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Driverless cars: How innovation paves the road to investment opportunity

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About this paper

Disruptive technologies and trends are radically reshaping the investing landscape across sectors, asset classes and geographies. This paper is the first in a series examining the investment implications of these innovations.

We are at a point in history where computer science and technology are enabling the creation of products and services that previously existed only in the realm of science fiction. In this article, we consider the investment implications of one such game-changing innovation: autonomous driving technology, or driverless cars. The global market for these vehicles is expected to reach the trillion US dollar mark by 2025.[1] We also explore the impact of the technology on key global industrial sectors, such as auto manufacturing, transportation services and freight.

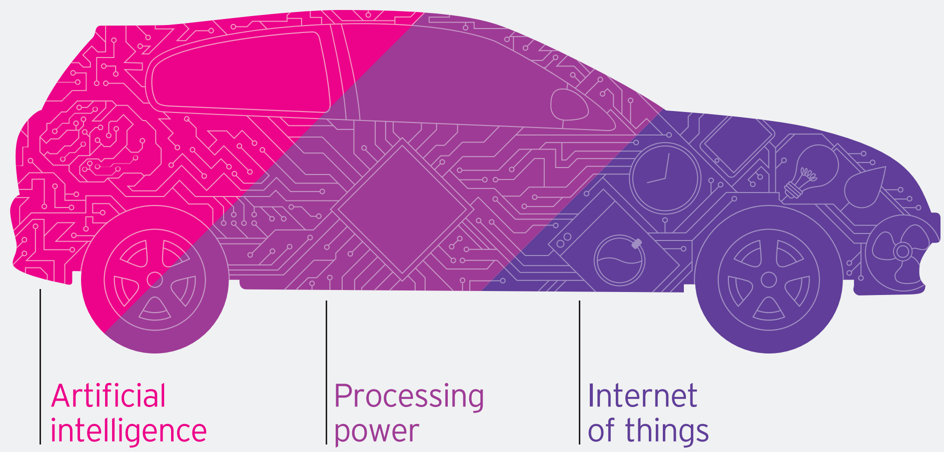
Continuing improvements in computer processing power, artificial intelligence (the ability to program computers to "learn" like humans) and the growing network of smart devices communicating directly with one another (often referred to as the "internet of things") have created a new ecosystem ripe for disruption and new entrants in global industry. Artificial intelligence began as a sub-discipline of computer science in the 1950s. The scope of what we continue to "teach" computers has become increasingly complex as input data sets grow larger and data scientists develop deeper "thinking" algorithms.

In recent years, artificial intelligence has moved beyond machine learning, which gives a computer the ability to predict outcomes based on previous data, to so-called "deep learning," which involves synthesizing numerous inputs and allowing computers to make decisions on their own. Computer scientists are designing artificial neural networks incorporating algorithms that function in a similar way as natural neural networks in the human brain. This enables computers to understand complex and abstract concepts.

This type of intelligence has allowed machines to beat humans at games of skill such as poker and Go.[2] And it can also enable vehicles to navigate roadways with multiple inputs and constantly changing scenarios. This intelligence is already at work in today's smart cars, in technology such as adaptive cruise control, crash-avoidance systems, night-vision capabilities and intelligent parking assistance.

The autonomous driving experience is enabled by a complex network of sensors and cameras that recreate the external environment for the computer. Fully autonomous vehicles supplement destination information provided by passengers with information collected by radar sensors, LIDAR[3] and cameras — distance from surrounding objects and curbs, lane markings, visual information of traffic signals and pedestrians. This information is processed to tell the car when to accelerate, brake or turn. Because of the quantity of information involved and the speed at which the vehicle needs to compute continuous data inputs, processing power plays a crucial role in enabling the full development of autonomous vehicles (Figure 1).

Figure 1: What makes driverless cars possible?



Source: Invesco. For illustrative purposes only.

