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# Human factors concern on autonomous vehicles' safety, ethics and cost saving for the ridesharing industries

**Bankole K. Fasanya[a*] and Abosede O. Gbenga-Akinbiola[b]**

[a]*Purdue University Northwest, United States*
[b]*Morgan State University, United States*

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**ABSTRACT**

Artificial Intelligence (AI) is a motivation for full usage of autonomous driving. Many have predicted that autonomous technology would significantly disrupt the transportation industry. This research examines how autonomous driving might impact and disrupt the ridesharing industry and their drivers. The hypothesis is that autonomous vehicles (AV) will negatively impact the ridesharing industry. To examine the full effects of this disruption, we researched current literature on driverless technology cars and the ridesharing industry. Factors examined include: current economics of drivers and vehicles, public perception and acceptance, technological readiness, collaborations, regulations, and liability. Key findings from a host of resources were tabulated to build a case for the proposed hypothesis. The results provide a more comprehensive timeline estimate, predicted $0.75 cost estimate per mile by 2040, and documented the collaboration figure among the players that shows the significant investments across different industries. This research shows that the ridesharing industry's current business model is due for a significant disruption by autonomous driving capabilities. Drivers in the ridesharing industry might likely suffer the most, however not for at least another decade or so. There are many independent factors, which must be further scrutinized to develop a more comprehensive understanding as to the velocity of this disruption. Findings from this study would be applicable while evaluating the future of autonomous vehicles.



## 1. Introduction

Artificial Intelligence (AI) is enabling capabilities towards fully autonomous driving. This technology is expected to significantly reshape the transportation industry by improving safety and overall productivity. There are many predictions as to when fully autonomous vehicles (AVs) are to be part of everyday life. Modern vehicles equipped with automated driving systems and known as autonomous vehicles, now come with driverless, robotic, and self-driving (Stephan, et al., 2018), lane change information, electronic sideview system and blind spot information (Fasanya, et al. 2019). Various studies, reports, and predictions defined autonomous driving differently. For example, some classify autonomous driving as SAE levels 3-5, while some 4-5, or only level 5. In 2009, President Obama proposed a plan to spend over $4 billion to accelerate the acceptance of autonomous cars in the United States (Goodall, 2017 as cited in Fleetwood, 2017). Around the same time, Google began testing their autonomous driving system on public roads with drivers in the vehicles. They have collected over 1.5 million miles of data points towards enabling the vehicles to make smarter decisions on the road (Crayton & Meier, 2017). Ridesharing, on-demand, and point-to-point mobility services are all transportation network companies (TNCs) existing today (Johnson & Walker, 2016). Among the transportation network, Uber and Lyft have become very popular and are currently facing challenges regarding cost of operation. Per mile, the cost of owning and operating a personal vehicle is still 2-3 times less; which obstructs the amount of market share TNCs can penetrate. The 2018 estimate prediction for mobility services entering the market would charge the same ($1.00 per mile) amount, it costs to own and operate a personal vehicle (Johnson & Walker, 2016). The survey research conducted by Zoepf et al., 2018 on 1100 Uber and Lyfts' drivers using detailed vehicle cost data,

* Corresponding author.

E-mail address: fbankole@pnw.edu (B. Fasanya)


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reveals that the median revenue from driving is $3.37 per hour worked before taxes. Per mile, median income is $0.59 and after considering operating expenses, profits reduced to $0.29 per mile. Zoepf and colleagues conclude that about 30% of the sampled driver's lose money after the total vehicle expenses are calculated. As autonomous vehicle technology continues to improve, the current economic model for drivers seems unsustainable.

