Self Driving Cars: Today and Tomorrow

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Table of Contents

Introduction

The automobile as we know it was first available on the market in 1886, when Karl Benz invented the Benz Patent Motorwagen.[1] However, it was not until 1908, when Henry Ford released the Model T into the world, that the world saw a complete transformation in the way humans used transportation, and the industry was changed forever.[2] Since the release of the Model T, the automobile has had many iterative upgrades, but nothing quite like the transformation that the Model T itself had sparked. That can change, however, with the invention of the completely autonomous vehicle. It is entirely possible for self-driving cars to hit the market within a decade, but the purpose of this project is to discuss the ethical and economical ramifications of that future.

Autonomous cars are defined cars able to operate without a human driver controlling them. Autonomy in cars has been prototyped since as early as the 1980s[3], however not until recent years have autonomous vehicles been tested intensively on real roads shared with normal drivers. Automobile businesses now believe that car autonomy can be a big selling point for their vehicles, and many are racing to be the first to bring true autonomy to the market.[4]

Automation is not a new concept, and has been steadily growing alongside the growth of technology. Automated elevators were invented at the beginning of the 20th century, for example. However, the invention of autonomous devices, and the acceptance of autonomy are two different things. It took nearly 50 years for autonomous elevators to become commonplace,

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[1] https://www.mercedes-benz.com/en/mercedes-benz/classic/history/benz-patent-motor-car/
[2] https://www.history.com/topics/model-t
[3] http://www.computerhistory.org/atchm/where-to-a-history-of-autonomous-vehicles/
[4] https://www.wired.com/2017/05/mapped-top-263-companies-racing-toward-autonomous-cars/

but now manual elevators are practically nonexistent, as is the profession that relied on them, elevator operators.

The Purpose of This Project

Completely autonomous cars could require major shifts of daily life for humanity, some of which many may not even realize at this point in time. There are countless obstacles and factors that go into automation and driverless cars that humanity will have to face. These technological advancements have the potential to both benefit and harm humanity, so it is important to be cautious. This project is not a deep dive into the technical specifications and engineering of driverless cars, but a look into what effect they may have on society, both now and in the future.

There is far more to allowing autonomous vehicles than simply overcoming the technological barriers. There will be regulatory, cultural, and ethical problems that must all be addressed first, even if the technology is already there for full automation. Some vehicles, such as planes, are already very close to full automation. But to remove the pilot from the plane for commercial flights, even if full automation is reached, would take some drastic cultural faith in the technology. Even if only as a safeguard, humans are still able to take control of the vast majority of vehicles. This will not change until not only the technological, but all issues of automation are worked out.

The issues of automation, as well as its advantages, will be made clear in this paper. The focus will be on autonomous vehicles, as this category of automation is one of the most likely to affect a vast amount of people in the very near future. Driverless cars in particular, have the

potential to completely change the transportation industry forever, possibly as much as the original automobile changed transportation in its own right.

Automation

Automation is the technique of making an apparatus, a process, or a system operate automatically, and in the place of human labor.[5] There have been countless examples in history of automation completely changing the way humans operate. Machines have taken over a lot of functions within a business that were traditionally held by humans, but with the rise of the information age, automation may be utilized at an extremely fast rate.

The Automated Teller Machine, more commonly known as the ATM, is a prime example of recent automation that has completely changed the way society operates. People can now manage, withdraw, and deposit from their bank accounts via the use of this mechanical machine that contains money. No longer are the days that require someone to talk to bank teller to access their money. ATMs could do the job better, faster, and cheaper than humans could. These functions can now be done independent of not only human interaction, but the banks themselves as well. ATMs are used in many places where consumer business is located. Restaurants, gas stations, shopping malls, and even most college campuses have ATMs available and can be used at any time unlike the traditional restriction of withdrawing within a bank's business hours.

Automation of the future, however, will not be focused on only mechanical automation. With the advent of Artificial Intelligence, the theory and development of computer systems able to perform tasks that normally require human intelligence, many jobs can be automated without

[5] https://www.isa.org/about-isa/what-is-automation/

human interaction necessary as well, including functions necessary for driverless cars. Artificial Intelligence is its own huge societal concern that needs to be considered, but it goes hand-in-hand with modern automation. Many tasks and jobs that can be automated in the modern age will be done so via Artificial Intelligence automating a thinking process traditionally done by a human. Driverless cars are not using a rail system to keep themselves on a certain path, they have to be adaptive to any situation that might occur on the road, and to do that the car must have the driving intelligence of at least human-level.

Software automation already plays a big role in today's technological world, but that will continue to improve as well. For example, the Stock Market is now largely ruled by trading bots, called "Quants", which manage quantitative funds via computerized systematic trading strategies. These bots are now accounting for the majority of the stock market volume, and have accounted for up to 61% of trading. [6]

Not only can the jobs of day traders be automated by software, but many white collar jobs can be automated as well. When people think of automation, it is common to think of kiosks replacing fast food workers, but the reality is that companies see a bigger return on investment by automating expensive labor. In Japan, Fukoku Mutual Life Insurance has replaced 30 of its medical insurance claims representatives with an AI system based on IBM's "Watson Explore".[7] Insurance underwriting, financial analysis, inventory management, and more tasks currently performed by white-collar workers are now able to be automated with software, and often, much cheaper.

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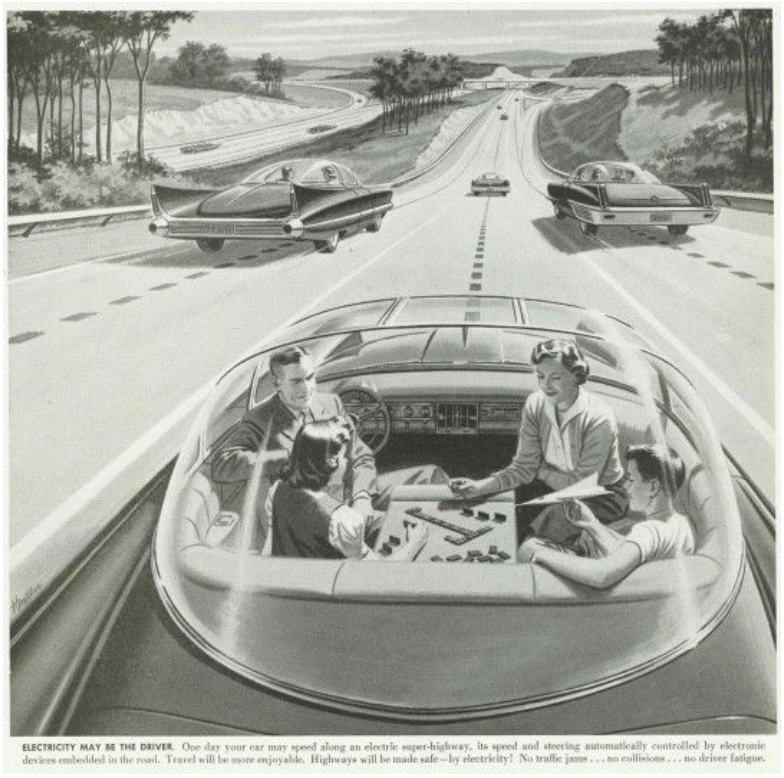
[6] http://www.investopedia.com/news/how-robots-rule-stock-market-spx-djia/