Where we are today

Many cars today already contain some elements of an autonomous vehicle. For example, as a driver approaches his or her vehicle with a key, a wireless chip may cause the doors to unlock automatically. As the driver shifts into reverse, sensors mounted in the front and rear corners of the car collect data via cameras and radar. That data, along with speed and other operating data, is collected by a processor in the car. Software algorithms that understand the relationship between speed and distance analyze the data and alert the driver or apply the brakes if an obstacle in the vehicle's path represents a collision risk. As the driver heads down the road, the vehicle's camera, radar, LIDAR and other sensors continue to observe the environment. These technologies send data back to the vehicle's processor to create a 3D image for analysis, and to prompt any actions that the software algorithm might deem necessary. In a fully autonomous vehicle, mapping software would also help identify when a vehicle should change directions. Currently, there is no standard platform for all of these technologies and so, for example, one automaker might choose to include multiple cameras while another might choose to use a single camera but more radar sensors.

While great strides have been made over the past several years in the development of autonomous driving, fully autonomous vehicles have yet to be introduced on a large scale. Figure 2 highlights increasing Levels of driver automation as defined by the US Transportation Security Administration (TSA).

To date, most people have only experienced Levels 0-2. However, Uber recently began operating Level 3 self-driving vehicles, which include drivers but operate in self-driving mode in a limited number of US cities. Meanwhile, in late 2016, Baidu ran a trial operating Level 3 autonomous vehicles from three Chinese automakers carrying passengers within a two-mile district. Level 3 was also successfully demonstrated in a recent real-world test conducted by Uber's self-driving truck company, Otto, in the US. The company partnered with beer brewer AB InBev to haul some 52,000 cans of beer across 120 miles of highway using a self-driving truck in which the human passenger only monitored the self-driving system from the back sleeping berth. The success of this test bodes well for the future adoption of autonomous trucking on a wider scale. For more details on US trucking see box on page 8 (Keep on truckin').

Figure 2: TSA-defined autonomous driving Levels

Level 0	Driver in full control at all times	No automation
Level 1	Driver is assisted by collision-avoidance technologies	Some assistance technologies, like blind spot detection and collision warning
Level 2	Driver can disengage from certain functions	Automation helps with the vehicle's "moving" functions, such as park assist and cruise control
Level 3	Driver disengaged but available if needed	Full automation but driver must be present behind the wheel
Level 4	Complete disengagement on controlled routes only, such as highways	In limited environments, no driver needed behind the wheel
Level 5	Fully autonomous	Human replacement; can go anywhere without a driver

Source: US Department of Transportation, Federated Automated Vehicles Policy, September 2016

McKinsey estimates that, by 2030, fully autonomous cars could represent up to 15% of passenger vehicles sold worldwide, with that number rising to 80% by 2040.

Are we there yet? Are we there yet?

Today's available technology likely paves the way for broader acceptance of Level 4 solutions, which target vehicles that operate under highway conditions. Currently, the hurdle between Levels 3 and 4 is mainly regulatory. However, between Levels 4 and 5, the leap is much greater — achieving the technological capability to navigate complex routes and unforeseen circumstances, a feat that currently requires human intelligence and oversight.

McKinsey estimates that, by 2030, fully autonomous cars could represent up to 15% of passenger vehicles sold worldwide, with that number rising to 80% by 2040, depending on factors such as regulatory challenges, consumer acceptance and safety records.[4] While many Level 3 vehicles will roll out this year, Volvo already has Level 4 vehicles on the roads in Sweden, and Tesla (which recently surpassed Ford and GM in market capitalization[5]) plans to include Level 4/5 autonomous technology in certain models to be shipped in 2017. Over the next four years, other major manufacturers also plan to roll out autonomous vehicles: Mercedes (currently road testing), GM (2018), Nissan (2020), PSA Group (2020), BMW (2021) and Ford (2021).

Given that it often takes two or three years to design and produce a new vehicle platform, suppliers to original equipment manufacturers (OEMs) are now jockeying for position. Also, given that the average vehicle remains on the road for well over a decade, it seems likely that some automakers will pack more electronics into their vehicles than may be necessary at first. That way, as road regulations and the market evolve, these vehicles may be easily upgraded or enabled to take advantage of the changes.