A polling study conducted in Austin Texas reveals that 41% of people would use automated driving services at least once a week, if it costs less than $1.00 per mile. However, only 15% would use the same service if it costs $2.00 per mile. The low percentage of people willing to ride autonomous services at $2.00 per mile is indicative of the current cost of ridesharing companies today. Therefore, $1.00 or less seems to be the economic tipping point that may bring about a substantial transformation in the industry (Johnson & Walker, 2016). In 2014, Navigant Research Group estimated that about 75% of all light-duty vehicle sales around the world would have the potential for autonomous capability by 2035. They also explain that the benefits of autonomous vehicles on safety and congestion will most likely appear between 2040 and 2060; and by 2060, human drivers may be limited to certain areas (Bansal, Kockelman & Singh, 2016). The Victoria Transport Policy Institute reports that around 2020s-2030s, independent mobility is likely to be available for well-off non-drivers. However, benefits such as reduced traffic and parking congestion, increased safety, energy savings, pollution reductions, and independent mobility for lower-income people are only possible when AVs become more common and affordable. However, human-drivers may be prevented from sharing the same roads, furthering the estimates to around 2040-2050 (Litman, 2020). Thus, AVs could help to eliminate accidents caused by human error and reduce traffic deaths by 90%. With these statistics, AVs have the potential to save roughly 29,000 lives per year in the United States, and 10 million lives per decade around the world as compared with the human driving cars (Fleetwood, 2017). Excellent projection, but the feasibility of producing an autonomous car that never crashes is doubtful to be achieved, according to some analyses (Fleetwood, 2017). Considering the pros and cons of this day, it is difficult to predict when autonomous vehicles will be integrated into the public space. Optimists predict autonomous cars to be affordable, readily available, and capable of displacing most human-operated cars by 2030. During this time, non-drivers would have greater access to mobility, eliminating the burden of driving, and problems of traffic congestion, accidents, and pollution. According to ARK Investment Management LLC, a disruptive consulting firm, autonomous taxis should be the leading form of door-to-door mobility by the late 2020s (Keeney, 2017). Many current predictions came from those with financial interests in the industry. Those predictions are based on experience with other technologies such as smartphones or similar type devices without considering the challenges AVs might pose regarding public safety (Litman, 2020).

The Society of Automobile Engineers (SAE) defines five levels of autonomous driving. Levels one through three require a driver to be present, while levels four (high automation) and five (full automation) allow for driverless operation (Litman, 2020). According to SAE, the narrative definition of full automation is the full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver (Litman, 2020). Level 5 can do everything a human driver can do in all situations, while level 4 only works in certain environments and conditions. Legal liability is found to be the most challenging barrier to level 5 autonomy and consumer acceptance the least from over 217 industry experts' surveys (Bansal, Kockelman & Singh, 2016). Therefore, it is imperative to understand all preventive steps and corrective actions for all types of failures associated with the autonomous vehicles; since system failures and issues such as hacking could lead to severe injuries and even deaths while operating the AVs. There are also primary ethical considerations in tackling programming decisions and upgrades in the AVs according to experts and safety professionals. For instance, algorithms developed for situations of forced choice require much more scrutiny and understanding. What decision should be programmed into the autonomous system when it must decide whether to hit a parked car or a pedestrian on an ice-covered road? Or is it better to hit four autonomous vehicle passengers or four pedestrians or run off the road to hit curbs? Forced choices like these require programming into advanced algorithms. Therefore, in 2016, the first Federal Automated Vehicles Policy by the US Department of Transportation indicates that autonomous vehicles "could prove to be the most significant personal transportation revolution since the popularization of the personal automobile nearly a century ago" (p. 5). The statistics on US highways road accidents because of human errors has accelerated the National Highway Traffic Safety Administration's (NHTSA) interest for AVs on our highways. Fasanya et al's., 2020 findings support NHTSA's argument for the development of automated vehicle initiation in the world. In support of the interest, Google requests the National Highway Traffic Safety Administration (NHTSA) to consider a computer system a "driver" since most state and federal regulations are designed for the "driver" (Johnson & Walker, 2016). Thus, this would lower the current barrier that exists for consumer's use; however, not all states are accepting this quick deployment. For example, the California Department of Motor Vehicles has proposed to ban AVs from operating without a licensed driver to take control (Johnson & Walker, 2016). In 2016, a public poll conducted by Bansal, Kockelman & Singh (2016), to assess AVs acceptance, 72% of the participants believe that AVs should be twice safer as conventional vehicles before being allowed into the public road. At the University of Texas, an Internet-based survey was also conducted on smart-car technologies, 347 Austin residents participated in the study. Findings show that participants view fewer crashes as the main benefit of autonomous vehicles, with equipment failure being their top concern (Bansal, Kockelman & Singh, 2016). Major tech and automotive companies are making moves to stay afloat in this highly anticipated multi-trillion-dollar market for autonomous vehicles and mobility services. Former CEO of Uber, Travis Kalanick states that for them to have any chance of surviving, they must provide rides with AVs. In agreement with all other technology industries, Apple invested $1 Billion in Chinese ride-sharing service Didi Chuxing, as they are working on an advanced electronic autonomous vehicle (Johnson & Walker, 2016). Uber teamed up with