[7] https://www.theguardian.com/technology/2017/jan/05/japanese-company-replaces-office-workers-artificial-intelligence-ai-fukoku-mutual-life-insurance

Self-Driving Cars: Today and Tomorrow



ELECTRICITY MAY BE THE DRIVER. One day your car may speed along an electric super-highway, its speed and steering automatically controlled by electronic devices embedded in the road. Travel will be more enjoyable. Highways will be made safe—by electricity! No traffic jams . . . no collisions . . . no driver fatigue.

8

History of Driverless Cars

The idea of driverless cars as we know them has been the work of Science Fiction since the 1930s. It was not until 1939 when renowned designer Norman Bel Geddes introduced the Futurama exhibit for the 1939 World's Fair, where the concept exploded into popularity and the general populace was able to see the potential of what driverless cars could offer. A more personal system than railways, with the same benefit of not needing to manage the operation of the vehicle while one reaches their destination. The original concept at the World Fair was, however, similar to a railway because the concept was for cars to operate like normal until the driver shifts into "trench-like lanes that would keep cars apart in their own tracks". This was

before technology was near powerful enough to offer a car that could make its own decisions, but it could operate along a path like a railway can fairly easily on its own. Related early ideas for driverless cars involved "magnetic trails built into the road's surface" or "train-like rails engaging hidden steel wheels on the inside of each tire". [8]

While the methods used to achieve driverless cars are changing today, the principle is the same: An automated way to travel with a car without human operation. The problem with these early envisionments of the driverless car is that they required smart highways, and would have to be driven manually everywhere else. With no ability for the car to detect traffic lights, stop signs, or even pedestrians in its path, driverless cars of the era were basically envisioned to be hybrid trains.

GM and RCA did some testing during the 1950s, creating "automated highway prototypes with radio control for speed and steering", while magnets in the car tracked a steel cable embedded in the road. The first tests for driverless cars showed that the idea was certainly possible, and the technology for a rail-like driverless experience was within the realm of possibility. However, these early designs required much more public support than what was possible at the time. For this way of driverless cars to exist, there would have to be a massive public infrastructure overhaul, the likes of which has never happened in any country to this day.

Because the limitations of public support would not feasibly allow smart highways to be implemented anytime in the near future, by the 1960's, the enthusiasts for Artificial Intelligence began to change the interpretation for a driverless car from a smart highway system, to a smart automobile system. Using artificial intelligence, the car could sense its environment, process

[8] http://www.computerhistory.org/atchm/where-to-a-history-of-autonomous-vehicles/

what was happening, and finally react with appropriate movement. None of this would require massive infrastructure overhauls, and the driverless car could be used in more ways besides just on select railed down highways. A system could be conceived to make turns, stop at stop signs, and brake for pedestrians. It was far away during the 1960's, but technology was increasing so rapidly that people realized it was indeed possible.

 [9]

Benefits of Self-Driving Cars

Self-driving vehicles could be a major convenience in day-to-day life, but there are a lot of benefits and positive impact that driverless cars could have on society that perhaps are not so obvious. While they do not come without drawbacks, it is worth it to do a deep dive into strictly the benefits of a self-driving society before determining whether or not the drawbacks are so large they should impede on the technology's progress.

[9] https://www.youtube.com/watch?v=cdgQpa1pUUE

Perhaps the greatest benefit to a self-driving society is the elimination of driver error. More than 30,000 die due to automobile collision every single year in the United States alone and driver error is the number one cause of those accidents, being a factor in 93% of all crashes. The Eno Center for Transportation estimates that if 90% of cars on the road in the United States were self-driving, then 21,700 lives would be saved every year, over 4 million fewer crashes would occur, and over 100 billion dollars of cost from crashes would be saved. If even just 10% of cars were self-driving, the study estimates that 211,000 fewer crashes would happen per year.[10] Cars that drive themselves cannot get tired, aggressive, or drunk like a human driver can. Alcohol impairment alone accounts for "nearly one-third (29%) of all traffic-related deaths in the United States".[11] A fully autonomous infrastructure could potentially stop 93% of accidents and for many people, the safety benefit alone makes the prospect of pursuing self-driving vehicles a worthy one.

The decreased risk of accidents leads itself to a second benefit of driverless cars: traffic efficiency. Driving, as it exists today, is very human in its execution. Traffic as it exists today is comprised of tailgating, speeding, randomly changing lanes, refusing to let people pass, and traffic accidents. With self-driving cars, most of these problems no longer exist. In fact, a study from the University of Illinois suggests that just one autonomous vehicle "can control the flow of at least 20 human-controlled vehicles around it, with substantial reductions in velocity standard deviation, excessive braking, and fuel consumption".[12] This research has shown that just one autonomous car in a pool of 20 vehicles reduces the standard deviation in speed of all the cars in a traffic jam by almost 50 percent, and the amount of sudden braking in vehicles from around

[10] https://www.enotrans.org/wp-content/uploads/AV-paper.pdf
[11] https://www.cdc.gov/motorvehiclesafety/impaired_driving/impaired-drv_factsheet.html
[12] https://arxiv.org/pdf/1705.01693.pdf

nine per vehicle to at most 2.5 per vehicle. These tests were all done with low-level autonomy in the form of adaptive cruise control that already exists in many current day vehicles, and so the benefits of hands-free driving can be felt on the roads today. If every vehicle on the road were autonomous, then it is possible traffic would be almost nonexistent.

