Technology Revolutionizing The Auto Industry

EVs and AVs Will Be Key Disruptors Going Forward

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Highlights

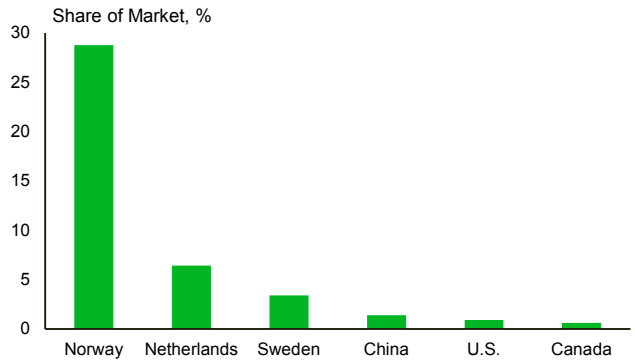
- Technological advances have been revolutionizing the auto industry in recent years, and this disruption will continue for years to come.
- In particular, while still a number of years away from mass adoption, electric and fully-autonomous vehicles have been making inroads and will be key disruptors in the auto industry in the years ahead.
- Barriers to electric vehicle adoption are being addressed, with battery prices falling, ranges being extended and charging infrastructure slowly building up. Moreover, some governments and automakers have announced plans to shift toward electrified vehicles in the coming decades, which will help to increase consumer demand for these vehicles.
- Mass adoption of autonomous vehicles is likely further out on the horizon, but the technology is gradually falling into place and will eventually change the way people move around.
- These innovations will have implications for not only automakers, but also on suppliers, governments and the oil industry.

Similar to other key sectors, disruptive technological trends are revolutionalizing the North American auto industry. Among these transformative trends, growing "connectivity" and integration of software applications (i.e., GPS/mapping) have been the most prevalent to date. Other, more potentially disruptive technologies – notably electric (EV) and fully-autonomous vehicles (AV) – have been making inroads, but remain a number of years away from widespread commercial use. In this report, we address some of the often-raised questions surrounding the impact of technology in the auto industry, beginning with developments in electric vehicles.

How successful have electrified vehicles been in penetrating the market?

Electrified vehicles, which we define as hybrid, plug-in, battery electric and fuel cell, have been around for some 20 years, but consumer uptake of these vehicles has been slow. Although outpacing the growth in overall sales, electric and hybrid vehicles still account for less than 1% of total sales in the U.S. and Canada. Even in China, which makes up roughly 45% of global sales of electric and hybrid vehicles, the EV market accounts for only 1.3% of the country's total auto market. Within the OECD, Norway has stood out as the most notable exception to the rule, with electrified vehicles accounting for nearly two in

CHART 1: SHARE OF ELECTRIC VEHICLES*



*Battery electric and plug-in hybrid
Source: IEA, TD Economics.

five vehicle sales in 2016. Norway's success has largely revolved around government buying incentives, which are the most generous in the world. A few other nations that have seen a somewhat more meaningful shift towards EV demand include the Netherlands (6.4%) and Sweden (3.4%).

What have been the key barriers holding back growth in the sector?

The slow adoption of EVs reflects a number of ongoing barriers. Most importantly, EVs continue to have a high price tag relative to similar vehicles with internal combustion engines (ICE). The sticker price of an EV can be $10,000-20,000 more than a comparable vehicle with an ICE. When subsidies and other costs of ownership are factored in, the gap can narrow to under $5,000 depending on a number of factors including vehicle model, gasoline and electricity prices, miles driven and financing costs. But, several comparisons suggest that it would take at least 4-5 years of ownership to make up the difference in cost.

Most governments in North America and around the world provide subsidies for the purchase of EVs as part of their policy tools to address climate change and promote cleaner technologies. However, these grants have generally not been sufficient to eliminate the cost gap.

The challenge with over-reliance on subsidies is that they do not tend to be sustainable. In China, which has particularly generous subsidies, demand fell significantly once they were scaled back. In Norway, the government has signaled that it plans to phase out some of its subsidy programs over the next few years, as the cost of the incentives has not been perceived as exceeding the social benefits.

Range anxiety is another barrier to adoption with respect to pure electric vehicles, as the driving range and charging infrastructure are simply not adequate for many who wish to drive longer distances. More powerful batteries have become available, but those also tend to come at a higher cost.