Ford to begin testing autonomy on their Ford sedan. Ford CEO Mark Fields announced their intention to mass produce AVs with no steering wheels for US ridesharing services by 2021 (Johnson & Walker, 2016). Tesla is en route to launch a mobility service and intends to begin electric, automated, and on-demand mobility service by 2018, according to Morgan Stanley (Johnson & Walker, 2016).

Once autonomous technology is ready for public use, automated mobility providers may initially work in certain markets dependent on varying demographic, environmental and regulatory parameters. The Federal Department of Transportation (DOT) has been urging cities to equip themselves with autonomous vehicle technology and mobility services in its Smart City Challenge Notice of Funding Opportunity. Seven finalist cities out of seventy-eight proposed cities were to develop comprehensive plans that will support the capability and infrastructure for AVs in their respective cities by 2019 (Johnson & Walker, 2016). The Harvard Business Review outlined five potential threats to driverless vehicle adoption: system meltdown, public panic, endless errands, car-lover revolt, and benefit erosion (Johnson & Walker, 2016). As the economics of owning a vehicle appears no longer practical, demand for autonomous cars balances out the lost demand for personal vehicles. The core business model of these ridesharing companies is heavily dependent on drivers being available. Therefore, removing the drivers from the equation, ridesharing industries add no value to the business model (Hahn & Metcalfe, 2017). The ridesharing industry has benefited millions of people by having a vehicle readily available by the touch of a button. Tracking and monitoring the driver throughout the ride experience, and an automatic payment system has made this platform extremely appealing for riders. Ridesharing companies function much like a dating service for those that search for matches and those looking for matches. The ridesharing service does not employ the driver; they are merely registered to participate in this service. Ridesharing companies do not own any vehicles; they only provide the platform and charge a fee for arranging this date. Currently, AI is improving many aspects within the transportation industry. Neural networks, a technology within the AI is being used to build smarter and safer cities by predicting demand for the ridesharing and taxi service industries. Improved prediction is lessening the idle time and improving safety by better predicting congested and high-risk areas (Swayne, 2018). Research from a McKinsey study suggests that shifting to a self-driving vehicle provides a compelling incentive to fuel the ride-sharing disruption. They estimate that the net cost-reduction potential for a single autonomous car would be roughly $75,000 per year (Hensley, Padhi, & Salazar, 2017). Assuming vehicles last about four years while operating 24/7, this would translate to about $300,000 in savings over the lifetime of the vehicle. Negative impacts on the driver through second-order effects of this transition are difficult to predict since more than half of ridesharing drivers do so to increase their income aside from other forms of primary income. The study suggests that this transition is still unlikely to become widespread in most cities for at least a decade or so (Hensley, Padhi, & Salazar, 2017). As beautiful and easy the AVs, the growth rate will be dependent on the technology and regulations (Johnson and Walker, 2016). Artificial intelligence (AI) technology is accelerating the development towards fully autonomous driverless technology in the world. This technology allows the systems to correct for human mistakes and learn from the experience of other autonomous systems. Therefore, it is imperative to study the human factors' concern on AVs and the cost effect that the operation could have on the ridesharing industries.

## 2. Objective of the study

The goal of this study is to examine the impact, rate of disruption on the ridesharing industry and their drivers, and factors that could affect full operation of AVs in the future. To complete this study the following objectives were carried out.

1. Reviewed past studies on AVs from online search.
2. Reviewed past studies on ridesharing industries and the intention to adopt AVs in the future.
3. Evaluated past predictions to develop compressive prediction of the full operation of AVs on our roads.
4. Evaluated cost per mile of the self-drive vehicles and the AVs operation systems.
5. Developed robust visual representation of key players in the development of AVs around the world.
6. Documented findings and make it available for public use.