Another benefit that comes with increased traffic efficiency is increased fuel efficiency. Fuel efficiency is largely dependent on traffic as fuel use increases when cars have to adjust their speed very often as they do in traffic congestion. In the study conducted by University of Illinois testing the ability of a single autonomous car's influence on traffic, fuel consumption was also tested and studied. The results showed "up to 40% less fuel consumption" among all vehicles. This data is just with one autonomous vehicle in a pool of 20, meaning that if every vehicle on the highway was nearly always at the same speed then there is room for that fuel efficiency to grow even further.[11] Less fuel used is better for the environment, requires less costs for drivers, and allow cars to drive further without needing to stop to refuel. The benefit of increased fuel efficiency is just as important as the decrease in traffic that self-driving cars could bring.

Driverless vehicles would also bring a lot of free time to its passengers. Because traffic would likely be severely decreased in a driverless society, the time to travel distances would likely be must shorter. Not only that, but time spent within the vehicle is no longer required to be spent driving. Commuters can now text and drive without danger. Telecommuters could potentially work from their vehicle and include their commute time as part of their hours worked. McKinsey & Company estimates that time saved by commuters every day "might add up globally to a mind-blowing one billion hours- equivalent to twice the time it took to build the

Great Pyramid of Giza".[13] There are many uses and productivity opportunities for the time people spend on driving every day, and perhaps in a driverless society, those opportunities can be utilized.

Driverless cars can also increase mobility and ease of transportation for everyone. While cars today require able-drivers, hence the need for a driver's license, driverless cars need no sort of restrictions on the passengers it drives. Blind, and disabled passengers can finally become mobile without the need for someone else to drive them. Children, and the elderly who do not possess the skills to drive themselves, can now use driverless vehicles without problem. Self-driving cars can ease the burden of transportation for a large number of people. One may not even need a car themself, as driverless cars would undoubtedly affect the ride-sharing and taxi industries. Uber is already testing a self-driving line of vehicles as of 2016.[14] Perhaps in the future one can have an uber driverless car come pick them up, and drop them off wherever they need, without any sort of human interaction. Maybe if it were this easy, even fewer people would feel a need to own cars when they could essentially rent automated transportation for any commute necessary. With today's cars being parked about 95% of the time[15], it makes sense that a lot of people would no longer see the value in owning their own when driverless rentable cars can be driven to their location on call, pick them up, and drive them to any other location they need for a per-use fee.

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13 https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/ten-ways-autonomous-driving-could-redefine-the-automotive-world

14 https://www.bloomberg.com/news/features/2016-08-18/uber-s-first-self-driving-fleet-arrives-in-pittsburgh-this-month-is06r7on

15 http://fortune.com/2016/03/13/cars-parked-95-percent-of-time/

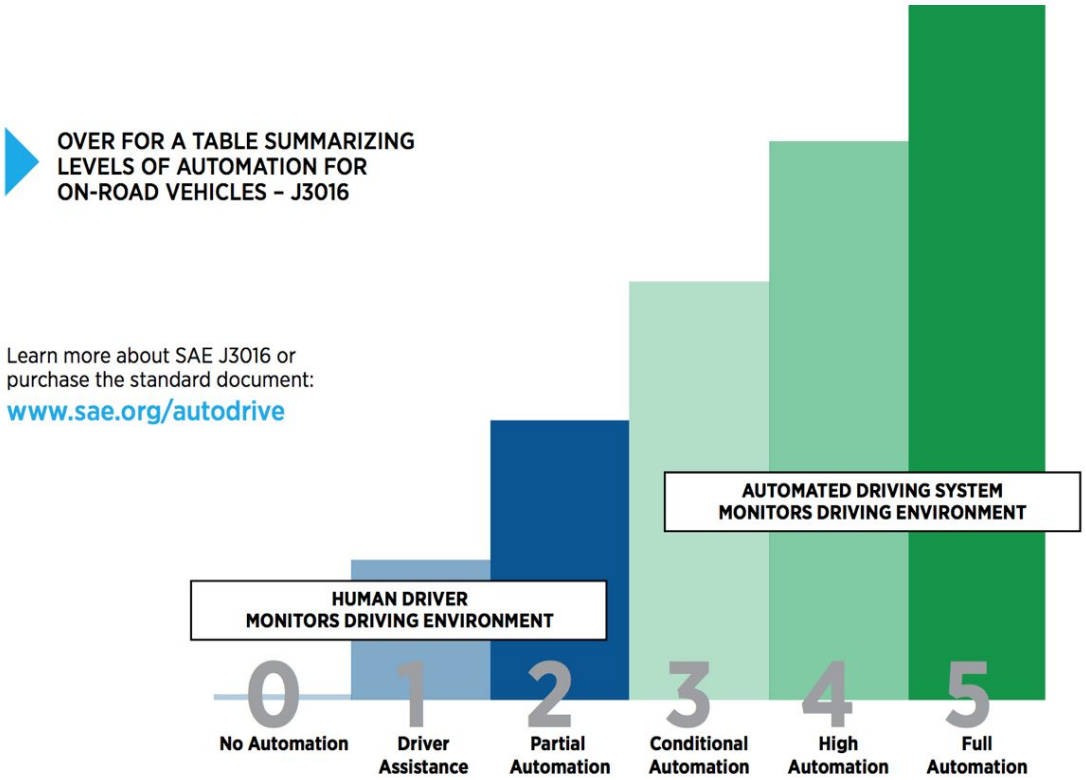
One final benefit is that without the need for hardware traditionally used by a human driver, such as the steering wheel and pedals, cars can be fundamentally redesigned to fit a passenger's needs. Cars today are designed with the driver in mind first and foremost, but driverless cars of tomorrow will not need to be designed around the driver, and that leaves much more free reign for a more relaxing, or entertaining driverless experience. No longer does a car have to restrict from features that could be distracting to a human driver. A driverless car of the future could have any modern amenity one might find in a living room. And with the safety benefits of driverless cars causing accidents to be exceedingly rare, a driverless society would likely no longer require a need for seat belts, and allow for full movement around the cabin in perfect conditions, much like passenger air transportation today.