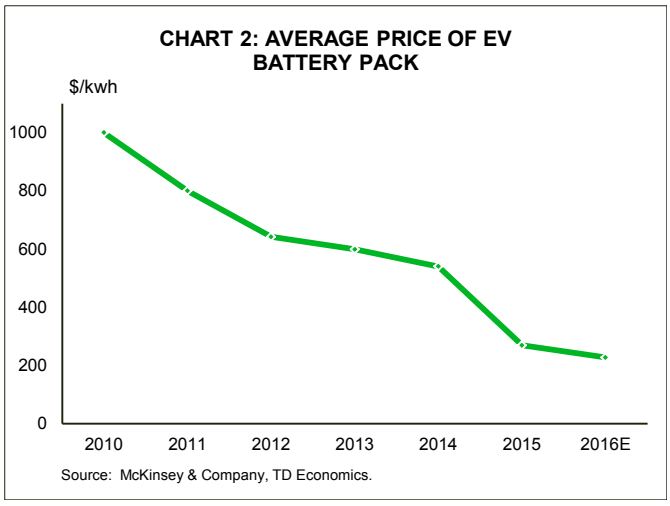
Cost and charging concerns are perhaps the most important, but not the only barriers. Another challenge is a lack of supply, with no options available in some vehicle classes. As gasoline prices have fallen since their recent peak in 2014, the U.S. has seen a shift in sales toward light trucks, as consumers are "buying as much car as they can". But there are few electric or hybrid light trucks on the market at present. So even beyond higher price tags, a shortage of product mix is likely a factor that is contributing to a lack of EV traction.

Can these barriers be addressed?

Like many new innovations, EVs suffer from a classic Catch 22 situation. Consumers aren't willing to spend the extra money for an EV and costs are unlikely to come down until there is sufficient demand and economies of scale in production can be utilized. Further, the incumbent technologies do not remain static. Facing increased regulation around energy efficiency and higher carbon costs, the auto industry continues to invest in improving the performance of the internal combustion engine. In fact, new technology has led some industry players to announce expected efficiency improvements of 30-50% over current performance in the next generation of engines, helping to keep conventional engines alive.

The penetration of EVs may have disappointed analyst forecasts over the past five years, but that has not dissuaded them from their prognostications that EVs and hybrids will "go big" over the next decade. That being said, the forecast range remains wide – from a low of around 10% of the global market to as high as 35% by 2030. Accompanying these forecasts are commitments from a number of automakers – including GM, Daimler, BMW, Honda, Toyota and Volkswagen – to ramp up the number of electric models offered over the next decade, with one OEM (Volvo) announcing that all of its models introduced in 2019 and beyond would be hybrid or electric. Lastly, some governments have announced bold targets. China and several European countries have proposed to ban the sales of vehicles with internal combustion engines by 2030 or 2040.

Forecasts at the upper end of the range see the industry hitting a "tipping point" over the next several years. Particular focus remains on battery innovation. Batteries not only make up the highest part of the cost gap, but are also a root of charging anxiety. On this front, there is reason for optimism. New innovations and increased demand have taken the cost of batteries down sharply



in recent years. The industry has set a target of $100 per kwh where battery costs would be considered "affordable" for consumers, and current projections suggest this target could be met by 2020-22. The lower price could also make it more affordable to have a longer range by way of a larger battery.

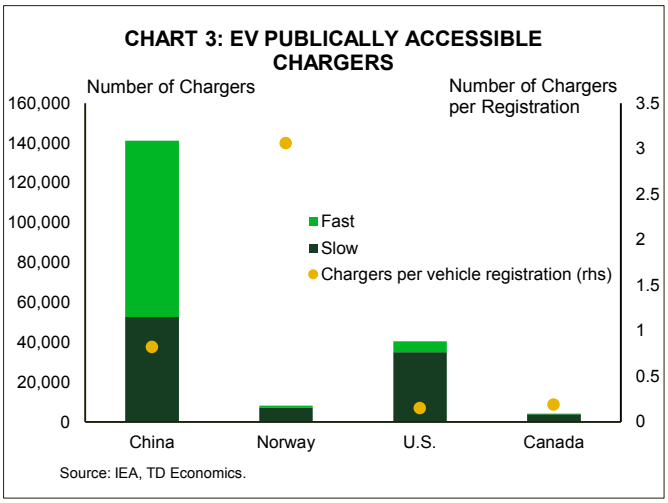
Efforts are being made to increase charging station networks in North America and around the world. In the US, over 50,000 charging stations were in operation in 2017, up from 5,000 in 2011 and 25,000 in 2014. The charging network is most pronounced in California, which alone has nearly 16,000 stations. It is no coincidence that California also has the largest share of EVs, accounting for 12% of the market in 2015. Such moves to increase the charging network should be supportive of demand, but more is needed in order to eliminate range anxiety. Overall, EV uptake is likely to be more pronounced in areas that are densely populated where drivers would benefit from free parking and use of high occupancy vehicle (HOV) lanes versus more rural areas that require more dependence on driving and are likely to have less charging infrastructure.