As investors, we must identify potential winners and losers well before automakers roll out their final products. Corporations understand this too, and in only the last six months there have been four announced acquisitions amounting to nearly US$70 billion for technology suppliers with strong competitive positions in the autonomous driving market (Figure 3). These large-scale acquisitions, and others that presumably lie ahead, are likely to accelerate the pace of autonomous vehicle development. While we may not see fully autonomous vehicles in widespread use on the roads for some time, value is already being recognized by the market.

Figure 3: Recent autonomous vehicle technology acquisitions

Date	Target	Acquiror	Value (US$ billion)	Product
Pending	NXPI	Qualcomm	46.0	Components
March 2017	Harman	Samsung	8.7	Software
Pending	Mobileye	Intel	14.1	Software
March 2016	Cruise Automation	GM	1.0+	Software

Source: Company press releases.

Safety first

Perhaps the greatest challenge in bringing Level 4/5 vehicles to the public is in meeting safety standards, since the more autonomous a vehicle is, the more powerful and fail-safe the technology must be. As a result, some regulators are beginning to mandate smart features in vehicle manufacturing. For a set of driving hazards, a safety Level is determined based on the hazards' potential severity, probability of occurrence and controllability (driver's ability to react). Fully autonomous vehicles are currently considered to have low or no controllability, creating much higher hurdles to acceptance.

We believe that the fully autonomous driving investment opportunity will reward significant technology and engineering advancements: Technology providers that help reduce the probability and severity of an accident are likely to be rewarded, while those companies that do not adapt are penalized – or fall by the wayside. As an example, the National Highway Traffic Safety Administration studied Tesla before and after the company deployed its Autosteer lane-keeping technology, and found a 40% reduction in crashes. In response to this, some insurance companies are providing discounts based on the number of miles driven while using Autosteer. This is an initial manifestation of a forecast by KPMG in 2014 that personal auto insurance industry premiums would decline by 40% from current Levels within 25 years, due to a sharp reduction in the frequency and severity of accidents.[6]

Greater complexity = greater opportunity

The US experienced approximately 40,000 road fatalities in 2016, with an additional 4.6 million people injured and associated costs estimated at a staggering US$432 billion.[7] Most of these accidents were caused by driver error. With economic incentives to automate driving already becoming apparent, the push to achieve higher levels of autonomy should generate even more interest. The volume of electronics in a vehicle grows exponentially as the Level of autonomy increases, providing a significant growth opportunity for technology companies with the right products. For example, to achieve Level 2 autonomy, a vehicle needs four specific sensors – but that requirement doubles to achieve Level 3. Achieving Level 4/5 autonomy necessitates up to 21 sensors to create a road- and hazard-monitoring cocoon around a vehicle (Figure 4). The sensor dollar content opportunity alone increases from US$35 per vehicle at Level 1 to US$325 per vehicle at Level 4, a more than 9x increase for technology providers.[8]

Level 4/5 autonomy will require an increasingly powerful chip to process the huge quantities of data generated by these sensors and to change a vehicle's actions. Furthermore, separate chips will be needed to control the physical movements of the vehicle. Autonomous driving is pushing research, development and consolidation in the chip sector much like internet gaming did in the previous decase.

Autonomous vehicles will also require microphones for voice commands, chips to permit communication with other vehicles and objects, and more. We estimate that additional components will rise from US$20 per Level 1 vehicle to US$370 in a Level 4 vehicle. Mapping software and software algorithms that provide the intelligence to power the chips will become competitive differentiators, as will the vast quantities of data (collected from real-world driving experience) that are used to train the software. In fact, Ford recently announced that it would invest US$200 million to build a new data center to house consumer information associated with connected and autonomous vehicles.