 [16]

[16] http://readwrite.com/2014/02/20/concept-driverless-car-rinspeed-xchange/#awesm=~oxd5xS1q3wIRSU

Current State of Technology

While there are legal, cultural, and economic barriers to allowing driverless cars on the road, none of those matter if the technology to produce a self-driving car is not advanced enough yet. But the rate of improvement in the technology is why these other barriers are finally being commonly discussed, even if the idea for self-driving cars has existed for decades. The Society of Automotive Engineers, or SAE, has designed a six-level system, where every level dictates how well automated a vehicle is. In this section showing the current state of driverless technology, each level will be explained, as well as what level can be reached currently, both in practice and testing.[17]



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[17] https://www.sae.org/standards/content/j3016_201609/

The first "level" of automation, is actually **Level 0**, or the state of no automation. This is what almost every car, even in the 21st century, is currently equipped with. This is for cars that cannot automate neither the steering nor the acceleration process at all. Even cars with automated emergency preventive measures, such as automated emergency braking, can still be viewed as level zero if they do not actually automate any part of the driving process, or what SAE calls the Dynamic Driving Task (or DDT). Normal cruise control, which most cars in the 21st century do have, does not count as automated, because normal cruise control does not adapt at all with real-time traffic to keep a safe distance behind the car in front of it.

Level 1 automation is for cars that offer "Driver Assistance". The car can still not drive itself, but it can assist the driver with the driving process. This means that the car can either take control of the steering wheel *or* the pedals, although in real-use level 1 cars almost always take control of just the pedals. There are plenty of level 1 automated cars on the market today, almost entirely due to the popular adaptive cruise control feature which has become popular amongst luxury vehicles. Adaptive cruise control does not set a single speed, but will alter the speed of the vehicle to keep a safe distance between cars in front of, and behind it, as well as braking when necessary. Adaptive cruise control, and therefore level 1 automation, has been in production vehicles since 1999, with Mercedes, Jaguar, and Nissan offering some form of this feature on its cars for the first time.[18] Adaptive cruise control uses "lidar", which is a technology that measures the distance of light.[19] In the case of Adaptive Cruise Control, the light between the lidar sensor and the car in front of it is measured to detect what a safe distance is, and then tells the car's electronics to change its speed to keep to that safe distance.

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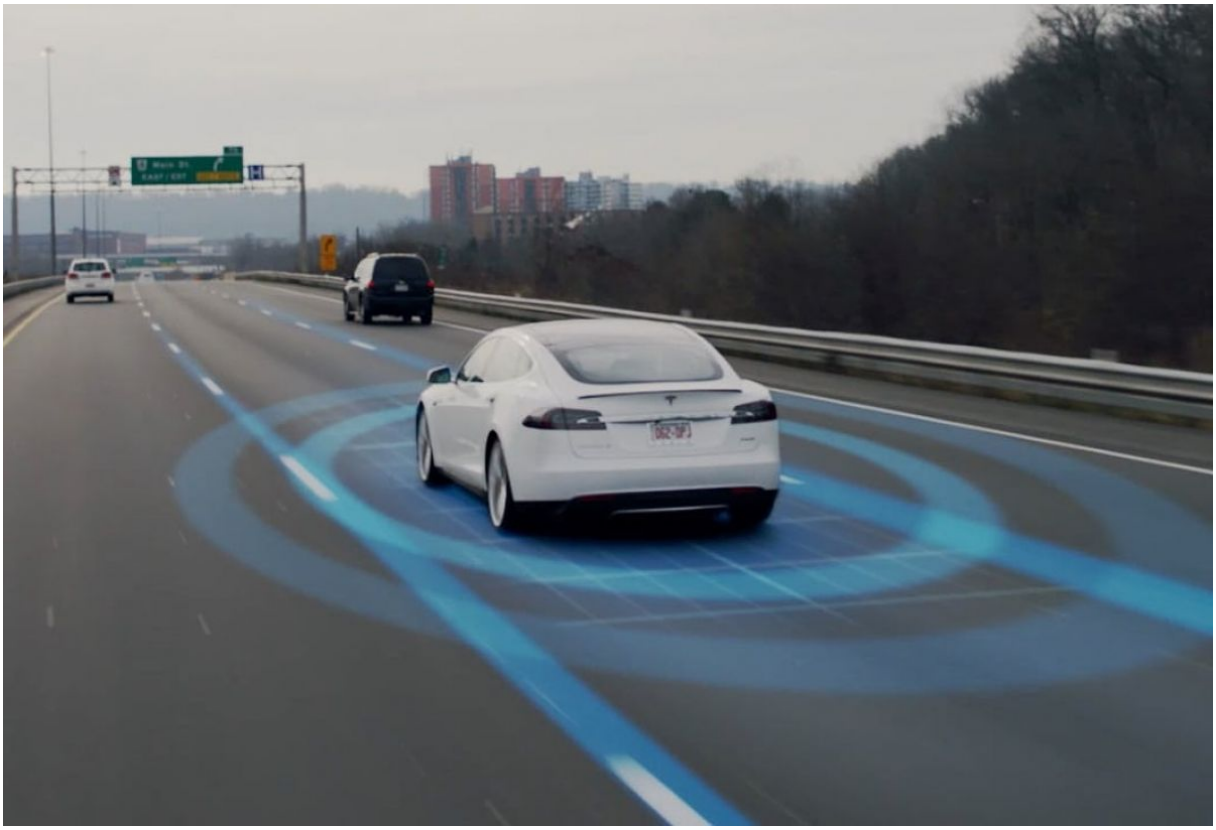
[18] https://en.wikipedia.org/wiki/Autonomous_cruise_control_system#Timeline
[19] https://en.wikipedia.org/wiki/Lidar

 [20]

Level 2 automation is considered "Partial Driving Automation". This is the first level of automation that allows, in some fashion, the driver to take their hands off the pedals *and* the wheel, but under only very limited conditions. The driver must still maintain control over the vehicle and be ready to react to the DDT at all times. This is also the furthest that production cars today have reached, with Tesla's Autopilot features being the first consumer system to achieve Level 2 automation in 2014. Generally, Level 2 automation is created with both a combination of lane assist features and adaptive cruise control. Lane assist technology uses cameras, sensors, and AI to detect both the lane and other cars while driving, and how to adjust the steering wheel to stay in that lane and away from other cars, even when not going completely straight.

[20]https://www.tesla.com/videos/enhance-your-commute-autopilot

Combined with adaptive cruise control, the car can now achieve partial automation. This automation is not at the point where it can detect all road obstacles, signs, or stop lights, but it can be used in good weather conditions during daylight on most highways. If the car starts having trouble at any point, however, it will shift the driving task back to the driver. It cannot be used to enter or exit highways, but some level 2 systems such as Tesla's autopilot can be used to change lanes. It is the first level of automation where drivers can take their hands off the wheel and feet off of the pedals, but they must still keep their eyes on the road at all times to take control if they notice something the car cannot detect.