Could Tesla's ambitious growth plan help to take the EV market to the next level?

All eyes are currently on Tesla Inc. and its recently launched new EV product – the Model 3 – that it hopes can sell on a mass scale, and in turn move down the production cost curve. The rollout has been slower than initially planned, with the company citing "production bottlenecks" as the cause. Production targets have thus been pushed back by a few months. Given the delays, it will likely be a year or so before analysts have a better sense for whether Tesla's strategy is paying off.

As part of its growth strategy, Tesla has recently opened the world's largest battery factory – the Gigafactory – which is expected to ramp up production rates to supply 500,000 EVs with batteries per year, and the automaker is talking about building additional Gigafactories. In fact, there are reportedly 12 new or expanded battery factories set to open by 2020. This production scale could help to add further downward impetus to battery prices, but could create other challenges. There are concerns that there will not be enough raw materials to support the number of lithium-ion batteries that would be needed to support an entire fleet of electrified vehicles. In particular, cobalt is costly to mine and the majority of the mineral is found in an unstable country (DRC). However, if demand picks up, cobalt projects in other countries could become economical. As well, research is being conducted to see if batteries can be produced using other metals, or reduce the amount of cobalt in each battery. Further research and development is needed on this front, but if demand is there, batteries should be as well.

Hydrogen fuel cells are another environmentally friendly technology that has been developed. These vehicles use hydrogen and oxygen to produce electricity to run the motor. The fuel cell is quick to refuel (unlike EVs) and vehicles get a range similar to conventional cars. This could be a clean alternative if battery supply is lacking. However, associated infrastructure such as refueling stations would need to be ramped up.



What are the prospects for government-supported EV policies?

As part of the their carbon-reduction and environmental strategies, governments in North America and around the world are likely to continue to support both sales of electric and hybrid vehicles as well as R&D activities. For example, in the U.S., EV buyers can currently receive a federal tax rebate of up to $7,500, with some states and cities offering additional incentives. Tools other than purchase subsidies include breaks on municipal parking fees, road tolls, purchase and import taxes, licensing fees and/or charging costs as well as permission to drive in HOV lanes. On the flip side, one negative for the government of a shift toward electric vehicles is the lost revenues generated by gasoline taxes.

However, governments continue to face fiscal pressures from across the gamut, which is likely to limit the extent to which financial support can be ramped up further. And in jurisdictions that face significant budget pressures (such as the U.S. federal level) there could be increasing pressure to reduce or eliminate revenue initiatives. In that case, the success of EVs will boil down even more to the success of auto producers in eliminating the cost gap with ICEs.

To the extent that governments move to price carbon and increase regulations on fossil fuel industries, this will naturally shift incentives towards EVs. Not only will this make EVs relatively more appealing, this will also generate revenue, a share of which could be recycled to supporting incentives for EVs and other clean technologies.

As well, the government can invest in associated infrastructure, including measures to ensure adequate supply and distribution of electricity. As mentioned, some governments have already undertaken such initiatives, but further increasing the network of charging stations throughout North America will be necessary once electric vehicles become more common. And, if done sooner, it would also help increase consumer demand by reducing range anxiety. Consumers need to know that they'll be able to charge up no matter where they drive. Ideally, governments should invest in fast chargers in order to improve desirability for consumers.

Will electrification be the way of the future?

Assuming that battery costs continue to decline, prospects remain bright for EV sales to jump to at least 10% over the next 5-10 years. However, Norway-like shares of 40% appear to be a very tall order. It is clear to us that the industry is still decades away from having a pure electric fleet of vehicles.

Are AVs ready for prime time?

Mass adoption of autonomous vehicles is likely much further out on the horizon than EVs, given that EVs are already on the roads today. But, the technology is gradually falling into place. A number of new vehicles now offer a host of technologies that will eventually work together in a self-driving vehicle. These features include: adaptive cruise control, automatic emergency braking, lane assist, back-up cameras, etc. Right now, these are considered safety features. But, step-by-step, they are bringing the industry closer to fully autonomous vehicles.