The autonomous vehicle opportunity is strategically important to a large and diverse set of incumbents, including technology companies (e.g., Google, Uber, Baidu and Nvidia), automobile manufacturers (e.g., GM, Ford, Tesla and Toyota) and original equipment manufacturers. Creating autonomous vehicles is also a capital- and labor-intensive process in a heavily regulated industry. In other areas of technological disruption, where the product and challenge is software-based, startups can leverage cloud computing and storage to build and release a product with more limited capital. However, the challenges with autonomous vehicles are rooted in hardware and regulatory dynamics that inevitably require more capital investment, limiting participation by companies that are not well-capitalized. Moreover, sensor, mapping and vehicle usage data will provide competitive advantage for incumbents like Uber, Lyft and Didi (China's largest ride-sharing service), creating a barrier to entry for startups. As a result, many startups are focusing on niche, enabling or derivative opportunities stemming from an autonomous world. Startups with a head start quickly become acquisition or investment candidates for strategic players keen not to get left behind. GM bought the self-driving technology startup Cruise Automation last year. Meanwhile, Ford purchased the ride-sharing service Chariot, and more recently committed to invest US$1 billion in the Pittsburgh-based Argo AI in hopes of both expediting Ford's ability to get a self-driving car to market and potentially licensing the technology to others. Thus, in our view, incumbent (public and private) technology and automobile companies will significantly drive the adoption of autonomous vehicles, but new entrants will contribute throughout the value chain.

As noted above, safety regulations pose a significant near-term challenge to getting fully autonomous vehicles on the road in non-controlled settings. A number of startups are addressing this intermediate step. ZenDrive focuses on the overall safety of the driving ecosystem, utilizing smartphone sensors to deliver safety insights to fleet owners and other enterprise customers. Nauto, meanwhile, designs artificial intelligence for collision avoidance with an aftermarket component add-on that collects and processes visual data. Rather than functioning as a core-autonomous vehicle company, Nauto is more focused on upgrading existing connected cars. Another company, INRIX, leverages real-time, predictive data analytics for traffic and mapping to assess the safety and traffic implications of accidents.

Companies that provide the components required for technological upgrades can benefit as consumers demand safety features that reduce their risk and can lower their insurance bills. Many startups and venture capitalists have identified enabling technologies, like computer vision and - user-generated mapping, as areas where they can facilitate the development of autonomous vehicles. Navigation (including understanding signage) and mapping are necessary to build the autonomous vehicle operating system and artificial intelligence training, as autonomous vehicles require much greater detail than pedestrians. Google's self-driving car division, Waymo, has been engaged in a whole new Level of mapping the world, including "the height of a curb, the width of an intersection and the exact location of a traffic light or stop sign."[9]

Computer vision has many applications, but is of growing importance to autonomous vehicles in mapping environments to the nearest centimeter, as well as avoiding pedestrians and other vehicles. Increasingly, manufacturers are planning for a future in which mapping and obstacle detection and avoidance are driven by computer vision in addition to LIDAR sensors. Tesla recently stripped out Mobileye technology from its vehicles and built its own camera-based system that leverages ultrasonic and radar sensors. Here, a Nokia spin-out company backed by BMW, Daimler and Audi (named Here), is focused on mapping roads in the US and Europe using a combination of sensors and computer vision. The company, which last year announced a partnership with Mobileye, relies on a combination of data from scanning systems installed in trucks, alongside its own image-collecting fleet. The data is then annotated (manually or by computer) to produce the maps. In a similar vein, Mapillary is a service for crowdsourcing street-view photographs and matching them across time and location, leveraging computer vision. Mapillary uses machine learning to sort through its vast database of street-view photos and identify those most relevant to autonomous vehicles, which the company then sells to manufacturers. Computer vision and navigation may not create large, stand-alone public companies, but are crucial enabling technologies, and could spawn companies that will help shape the development of autonomous vehicles and become prime candidates for strategic acquisition.

At the same time, other players are building the full autonomous kit (using both hardware and software) to sell to car manufacturers or aiming to create full autonomous vehicles themselves. Aurora Innovation, founded by former Alphabet self-driving guru Chris Urmson, is in stealth mode, but is reportedly taking the former approach. Drive.ai has adopted a more holistic approach, using deep learning throughout instead of manually creating rules to help algorithms identify objects. On the service side, Zoox has raised almost US$300 million, at a US$1.5 billion valuation, to create a fleet of autonomous vehicles for the purpose of mobility-as-a-service – competing with the likes of Uber and Didi. While these players will likely see outcomes further down the road than the smaller niche players discussed above, they have the potential to become either strategic partnerships for other, more vertically focused solutions, or eventually, acquisition targets for large autonomous vehicle incumbents.