Level 3 automation is considered "Conditional Driving Automation". Level 3 automation is the beginning of a truly driverless system, and while it still requires a driver present, it will let the driver know when to take control of the vehicle, rather than needing the driver aware enough to detect any possible issues during the DDT. There are no production vehicles with level 3 automation quite yet, and there likely will not be many. Most companies do not want to ship a car that can detect issues it cannot overcome but will push all tasks to overcome those issues to the driver. It is the most ambiguous level of automation in terms of liability, because if the car suddenly tells its passenger it needs driver control, and the driver cannot detect the issue of the DDT fast enough to react after realizing there is an issue, it can create an accident. And at that point, determining whether it is the driver's fault for their reaction time, or the car's fault for not shifting driving responsibilities soon enough for the driver to do anything can be a very gray area. So far both Google and Ford believe "it's not realistic to tell human drivers that they can divert their attention and then expect them to intervene quickly enough to avert an accident". Audi, however, is planning to have some Level 3 autonomous driving functionality in their

upcoming 2018 Audi A8 model.[21] The functionality will technically be at level 3, but in extremely limited conditions, and only working on roads with very clear dividers, clear lane markings, no cross traffic, no pedestrians, no merging traffic, and only up to speeds of 60km/h or about 37mph. They call the feature "AI Traffic Jam Pilot", because like the name implies it is to be used almost exclusively for traffic jam conditions. Level 3 automation in slow moving traffic is easier for the car to achieve, and gives the driver much more time to pick up the wheel when the traffic picks up. Mistakes at that speed are also very unlikely to create serious injuries or damages.

Level 4 automation is considered "high driving automation" and is where automation starts to become truly advanced. A level four vehicle can still be driven by a human, but at no point does it ever require human interaction. It can drive itself full time under the right conditions, but if it encounters something it cannot handle it can park itself to escape danger if no driver is present to give assistance. So if it starts entering an area with roads that are hard to read, instead of requiring a driver to take over, it can ask for driver assistance, but if none is given it can park itself safely until human help arrives. This level is exciting because this is the level of automation technology engineers have been able to achieve so far. Google's self-driving car company called "Waymo" has been operating at level four with its test vehicles on private roads since 2015, and a whole fleet of level 4 vehicles with no driver on public roads in 2017.[22] As level 4 automation gets more refined, this will be the first true self-driving experience where passengers need to pay no attention to the road if they do not want to.

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[21] https://www.forbes.com/sites/michaeltaylor/2017/09/10/tthe-level-3-audi-a8-will-almost-be-the-most-important-car-in-the-world/

[22] https://waymo.com/journey/

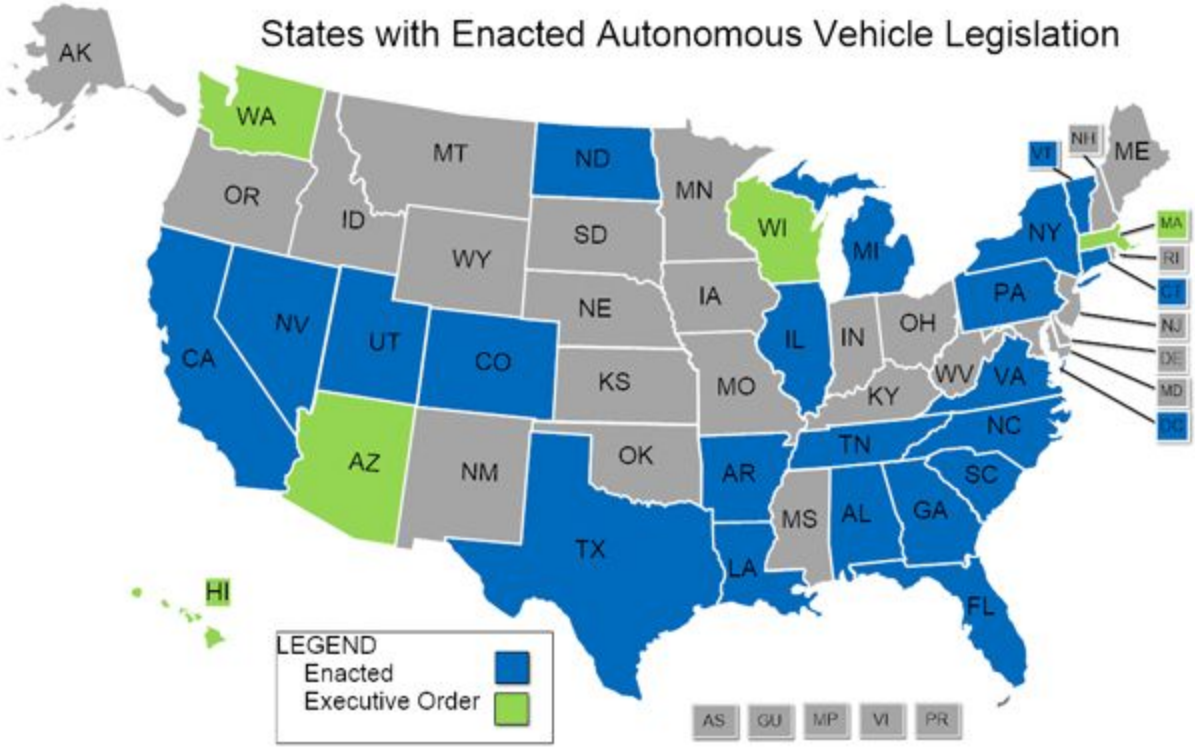
 [23]

Level 5 automation is considered to be "full driving automation". This is the final level of automation a production car could accomplish, and while in level 5 automation, the passenger does not need to perform any driving tasks at all. Level 5 brings full automation at all times under any conditions, and does not even require a human on board, nor a steering wheel to be installed in order for the car to be driven. We are still some time away from even the testing phase of level 5 automation, but as level 4 vehicles start to enter production, level 5 vehicles will soon after begin to be tested. In fact, the AI required for successful level 5 automation may only be possible with enough data collected from a widespread production and adaption of level 4 automated vehicles amongst drivers. Unlike the jumps between other levels, the switch from level 4 and level 5 will be more gradual. A level 4 may be able to work in 95% of the situations

[23] http://www.businessinsider.com/gm-cruise-fully-autonomous-electric-car-no-steering-wheel-2018-1

that the level 5 can, but until it gradually is able to work in all conditions, self driving cars will remain at level 4 in the near future.