Similar to electrified vehicles, these features come with a price tag, so not all consumers are purchasing vehicles with this technology, but some are becoming standard. While there is no requirement for an AV to be an EV, the two are often talked about together given the goal of reducing human input. In addition to less maintenance than a traditional vehicle – which is useful for ride sharing companies – the ultimate goal is that the battery in the EV will also power the onboard technology in the AV.

When are fully autonomous vehicles expected to hit the roads?

Predictions vary widely on timing of when fully autonomous vehicles will hit the road without any restrictions, with some automakers making bold predictions that they will have AVs on the roads within the next few years. For example, GM has announced a large-scale fleet of AVs by 2019; Nissan to begin robo-taxi service by the early 2020s; Mercedes to begin selling AVs by 2020 and BMW by 2021. Some industry forecasts suggest that AVs could account for up to 15% of new car sales by 2030. These announcements, however, all came with the caveat that safety comes first and the timing will depend on when vehicles are deemed safe enough. So, these dates may be premature. In fact, Volvo has recently scaled back its

experiment for AV testing of Level 4-ready vehicles (in which the driver does not need to be engaged) with regular people in Sweden from 2017 to 2021, as they have found more issues to solve than they had expected. As such, most industry estimates suggest we are at least a decade away from the widespread deployment of fully self-driving vehicles.

But, the testing is underway. A number of US states have already announced legislation for testing autonomous vehicles on public roads in some capacity. Perhaps the most advanced testing is being done in some parts of Phoenix Arizona, where Waymo is testing a Level-4 vehicle with no driver in the seat. The more places that these vehicles can be tested the better, as AVs must experience and succeed in navigating all types of terrains and weather/road conditions before they can be deemed safe for public roads. Few regions require safety incidents to be reported, so getting a clear picture of how AVs are doing on public roads thus far is not easy. Still, automakers are using these experiences – such as when the technology fails or needs to be tweaked to respond to a certain situation – in order to perfect the technology. It will likely take time to ensure there is an appropriate response to any and every type of situation.

It is clear that autonomous vehicles are still in the very early stages of testing and there are a number of kinks that will need to be worked out before they are safe to put on the roads. But, even once they are ready, public appetite for self-driving cars is still unknown. Surveys indicate that the majority of respondents would not consider riding in a fully self-driving vehicle. Comfort and acceptance is likely to grow as these vehicles are further developed and marketed, but it will likely be a gradual process. Perhaps introducing these vehicles first within mobility services such as driverless taxis – as some companies have indicated the intent to do – will allow consumers to experience and become more accustomed to the technology before they are ready to own one.

Other than the technology, what other issues are holding back AVs?

Once the technology is ready, there are other serious issues that will need to be addressed. Regulations, guidelines and vehicle licensing relating to requirements that vehicles will need to be allowed on public roads will be key. For example, there are multiple levels of autonomous driving capabilities, so regulations on which level(s) will be permitted will need to be determined. Ideally this should be done at the national level so that rules are consistent across a country.

Self-driving cars will also fundamentally change the insurance industry, as insurers will be covering the technology rather than the drivers. This raises the question of whether it will be the OEMs that will be insured similar to cruise lines and shipping companies or if vehicle owners will have to be insured as well. Determining who is at fault in an accident may also be difficult depending on the situation.

How will AVs impact mobility?

Mobility has been another area that automakers have been focusing on in recent years, with a number of ride sharing, delivery service and transportation programs popping up. Uber has been widely successful in disrupting the taxi industry, spurring taxi companies to move towards online or app-based technologies in order to remain competitive. Ride sharing programs have replaced vehicle ownership for some who live in densely populated areas where these services are most effective. Autonomous vehicles could enhance this mobility, as it removes the human element. Indeed, the concept of robo-taxis would use driverless cars to transport passengers around, picking them up and dropping them off in convenient locations such as their homes.

Moreover, self-driving vehicles could perform simple delivery services such as food delivery, eliminating the need for an actual delivery person. Self-driving trucks are also being tested in the trucking industry, which would allow transport trucks to transport goods without requiring a driver. Public transportation such as city buses could also shift to autonomous vehicles.

How will autonomous driving and mobility impact infrastructure?

Given the development of artificial intelligence, vehicles should be able to drive on many existing roads. But, with autonomous vehicles on the roads, there are a number of ways in which infrastructure and city planning will change. For example, repainting lane stripes,

improving/digitizing traffic signs and lights, and widening highways will become important as infrastructure is upgraded. Hence, city planners will place more emphasis on computing systems and digital technology that is embedded in roads, signs and traffic lights rather than focusing on the roads themselves which shouldn't need as much work. Weather information, speed center, and traffic management systems will also be a focus and is likely to become digitized.

