, Semcon, a Swedish engineering firm, devised a "smiling" car, which beams an electronic smile across the grille to inform pedestrians when it is safe to cross. The company claims that the use of eye-tracking and laser technology makes it easier for its vehicle to detect hand and eye movements – both crucial indicators in assessing the direction in which pedestrians are moving. The smiling signal works in a similar way to the emoji system being developed by another startup company, Drive.ai, which may include a thumbs up or a "safe to cross" message.

These are useful approaches when self-driving cars interact with a pedestrian who is making a more "predictable" movement. But what happens with a unruly group of pedestrians, perhaps even children, who are behaving less predictably? And what if a car faces a bleak choice between ploughing into a cyclist or hitting a pregnant woman? It is not yet clear how self-driving cars will be programmed to deal with ethical situations.

Carmakers are adept at conceptualising machines, designing them, engineering them and marketing them. Philosophers they are clearly not, which means that politicians will need to set clear – and inevitably controversial – rules. Indeed, the US government published its first rulebook regarding the manufacture and sale of self-driving cars in mid-September 2016. It featured a 15-point safety assessment, including a requirement for car manufacturers to divulge details on how they will address the ethical conflicts.

Data delivery

In the new US rulebook on self-driving cars, there is also a requirement for manufacturers to share the huge reams of data that a self-driving car is likely to produce with the federal authorities. This can include anything from car diagnostics to driver habits or a vehicle's safety record, and potentially in the future, data on a driver's health. Whether carmakers will willingly share this kind of data is uncertain, although a government representative has asserted that regulation will make data-sharing compulsory.

The size of data produced by a connected car, and the value attached to it by carmakers and external companies, is one of the big attractions of a fully connected, self-driving future. And this mass of data that needs to be transmitted also points to the importance of infrastructure. Investment is needed, so that the internet can cope with masses of cars using connectivity to communicate with each other in order to move seamlessly and in unison.

According to an expert at Strategy Analytics, a UK consulting firm, bandwidth will not prove as crucial in this as network coverage. Indeed, many of those interviewed as part of the research for this report took a similar view. Cloud storage and big data capability are more reliant on coverage than connection speed, so the advent of 5G connectivity is likely to be viewed as a "nice-to-have". As the Strategy Analytics expert states, it is like building a "mass walkie-talkie system". Point-to-point connection between vehicles and drivers is the most important consideration, while data being streamed from a vehicle will place a relatively low strain on the overall network.

So far, connected capability has been focused on EU and US markets, yet anecdotal evidence suggests that there remain big problems with network "notspots" around Europe, causing unwarranted interruptions with map streaming and navigation. The US tends to enjoy more reliable coverage, and emerging nations keen to push connectivity would be wise to note how important

this, together with low latency, is in establishing a healthy connected car market. Here, the infrastructure needs will be ever greater, and the gains just as lucrative. The phenomenal growth story that is China is a case in point, with swelling ranks of middle class consumers flocking to purchase luxury European car marques. There may well be other emerging market growth stories over the coming years, as the development of connected cars accelerates.

Everywhere, telecoms operators will need to invest in spectrum auctions, while governments will need to be supportive in releasing spectrum and setting competitive auction prices. Connected cars will need to have a big data and internet of things world where storage and streaming capability allows for a smooth and seamless transfer of information. In some ways, this is already happening – according to Chetan Sharma, a US consultancy, connected cars were responsible for 32% of cellular connections in the US market in the first quarter of 2016, outstripping phones (31%) and tablets (23%).

Conclusion

It has taken a long time for a connected car business model to emerge. GM's OnStar system first came into being around 20 years ago, and connected cars are now an established presence on our roads. The next challenge will be to make smart decisions that maximise the revenue potential of a connected system that can be regularly updated, and secondly, working towards realising a self-driving future.

According to a survey by Bearing Point, by 2020 around 80% of vehicles on the road will be connected. A multi-modal future awaits, with connected technology playing an important role in minimising traffic and streamlining the flow of vehicles through busy streets and junctions. It can also have an economic role to play, potentially freeing up time for commercial truck drivers to carry out a greater number of tasks, or even allowing self-driving car passengers to use commute times for more economically purposeful means.

Before then, however, a lot of details will need to be ironed out, from safety and privacy, to the layout of streets and the ethical rules that will apply. With the technology evolving at such a rapid pace, two things will need to happen, and fast. The first is some kind of workable legislative framework for self-driving cars, and the second is investment in the technological infrastructure for an autonomous world to become a reality.

Moreover, it is not clear whether connected and driverless cars can solve the problems of congestion in the world's towns and cities. Simply replacing human-powered vehicles with those capable of operating on the strength of their internal electrics will not detract from air quality and congestion problems.