While there are certainly a significant number of new entrants raising large sums of money to address the opportunity to manufacture and sell autonomous vehicles, others are more focused on getting vehicles to market more quickly and cheaply. Some companies are targeting lower-hanging fruits by getting products that are not fully autonomous into the market, while others (such as Optimus Ride and nuTonomy) are working to roll out slow-to-moderate-moving vehicles on private roads (e.g., private developments and college or corporate campuses), where the regulatory hurdles are not as significant. Optimus Ride and nuTonomy are taking this approach. Meanwhile Comma.ai, similar to Nauto, is focused on retrofitting existing vehicles using off-the-shelf components, while open-sourcing the data from its driverless trips.

Wider implications

The early winners in the shift toward autonomous driving are likely to be technology providers. This could create opportunities in the semiconductor, software, audio visual and radar technology areas that make autonomous driving possible. However, as mentioned above, there will likely be losers too: Figure 5 provides a sense of the enormous range of driver-dependent industries likely to be impacted. As the responsibility for driving shifts from individuals to technology companies and vehicle manufacturers, we are likely to see a significant impact on these firms' economic and business models.

Figure 5: Industries impacted by the shift to autonomous driving

Auto repair	Collision repair is a US US$30 billion industry
Medical	US$23 billion bn in medical expenses due to vehicle crashes
Auto insurance	US$220 billion bn in annual policy premiums
Municipalities	Reduced traffic violation revenues
Legal profession	76,000 personal injury attorneys in the US
Construction	Less parking; lane design changes
Digital media	Benefits from "free time" in vehicles
Oil and gas	20-30% decrease in demand

Source: Department of Transportation, McKinsey, KPMG 2015, Economic Effects of Automated Vehicles, Lewis Clements, Kara Kockelman, January 2017

The rise of autonomous vehicles may also disrupt the property and casualty insurance market, as auto insurance is currently this market's largest, most profitable segment. It could have a critical impact as this industry has been saddled with losses due to substantial decreases in premiums; insurers will also need to adjust their loss risk models significantly over time. If accident rates between human drivers and autonomous vehicles are sufficiently different, it may actually become illegal at some point to drive cars personally.

In the intermediate term, the cost to insure a vehicle may actually increase as loss severity (the cost to fix the vehicle) moves higher due to the increased dollar content of the components and the software featured in newer autonomous vehicles. However, over the longer term, we would expect the frequency of accidents to decline, which should reduce industry loss costs and, ultimately, premiums. The impact of this trend is already being felt, as some insurers with significant auto underwriting exposure are expanding into new business lines in order to remain relevant to the consumer.

Autonomous vehicles could also have a profound impact on real estate markets. First, the potentially significant reduction in traffic and travel times will undoubtedly change the value proposition of living in cities versus living in suburbs. Simultaneously, their presence may free up urban real estate previously occupied by curbside parking or parking lots and garages, including those at airports, as more people rely on autonomous vehicle services rather than driving and parking their own vehicles. These dynamics could lead to a substantial decline in urban real estate prices in both the commercial and residential markets.

Autonomous driving has the potential to affect a host of seemingly unrelated industries as well. Ancillary businesses are already popping up to capitalize on the new trend. For example, the online education company Udacity, which is striving to become the "University for Silicon Valley," just launched a "self-driving car engineer nanodegree" to address the dearth of qualified deep learning engineers with autonomous vehicle experience.

The road ahead

While, as noted earlier, 2016 saw significant advances in the development of autonomous driving hardware and related M&A activity, there are - sub-segments of autonomous vehicle-enabling technology that clearly need to be developed before fully autonomous vehicles can become a day-to-day reality.[10] As noted earlier, regulation may also create headwinds as governments try to ensure public safety while encouraging continued technological advancement. Moreover, the increasing prevalence of driverless vehicles and other automation technology will be accompanied by a variety of novel and difficult ethical and societal issues,[11] such as how to deal with the significant job losses they will cause. Finally, widespread acceptance of autonomous vehicles will depend in large part upon manufacturers' ability to produce them at price points that are accessible to large numbers of consumers.