Current State of Laws & Regulation



[24]

The current state of laws and regulation has been improving quite rapidly over the past few years. Since 2012, and as of January 1st, 2018, 41 states and Washington D.C. have at least considered legislation regarding autonomous vehicles. Of those, thirty-three states have introduced legislation, twenty-one have passed legislation, and six governors have issued executive orders related to autonomous vehicles.[23] This means that the majority of states have addressed rules and allowances for driverless vehicles. However, every state also has its own defined regulations, which allow for testing of various stages of driverless cars. For example,

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[24] http://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx

only Michigan and soon to be California actually allow for cars to be tested without a passenger in the driver's seat. [25]

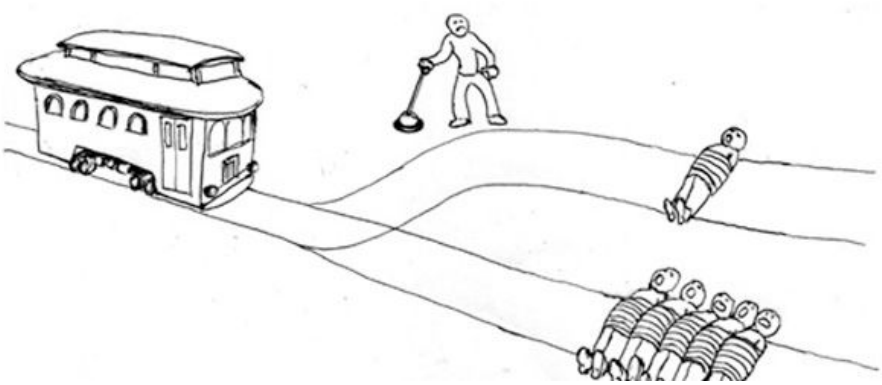
Local allowances have been made for driverless cars as well. Chandler, Arizona has made allowances for Waymo, Google's driverless technology company, to test their level 4 autonomous vehicles in their town without anyone at the wheel in case something goes wrong, even though Arizona itself does not have legislation for that. Waymo also plans to conduct similar tests in Austin, TX.

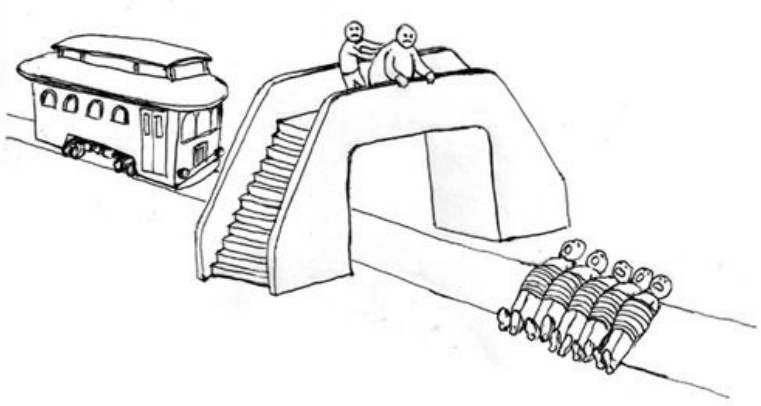
The federal government has also finally started to work on legislation for driverless vehicles. On September 7th, the House of Representatives passed the "SELF DRIVE Act", with bipartisan support. SELF DRIVE, or "Safely Ensuring Lives Future Deployment and Research In Vehicle Evolution" shows that Congress is creating a serious plan to allow the innovation of self-driving vehicles to flourish. This legislation is mostly for test vehicles, and not for production cars, but that is where this will start. If the legislation can keep up with the test vehicles, it can hopefully prepare itself for when level 4 autonomous vehicles finally hit the market. The SELF DRIVE Act still needs to pass through the Senate before the bill can become law.[26]

[25] https://en.wikipedia.org/wiki/Autonomous_car
[26] https://www.wired.com/story/congress-self-driving-car-law-bill/

Ethical Dilemmas of Driverless Cars

The Trolley Problem





[27]

A runaway trolley is heading down the track towards five people who will all be killed if the trolley proceeds on its present course. You are standing next to a large switch that can divert the trolley onto a different track, which only has one person on the track. The only way to save the lives of the five people is to pull the switch and sacrifice the single person. Should you pull the switch? Most people would say yes, it is ethical to sacrifice one person to save five. However, consider a slightly different version of this scenario: The runaway trolley is still

[27] http://shikharsachdev.com/trolley-problem/

heading down the track towards five people who will all be killed if it proceeds on its present course. You are now on a footbridge over the tracks. Next to you, there is a stranger that happens to be very large. The only way to save the five people in this scenario is to push this stranger off of the footbridge and onto the tracks where his large body will stop the trolley. The stranger will die, but the five people on the tracks will be saved. In this scenario most people would say not to push the stranger even if the end product is the same in both scenarios: sacrificing one life to save five.[28]

This is known as the Trolley Problem, and it is a very famous ethical dilemma in general, but one that is very relevant to the ethical dilemmas of driverless cars. Driverless cars can save tens of thousands of lives, but even though they could become far safer than human drivers, they will still need to make some tough decisions. Picture a scenario where five kids run down a busy street as a driverless car comes speeding toward them. The car could decide to swerve into a convenience store on the side of the road, saving the kids but killing the driver, or continue its path running over the children. From an outsider's perspective, our humanity tells us that the car should save the kids. For driverless cars, these sorts of dilemmas have to be accounted for in advance, because the car needs to know what to do if it should ever face such a situation. There is no easy solution for this. Should a car save the driver if there is just one person in the road? Should it save the driver depending on if the pedestrian is old or young? Rich or poor? Now the car resorts to stereotyping the pedestrians it analyzes to make a more perfect "moral" judgement.

The Trolley Problem is a dilemma, to be sure. However, it is, for the most part, already solved when one thinks about it a little bit harder. From a utilitarian viewpoint, our humanity

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28 https://www.theguardian.com/science/head-quarters/2016/dec/12/the-trolley-problem-would-you-kill-one-person-to-save-many-others

wants us to do the most good. But from a personal viewpoint, would anybody buy a car if it could choose to personally kill them? In either of the original trolley scenarios, whether you sacrificed one to save many or not, it would likely be a choice of instinct and passion. In the driverless car variation, this is a decision premeditatively decided. We want other people's cars to maximize the number of lives saved, but think our own should put our own safety above all else. In a capitalist society, unless regulation rules otherwise, most production vehicles will likely put passenger safety as a priority above all else. Cars may still, however, have to make decisions between hitting one group of people or another. The trolley problem at one point in time was a fun thought experiment, but now is a real-world dilemma, and understanding our own morality to prepare for it is now a necessity, not just a thought.