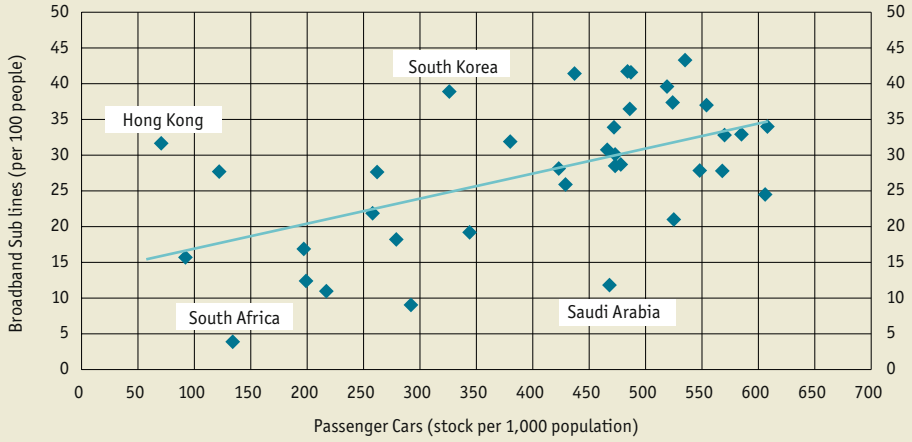
The sector must not be lulled into a false sense of security by the seductive, futuristic nature of what might be possible with self-driving cars, therefore. Many obstacles remain, and to realise all this burgeoning potential will require perseverance, innovation and collaboration. Nonetheless, connected and self-driving cars are here to stay. The projected gains are simply too great for any of those involved in the sector to ignore.

Car ownership vs broadband subscribers

Economist Intelligence Unit data regarding car ownership and broadband subscriber penetration across developed and developing markets appears to back up the assumption that both the US and the more advanced EU economies are best placed to realise the potential of a connected car future. That said, there are a few outliers in both groups that show relative strength in either connectivity or vehicle numbers. In the emerging markets space, Hungary and Bulgaria are potentially well-placed to integrate connected cars, given the high penetration of passenger cars and high broadband subscriber numbers. Although subscriber numbers alone are not necessarily indicative of the presence of advanced internet infrastructure, high usage does nevertheless indicate that some sort of high capacity network is in place. Azerbaijan and the Philippines however, show greater promise, with connectivity appearing to outstrip car sales, suggesting there is perhaps an opportunity for carmakers in these markets.

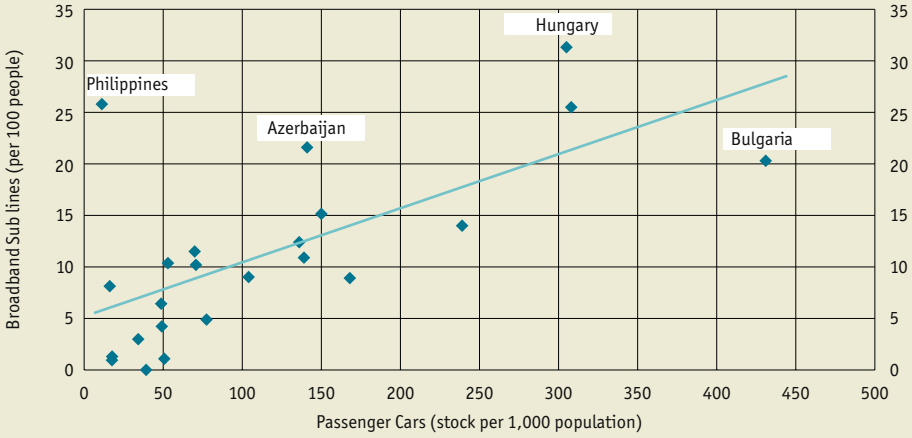
In developing countries, some interesting outliers emerge. While Hong Kong enjoys relatively high broadband subscriber numbers, it has the lowest car ownership penetration rate out of all the developed countries covered by our data. Meanwhile, Saudi Arabia is in the opposite position, enjoying a relatively high vehicle penetration rate, but a low number of broadband subscribers. In truth, this could be the result of Saudi Arabia's relatively interventionist approach to internet use, with heavy regulation and internet censorship acting as a constraint on growth. Elsewhere, South Korea enjoys strong penetration rates in both areas, while South Africa is in one of the most challenging positions, with the lowest number of broadband subscribers out of the list of developed nations, along with one of the lowest rates of car ownership (see graphs on page 25).

Car Ownership vs Broadband Connectivity (Developed Markets)



Source: The Economist Intelligence Unit,

Car Ownership vs Broadband Connectivity (Emerging Markets)



Source: The Economist Intelligence Unit,

Cover image - Tesla

LONDON
20 Cabot Square
London
E14 4QW
United Kingdom
Tel: (44.20) 7576 8000
Fax: (44.20) 7576 8500
E-mail: london@eiu.com

NEW YORK
750 Third Avenue
5th Floor
New York, NY 10017
United States
Tel: (1.212) 554 0600
Fax: (1.212) 586 1181/2
E-mail: americas@eiu.com

HONG KONG
1301 Cityplaza Four
12 Taikoo Wan Road
Taikoo Shing
Hong Kong
Tel: (852) 2585 3888
Fax: (852) 2802 7638
E-mail: asia@eiu.com

GENEVA
Rue de l'Athénée 32
1206 Geneva
Switzerland
Tel: (41) 22 566 2470
Fax: (41) 22 346 93 47
E-mail: geneva@eiu.com