We will likely see waves of innovation and newer entrants focused on the development of these enabling technologies. The industry has already seen this pattern; for example, innovations in the internet of things and connected cars have paved the way for safety, communication and navigation technology that leverages the wave of newly created data. Although some of these enabling opportunities may not be as truly transformative as autonomous vehicles, they can provide lucrative and nearer-term startup and venture capital opportunities. Moreover, many of these enabling and ancillary technologies can become prime acquisition candidates for strategic players in their race for autonomous primacy.

Autonomy could ultimately provide an additional boon to car manufacturers, as it represents a steep change in functionality that – combined with greater individual car utilization – may abbreviate the upgrade/replacement cycle, much like the phone or laptop. It could also modularize and lead to prioritization of different features across models. The "car as a platform" would also create many derivative opportunities and challenges, necessitating the creation of relevant applications and cybersecurity.

As personal car ownership declines, it is possible that autonomous vehicle manufacturers will shift from a business-to-consumer to a business-to-business model, which may ultimately result in consumers interacting with fleet operators as they currently do with air travel. This could happen not only for cars, but for other vehicles as well. For example, NEXT Future Transportation is already building modular autonomous bus systems focused both on highways and last-mile transport. Fully autonomous vehicle fleets could ultimately function like a city bike-share program, or perhaps even as a public utility, enabled by fleet optimization software and car-to-car communication capabilities. The latter may also involve a machine-to-machine payment system utilizing blockchain-based tokens like bitcoin (e.g., a driver in a rush makes a payment to other cars to move out of the way). Blockchain and bitcoin have long been transformative technologies in search of "killer applications" or use cases, and an automated world could finally provide this.

When assessing the investment implications of autonomous vehicles, new opportunities within the automotive, transportation and technology industries spring immediately to investors' minds.

Conclusion

When assessing the investment implications of autonomous vehicles, new opportunities within the automotive, transportation and technology industries spring immediately to investors' minds. However, it is important to consider those ramifications that may not be as readily apparent: Real estate portfolios could be affected by shifts in residential and commercial demand patterns driven by changing commute times and parking needs. Financial services providers could be impacted by new types of insurance policies or a move away from widespread vehicle ownership. The list of winners and losers in the driverless vehicle era will continue to evolve rapidly, just as the investment landscape did with the rapid growth of personal computing, internet retailing and other transformational trends. It will therefore be critical to anticipate, analyze and adapt to these changes, something that active managers like Invesco do every day, in order to identify and act upon tomorrow's investment opportunities, today.

US trucking industry

Quick facts
Moves 70% of US freight
15 million operational trucks
Mostly interstate highway driving

Challenges
Labor: 30% of trucking costs
Fuel: 40% of trucking costs
Scheduling, inefficient routing

Source: American Trucking Association, Auburn University, Roland Berger 2016 , Trucks.com, "Autonomous and Self-Driving Trucks will Improve Safety, Fuel Economy," Trucks.com, April 7, 2016.

Keep on truckin'

Aproximately 70% of all freight tonnage in the US is moved via trucks, so there are clear benefits to making this process more efficient and less costly, particularly for long-haul routes. Autonomous trucking has seen innovation come principally from startups. While it is a less universal market opportunity than self-driving cars, trucking may represent a nearer-term one for smaller companies since there are fewer well-capitalized or technology-focused incumbents focused on this space, and long-haul routes present fewer technical challenges than city driving.

Uber bought self-driving truck company Otto for US$680 million, plus 20% of future self-driving profits.[1] But Otto is not without competition. Peloton has focused on the intermediate step toward fully autonomous vehicles, creating a technology that allows trucks to travel in fleets, thereby reducing the need for driver control. Silicon Valley-based Embark has developed software enabling trucks to drive "exit to exit" on the highway without any human assistance.