Terrorism, Crime, and Hacking

A vehicle is one of the most dangerous tools that our society uses, and one of the leading causes for death in the United States. The vast majority of deaths involving cars are unintentional, but there is a rising trend of using vehicles as murder weapons. On October 31st of 2017, a Manhattan truck driver plowed his vehicle "down a crowded bike path along the Hudson River in Manhattan, killing eight people and injuring 11 before being shot by a police officer in what officials are calling the deadliest terrorist attack on New York City since Sept. 11, 2001", according to the New York Times.[29] These sort of attacks often put the attacker at risk, and almost always lead to an easy capture, and arrest, with it very unlikely the driver could get away with the crime unmasked. This may seem like a problem that applies to all cars, and it is, but it

[29] https://www.nytimes.com/2017/10/31/nyregion/police-shooting-lower-manhattan.html

becomes much more enticing, and opens many more opportunities for a criminal with a driverless vehicle.

Hacking and security is always a major concern among technology products, but it is of the utmost priority for a driverless vehicle. A driverless vehicle with bad security can either be hacked by someone besides the owner, or perhaps just as likely, could be hacked by someone purchasing the vehicle to use it as a tool to take innocent lives. Imagine the truck in Manhattan without a driver, hacked and programmed to kill as many people as possible before someone was able to do enough damage to the vehicle to stop it. It also becomes more appealing to criminals to be able to plan an attack without putting themselves in immediate danger, and even giving themselves a chance of getting away clean.

It is not only terrorism that driverless cars can be used for, but other crimes as well. Someone could hack a driverless car, reprogram the destination, and kidnap someone in their own car. It is possible a hitman could hack a car just to drive it off the road to kill all the passengers. There are a lot of negative outcomes that are possible if the security of driverless cars are not treated with the seriousness they deserve. MIT Technology Review points out that there have been no reports of hostile hackers targeting self-driving vehicles thus far, but also points out that in the 1990s, most dot-com companies did not have security problems either. Today, Windows is one of the most secure operating systems with Microsoft spending more than a billion dollars annually on cybersecurity, but hackers still find security vulnerabilities with Windows software all the time.[30] If security cannot catch up to the pace of the innovation, and

[30] https://www.technologyreview.com/s/608618/hackers-are-the-real-obstacle-for-self-driving-vehicles/

driverless cars can be easily hacked, then this ethical issue alone may doom them for decades until the security problems can be worked out.

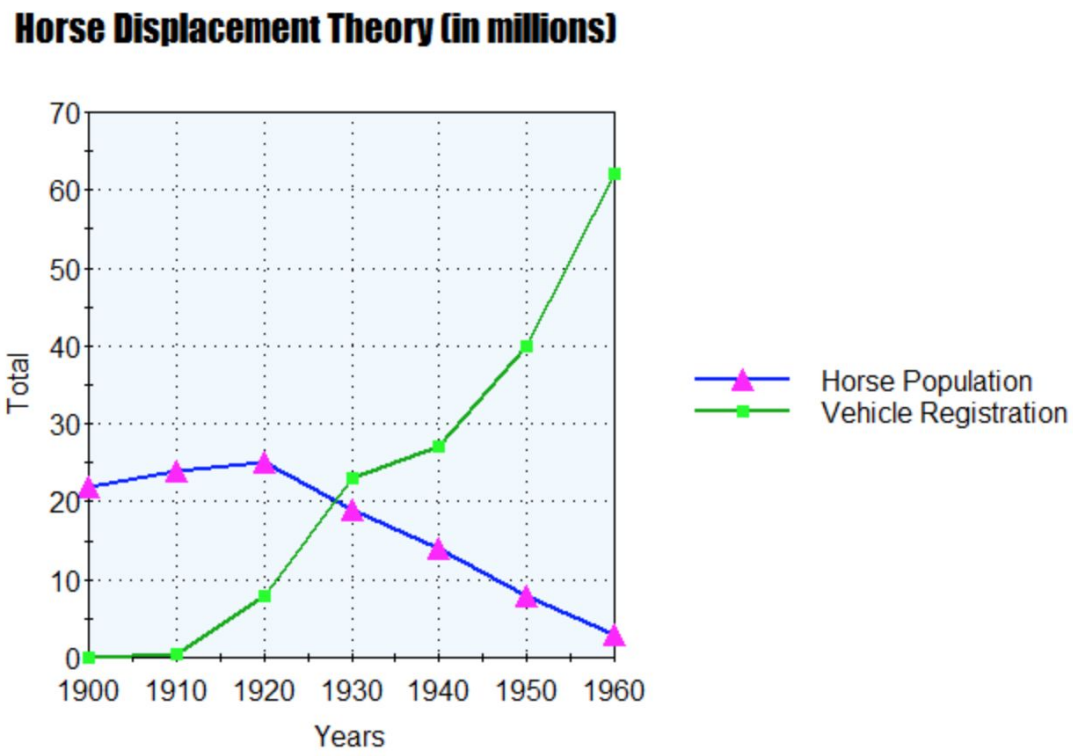
Impact on Business & Labor

Horse Displacement Theory

[31]

As mentioned previously, the automation of elevators eventually displaced the elevator operator once automated elevators became commonplace. However, with self-driving cars, it is much more likely to see a labor displacement much more closely resembling the way horse labor was discharged by all of humanity during the early 1900's. Horse-drawn carriages were the main mode of transportation for centuries before that of the 20th, but it was only a few decades before humans stopped using them almost completely in favor of the motor-vehicle.

[31] https://www.wired.com/2009/07/dayintech-0730/



Using a source from the Federal Highway Administration that shows the amount of U.S. motor vehicle registrations in the 19th century[32], and cross-referencing it with a study on the population of Equine during the mechanization of Agriculture[33], I created a line graph that shows roughly the time frame that motorized vehicles overtook the horse population. In the very late 1920's, likely during the peak of America's economic success known as the "roaring 20's", the amount of cars overtook the amount of horses in the United States, and even with the great depression, our country never looked back. In 1960, the amount of registered motor vehicles compared to horses was more than 2000%, with over 60 million vehicles registered, and only about 3 million horses still around.