Increased mobility services would require adding curb space for drop off zones, although to some extent, these services would reduce demand for parking and parking lots, potentially opening up land for other uses.

How will government responsibilities be impacted by AVs?

Governments at all levels will have to work together to develop plans for infrastructure, licensing and guidelines for autonomous vehicles, and figure out which jurisdiction each of these will fall under. While self-driving vehicles aim to make roads safer, they will also be trained to follow the rules of the roads. Hence, government revenues generated from traffic and parking violations will likely be reduced. Moreover, given that autonomous vehicles should reduce the amount of accidents, government resources could be shifted away from accident management, and toward technology and cybersecurity. As well, resources could be spent annotating the mass amount of data that is collected from vehicles, in order to turn it into useful information.

Another issue that will need to be addressed is privacy. With all the data that will be collected and shared in these high-tech vehicles, passengers will be watched constantly, with personal information and daily routines easily obtainable. Governments must set out rules on use of this data and help automakers ensure that it is used in a way that adheres to privacy legislation.

Which industries will be affected by the mass adoption of EVs and AVs?

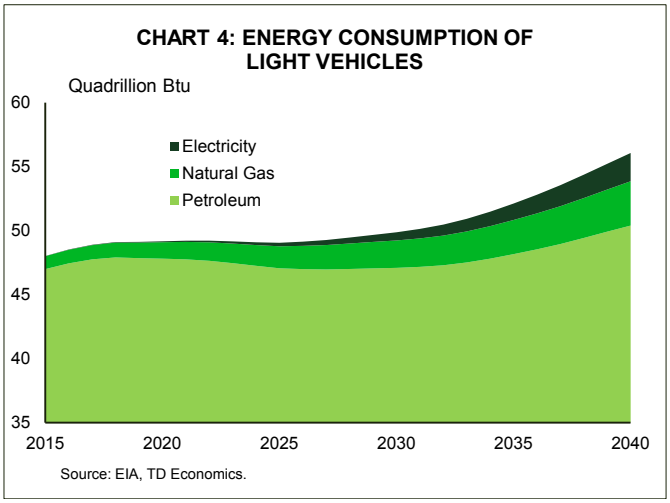
Even if the shares of electric and autonomous vehicles on the roads don't change dramatically overnight, the push towards these vehicles is definitely underway and could accelerate substantially alongside technological development. As such, economic and sectoral impacts could become increasingly visible in the coming years.

How will the oil industry be impacted?

The ultimate goal of electric vehicles is to reduce the carbon footprint. This would clearly have negative implications for oil demand. However, the reduction in oil demand will be quite gradual for a number of reasons. First, we are still years away from sales shifting to electrified only vehicles. Second, "electrified" includes hybrid vehicles, so the internal combustion engine will be around for some time still. Third, the stock of vehicles on the road today is heavily reliant on gasoline. And even if sales were to become solely electric, it would take decades before the current vehicles in operation were taken off the roads. According to the EIA – which expects EVs to account for 14% of global sales by 2040 – electricity consumption in light vehicles is expected to rise by 80% by 2040 versus 2016 levels. Even with this increase, petroleum based fuel consumption of light vehicles is expected to increase slightly by 2040.

The bigger issue for oil demand will be increased fuel economy standards (including improved efficiency of the internal combustion engine) and policies to reduce miles-driven (addressing congestion and pollution) and lower transportation linked to industrial production.

This will have implications for oil producing regions, including the U.S., with spillover effects on the refining industry. Eventually, demand for gasoline stations could be reduced, although we are still decades away from



that. All told, oil will still be the primary fuel used over at least the next decade, but growth prospects continue to be capped.

What does this new technology mean for automakers?

With all the new technology being developed, automakers have to ensure that they don't fall behind and become uncompetitive. Some have been late to the electrification game, choosing to let others spend the resources on developing the technology while others are striving to be market leaders. Either way, the selection of electrified vehicles has slowly ramped up in recent years, and is likely to accelerate going forward given the plans announced thus far.

With respect to automation, automakers have to decide how to package and price the advanced safety features, while remaining competitive on which features are offered and at what cost. While not all automakers have jumped into AV development, eventually, once the technology is ready, they are all likely to offer it.