Trucking's inherent challenges present opportunity for autonomous vehicles

A number of issues faced by the trucking industry make it an excellent candidate for autonomous innovation. According to the American Transport Research Institute,[2] the industry's key challenges include:

- **Driver fatigue**
  While completely replacing drivers is still years away, extending the service hours of a truck by making it autonomous is a nearer-term possibility. Current regulations mandate a 14-hour on-duty limit for truck drivers, of which only 11 hours can be spent driving. The industry already suffers from a shortage of drivers and retention issues. Autonomous driving technology could certainly help address these points. Even at Level 4, on-road hours could be extended and more drivers could be potentially moved into "supervisory" roles.
- **Safety and human error**
  As noted earlier, the overwhelming majority of traffic accidents are caused by human error and could potentially be avoided with advanced collision prevention technologies. One important development in trucking automation will be technology that enables autonomous city driving, which involves the ability to follow complex traffic rules and detect unexpected traffic situations, such as crossing pedestrians.
- **Need for infrastructure upgrade**
  Because autonomous vehicles require properly maintained infrastructure to operate well, US infrastructure will need to be significantly upgraded to enable full-scale adoption of this technology. For example, vehicles must be able to read lane markings and speed limits. It is worth noting in this regard that infrastructure improvements appear to be among the Trump administration's top policy priorities in the US. Autonomous driving technology could also provide a more efficient way to deal with congestion through lane and space management while potentially optimizing trucking routes.
- **Economics and cost efficiency**
  As noted above, the trucking industry plays a large role in the US economy, and there are clear benefits to making the process of transporting freight more efficient. The easy gains can be made through the extension of service hours, fewer interruptions and improved routes. If the goal is to get a truckload of products from point A to point B, autonomous driving promises to do it more efficiently, safely and cheaply than human-directed driving.

The cost breakdown of a trucking assignment shows that roughly two-thirds of the operational costs are related to driver compensation and fuel (see US trucking industry table to the left). Level 5 trucks would eliminate the personnel expense entirely, and even Level 4 (driver-present) trucks could provide economic benefits. Additional benefits would likely derive from efficiency gains. For example, trucks operated in an autonomous fashion could potentially drive more closely together and maintain steadier speeds, thereby generating significant fuel economies. According to the Otto study, even with a driver present, autonomous driving was estimated to potentially save AB InBev US$50 million per year in operating costs through reduced fuel expense and frequent delivery schedules.[3]

1 Source: Trucks.com, "Otto hauls Budweiser in First Commercial Use of Self-Driving Truck," Oct. 25, 2016
2 Source: American Transport Research Institute, November 2016
3 Source: Bloomberg LP, Oct. 25, 2016

1 Source: *The Telegraph*, "How do driverless cars work?", July 1, 2016
2 In 2016, a computer defeated human opponents to become the world champion at Go, a complex strategy game involving an almost infinite number of potential opponent moves. In 2017, researchers at Carnegie Mellon and the University of Alberta are testing their artificial intelligence talent in the No-Limit Texas Hold 'Em poker competition, where computers encounter not only the unknowns associated with multiple card decks, but also the irrationality of the human mind and opponents who may be purposely providing misleading information by bluffing.
3 Light Detection and Ranging, a system similar to radar using light pulses rather than sound waves.
4 McKinsey & Company, "Disruptive trends that will transform the auto industry," January 2016
5 Source: *The Wall Street Journal*, "Tesla, on a Hot Streak, Passes Ford in Investor Value," April 3, 2017
6 Source: KPMG, "Marketplace of Change: Automobile Insurance in the Era of Autonomous Vehicles," October 2015
7 Source: *Fortune*, "2016 Was the Deadliest year on American Roads in Nearly a Decade", Feb. 15, 2017
8 Source: Chris J . Needham, "Artificial Intelligence: The Road to Human Inference", December 2016.
9 Medium, "Building Maps for a Self-Driving Car," 2016
10 Tesla began outfitting its vehicles in 2016 with fully autonomous driving hardware, which will be supplemented by automatic software updates as related technology continues to advance.
11 For instance, the guidance software for an autonomous vehicle may need to determine whether to swerve into a pedestrian in order to avoid a head-on collision with another vehicle.

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