## 3. Methodology

### *3.1 Method*

Artificial Intelligence and autonomous driving are relatively new topics in the transportation system. Much information out there is on the predictions or the developments from other technology. As advancements in AI and driverless technology are substantial, there are still multitudes of factors to be considered before one could make an accurate prediction about the rate of autonomous driving disruption in the ridesharing industry. The hypothesis is that autonomous vehicles will impact the ridesharing industry by negatively impacting the drivers and changing the business model that ridesharing companies currently operate. To examine the full effects of this disruption, we researched current literature on driverless technology and the ridesharing industries. Various factors investigated include cost, public perception, ethics of operation, technology, infrastructure support, regulations, and liability. Key findings from a host of sources were tabulated to build a case for our proposed hypothesis.

*3.2 Procedure*

Internal secondary data research was collected by examining companies in the ridesharing and automotive industries. Data related to their operations and investment activities were obtained to consider how these companies envision and plan for future sustainability. Since AI depends on software and IT solutions; we examine similar activities from major technology companies. Mergers and collaborations between automotive giants, ridesharing companies and technology companies provide vital insights. External secondary data were collected using information such as government statistics and published reports from reputable consulting firms. The dependent variable is the ridesharing industry, and independent variables are the current economics of the ridesharing industry, autonomous vehicle technology capabilities, investments, and collaboration activities, legal and ethical factors, and societal influences. Online resources were reviewed every day for fourteen weeks. The focus was on the independent variables. The findings from the reviews were compiled and a table was formulated. Data collected is shown in Table 1 and in Table 2.

**Table 1**
AV Independent Factors Table

| Category | Year | Author | Article Title |
|---|---|---|---|
| Current Ride Sharing Taxi Economics | 2018 | Zoepf, Chen, Adu, &Pozo, 2018 | The Economics of Ride Hailing: Driver Revenue, Expenses and Taxes |
| | | Litman, 2020 | Autonomous Vehicle Implementation Predictions |
| AV Cost Per Mile Projections | 2018 | Litman, 2020 | Autonomous Vehicle Implementation Predictions |
| | 2017 | Kenny, 2017 | Mobility-As-A-Service: Why Self-Driving Cars Could Change Everything. |
| Law and Liability | 2018 | Grialfield, 2018 | The regulatory Goal for autonomous Vehicle. |
| | | J.K & D West, 2018 | The state of self-driving across US. |
| Societal and Environmental Factors | 2016 | Bonnefon, Shariff, &Rahwan, 2016 | The social dilemma of autonomous vehicles. |
| | | Bansal, Kockelman, & Singh, 2016 | Assessing public opinions of and interest in new vehicle technologies |
| | 2017 | Henry et al., 2017 | New Mobility: Autonomous Vehicles and the Region. |
| Technology Readiness | 2016 | Johnson, & Walker, 2016 | Peak Car Ownership - Rocky Mountain Institute. |
| Predictions | 2016 | Johnson, & Walker, 2016 | Peak Car Ownership - Rocky Mountain Institute. |
| | | Henry et al., 2017 | New Mobility: Autonomous Vehicles and the Region. |
| | 2017 | Henry et al., 2017 | New Mobility: Autonomous Vehicles and the Region. |
| | | Kenny, 2017 | Mobility-As-A-Service: Why Self-Driving Cars Could Change Everything. |
| | | Otto, 2017 | The Future of Mobility - On the Road to Driverless Cars. |
| | 2018 | Litman, 2020 | Autonomous Vehicle Implementation Predictions |
| Autonomous Vehicle Technology | 2017 | Jones, 2017 | A beginner’s guide to A.I and Machine learning. |
| | | Menke, 2017 | Self-driving cars. The technology, risk and capabilities. |
| | 2018 | Assiss, 2018 | A.I in 2018 |
| Autonomous Vehicle Industry | 2018 | Welch, 2018 | Who's winning the self-driving car race. |
| | 2017 | Muoio, 2017 | Ranked: The 18 companies most likely to get self-driving cars on the road first. |