Given the complexity and cost of developing fully autonomous vehicles, automakers have increasingly been looking to parts makers to help generate new innovative features. And, some have begun to form alliances. Not just with other automakers, but with parts producers as well as tech companies. Some are working with auto sharing companies or creating their own. It will take a collaborative effort to bring these vehicles to market and more alliances or partnerships are likely going forward.

The shift toward more electronics in vehicles means that upgrades will be required at some point. Automakers must also focus on building vehicles that can easily be upgraded without having to go to a dealership. Moreover, more electronics means that automakers must allocate some resources to cybersecurity, in order to ensure that vehicles cannot be hacked into and taken over remotely.

While much of the electronics manufacturing may be done in lower cost regions, the design and engineering of these vehicles can be done closer to home. All of this collaboration and innovation presents great opportunities for tech and engineering firms.

How will auto sales be impacted?

All the new technologies that have been introduced in recent years have attracted consumers to showrooms, helping to prop up sales. This is set to continue so long as new innovations that increase safety and connectivity make their way into cars.

Increased mobility such as auto sharing could eventually lead to lower ownership rates, which would reduce retail sales of new vehicles. Demand for fleet sales would provide some offset as these auto sharing companies would need to ensure enough vehicles to keep up with demand. Moreover, cars that are shared – including taxis and car sharing vehicles – tend to rack up the miles quicker than privately owned vehicles and thus wear faster. Hence, these vehicles will need to be replaced sooner than privately owned ones typically would, increasing the sales cycle.

However, despite being available for years, ride sharing accounts for less than a tenth of a percent of all vehicles on the roads, suggesting that consumers still feel the need to own their own vehicle. As such, auto makers should still focus on retail sales, as private ownership will continue to be the key driver of auto sales for the foreseeable future.

Will the auto retail industry change?

For dealerships, there has been some concern that technology that allows for online shopping and no haggle pricing could eventually eliminate the need for showrooms. However, many consumers prefer to test drive vehicles before purchasing them. Of course, there are some examples in which the vehicles pick consumers up at a certain location such as their work or home and allow them to take the test drive without ever having to visit the dealership. Autonomous vehicles could advance such a system. Still, many – particularly those that are not so tech savvy – prefer the dealership experience and find it beneficial to have a salesperson demonstrate some of the features of the vehicle in order be able to fully utilize them.

It follows that salespeople will have to have more of a technological background so that they are comfortable explaining and promoting some of these features. Some

automakers have a specialist in each dealership for such purposes. This could become more common as vehicles become more technologically advanced.

To the extent that ride sharing were to rise to the detriment of private ownership, auto lending would similarly shift from a focus on retail to more commercial lending, to meet the financing demand from fleet sales.

How will the service side of the industry be impacted?

Electric vehicles generally do not require as much maintenance as those with an internal combustion engine, as oil changes, spark plugs, and air filters for example are not found in these vehicles. However, with the rise in electronic components in newer vehicles, service centers will increasingly have to shift toward a workforce with more of a technology background rather than a mechanical background. Moreover, should something breakdown on an EV or AV, "do it yourself" repairs will not be as easy for drivers, and repairs are likely to be more costly.

Traditional body shops are likely to see a drop in demand, as all the enhanced safety features and eventually self-driving vehicles will result in less accidents, and hence less demand for body repair.

How is the role of supplier changing?

Suppliers are increasingly being looked to by automakers to play an active role in developing new innovative technologies. Indeed, new products from parts makers have contributed to the safety features and fuel efficiency measures already available in vehicles today and those that are forthcoming.

Moreover, with components becoming more complex, demand has grown faster than capacity in some instances, leading to longer lead times. Over time, suppliers are likely to adopt automated smart distribution technologies which could lead to leaner supply chains and reduce labour costs while boosting productivity.

With electronics becoming a more integral part of each vehicle, a great deal of design and engineering will be required. As such, in addition to traditional parts manufacturers, suppliers will also consist of technology firms, including those involved in hardware and software engineering, artificial intelligence, communications, and big data.

Bottom line

The bottom line is that disruption will continue in the auto industry for some time to come. How quickly new technologies such as EVs and AVs become adopted by the masses remains to be seen, but it is likely to be a gradual process with several speed bumps along the way. The impact on the number of auto sales is unlikely to be substantial, although there will be a shift in which vehicles are sold. Industry players – OEMs, suppliers, tech firms, insurance providers, governments – will all have to remain on their toes, and keep up with the evolution of the industry. Five years from now the industry may look largely similar to the way it does today. But that won't always be the case. Determining exact timing on when major shifts will take place is impossible, but decades from now, the industry and how we get around will likely be very different.

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