[32] https://www.fhwa.dot.gov/ohim/summary95/mv200.pdf
[33] http://www.americanequestrian.com/pdf/US-Equine-Demographics.pdf

The Transportation Industry

 [34]

Horse labor is not the only type that has disappeared from society before. After all, blacksmiths, cobblers, chimney sweep jobs, and yes, elevator operators, are no longer common professions. But the scale and rapidness of which horses were displaced after the superior motor vehicle came around that could transport humans without them, may tell us something about the effects to which self-driving cars will have on the transportation industry when vehicles no longer need human drivers either. As per the Bureau of Transportation Statistics, "One out of every seven jobs in the United States is transportation related. Transportation jobs in transportation industries as well as in non-transportation industries employed nearly 20 million people in 2002, accounting for 16 percent of U.S. total occupational employment".[35]

Nearly 5 million jobs in 2017 are explicitly for-hire transportation, and all are at risk of losing their occupation once self-driving jobs can do their jobs better. And oftentimes, self-driving cars already can. This likely will not be a slow descent, but a rapid loss of millions

[34] https://www.gizmodo.jp/2015/11/151106ndronejapan.html
[35] https://www.rita.dot.gov/bts/programs/freight_transportation/html/transportation.html

of good paying american jobs. Not much unlike the millions of horses that were quickly no longer valuable enough to feed and shelter. Truck drivers, taxi drivers, ride-sharing platforms, and many more people will be quickly replaced by automation, on a scale like nothing else our society has seen thus far. Elevator operators lost their jobs to automation, yes, but even the height of the elevator operator profession never offered even a fraction of what the transportation industry ever has. This rapid job loss would likely have a ripple effect like no other. This will not only affect cars and trucks, but likely every aspect of transportation. Amazon has already started making deliveries with self-driving drones during private trials in the United Kingdom.[36]

Make no mistake, this is a problem for America's labor force, but not for all businesses. Self-driving cars will produce extreme cost-savings to many companies. In the delivery and transportation process, the labor is often the most expensive part. The average annual salary for a truck driver is about $40,000 as of 2015.[37] Even if a self-driving semi-truck costs $200,000, more than double the average starting price for a semi-truck ($80,000[38]), the owner is making his money back on it compared to a cheaper truck in addition to a driver salary in just a few years. The owner likely also has to pay significantly less in insurance for a fleet of self-driving cars that will get into significantly fewer accidents. Semi-trucks with self-driving features are already coming to the market, with Tesla announcing the "Tesla Semi", an electric semi-truck starting at $150,000 that includes Tesla's famous "enhanced autopilot" features.[39]

[36] https://www.amazon.com/Amazon-Prime-Air/b?ie=UTF8&node=8037720011
[37] http://money.cnn.com/2015/10/09/news/economy/truck-driver-shortage/index.html
[38] http://www.costowl.com/automotive/auto-semi-truck-new-cost.html
[39] https://www.tesla.com/semi

Projections for an Automated Future

It is important to realize that this problem is not isolated to the transportation industry. Once AI technology is capable enough to replace all drivers on the road, it will likely be capable enough to wipe out large sectors of the human labor force. A highly cited study from the University of Oxford, examined 702 common occupations, and predicted the risk of the job to automated within the next twenty years. The study found that over 250 jobs had an 80 percent or higher chance of being automated in that time frame. This of course includes many transportation jobs such as Taxi Drivers, Cargo and Freight Agents, Industrial Truck and Tractor Operators, and Locomotive Firers just to name a few. But the more interesting thing to note is all of the other types of jobs one might never think would be automated: Insurance Underwriters, Mathematical Technicians, Title Examiners, Clerks & Tellers, Loan Officers, Cashiers, Dental Laboratory Technicians, Restaurant & Fast Food Cooks, Receptionists, Waiters & Waitresses, paralegals, and Nuclear Power Reactor Operators all had more than a 90% risk of the occupation being computerized based on our current rate of automation technology.[40]

Some commonly known professions are already being automated. Telemarketers today often have computerized systems making the calls. Tax preparation is largely processed by computers, with the ability of programs such as TurboTax completely replacing accountants for many. Any task that is highly repetitive can likely be automated, and this is only going to be more prominent as AI and automation technology advances. Over time, this might just become a fact of life. As AI gets smarter, and automation more complex, there will be fewer and fewer jobs that a robot cannot do better.

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[40] https://www.oxfordmartin.ox.ac.uk/downloads/academic/The_Future_of_Employment.pdf

Conclusion

The Power of Human Adaptability

While there are many societal ramifications that automation and driverless cars will bring, the real lesson to be learned here is that these technological advancements are inevitable, and rather than fear them, we should prepare ourselves for how to handle them. Humans have never been able to stop technological progress, and even though they have been able to slow it down, like the acceptance of the automated elevator, they will not be able to prevent change forever.

There is little that can be done to prevent AI and automation, and so our best course of action is to learn to use them for the tools that they are. For a long time computers seemed like a scary proposition as well, but now the vast majority of Americans keep one in their back pocket, and could not imagine life without them. In 2017, about 92% of younger adults aged 18 to 29 owned a smartphone.

Humanity has gone through many labor revolutions before in our history. We started as hunter-gatherers for thousands of years, and then for thousands more worked as an agricultural society. In 1870, almost fifty percent of employed citizens worked in agriculture, supplying to about 5 people on average with their products.[41] Now, no more than 2% of the population works in agriculture, supplying for the vast majority of the nation. This is all thanks to the industrial revolution, which allowed mechanical machines to perform all of the manual labor that agriculture requires. The Automation revolution may be very similar.

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[41] https://www.bls.gov/opub/mlr/1981/11/art2full.pdf

Humans are able to adapt quickly; Even during the great depression that perhaps was partly caused due to our transition into an industrial society, we were able to enact public policy that got the country back on track. Some of the foundations for our current social policy were formed during our lowest years as a labor force. Even if our worst fears about automation came true and 90% of the population was unemployable, humanity would not be doomed quite yet. Just like the great depression, society could still enact policy that helps everyone benefit from the advancements in automation. There are likely jobs that humans cannot even begin to think of right now that will be necessary in the future. A Universal Basic Income, where every family gets enough from wealth distribution to live comfortably, is also a commonly considered solution. But the important thing is that we do our best to come together as a society and start talking about these issues before they are out of our hands. We have gotten through economic and labor changes before, and we can do it again. Humans have been able to adapt through all progress we have pushed upon ourselves so far, and will undoubtedly do so for the rest of our days.

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