**Table 2**
AVs cost variables from industries

| Category | Year | Highlights | Key Findings |
|---|---|---|---|
| Current Ride Sharing Taxi Economics | 2018 | Surveyed 1100 drivers with detailed vehicle cost data from January 2-9, 2017 | Average Profit over $661 per month, Median profit drivers earn per hour $3.37 before taxes. 74% of drivers earn less than their states minimum wage, and once you calculate vehicle expenses, 30% are losing money. |
| | | Current economics of ridesharing and taxis services | Today Taxis cost $2.00 to $3.00 per mile, ride-sharing services cost $ 1.50-2.50 per mile. |
| AV Cost Per Mile Projections | 2018 | Projection (Stephens, et al., 2016), Projection (Johnson and Walker 2017) | AVs for next 10-20 years will average around $0.80 to $1.20 per mile, will further reduce to $0.60 to $1.00 per mile, more expensive than human-operated vehicles at $0.40 to $0.60. |
| | 2017 | ARK Investment Management LLC Projection | AV taxis will cost $0.35 per mile, leading to widespread adoption |
| Law and Liability | 2018 | National Traffic and Motor Vehicle Safety Act of 1966, enact laws based on today's federal and state laws. | The concern is if states laws are put in place before federal laws, it could slow down the technology, what is the best approach that will mesh federal regulations and state tort law? |
| | | Number of test miles driven by AV's, Testing with and without a driver | More than 1 million miles were logged between 20 companies within 2 years, Reduction of motor vehicle deaths, which in 2016 was more than 40,000. |
| Societal and Environmental Factors | 2016 | Study 1 (n = 182) participants strongly agree that it would be more moral for AVs to sacrifice their own passengers, Study 2 (n = 451) participants presented with dilemmas that varied number of pedestrians' lives that could be saved, | 76% of participants feel it would be more moral for AVs to sacrifice one passenger than kill 10 pedestrians, with a 95% CI of 69 to 82, Participants don't feel AVs should sacrifice their passenger when only one pedestrian can be saved. |
| | | Fewer crashes is main benefit of AVs, while equipment failure was top concern | 50% concerned about equipment or system failure, 48% concerned about interaction with conventional cars. |
| | 2017 | Average Willingness to Pay (WTP): 38% concerned about affordability, Declining Auto Ownership | Average WTP for adding level 4 automation $7,253 compared to $3,300 for level 3 partial automation. |
| Technology Readiness | 2016 | Ford CEO Mark Fields, GM and Lyft Collaboration | Will mass produce AVs with no steering wheels for use in ride-sharing services by 2021 |
| | 2016 | Based on early adopter analysis- if AV technology grows on typical logistic S-Curve | Market potential of Americans living in urban cities could reach 70% market share by 2035 |
| | | Institute of Electrical and Electronic Engineers (IEEE) | By 2040, self-driving vehicles will make up 75% of vehicles on the road |
| Predictions | 2017 | McKinsey Report Prediction | By 2030, one of ten cars will be used as a shared vehicle, by 2050 one of every three could be a shared AV |
| | | ARK Investment Management LLC projection | Full AVs will become commercially available by 2019, by late 2020s they will be dominant form of door-to-door mobility |
| | | German Association of the Automotive Industry | By 2018, German manufacturers and suppliers will be ready to facilitate with initial automated systems. Between 2021-2025 full autonomy in all driving conditions will hit the market |
| | 2018 | Prediction | Benefits like improved mobility for upper-class non-drivers may begin anywhere from 2020 to 2030. Major benefits like reduced traffic congestion, safety, and better mobility for middle-class will occur in 2040s-2050s |
| Autonomous Vehicle Technology | 2017 | AI is the foundation for Autonomous Vehicles | Artificial Intelligence (AI) is the principle technology that makes Autonomous Vehicles (AV) possible. |
| | | Technology and human functions | There are three categories of technologies in Autonomous Vehicle - perception, computing and control. Each category emulates a human function - sight/hearing, brain and hands/feet. |
| | 2018 | Advancement of Autonomous Vehicle technology | Autonomous Vehicles have 5 stages of autonomy - stage 0 (No Assistance) to stage 5 (Fully Autonomous) |
| Autonomous Vehicle Industry | 2018 | Non-traditional partnerships among manufacturers are being created for the Autonomous Vehicle market. | Daimler and Uber (ride-sharing service), Delphi (an electronics supplier) and Intel along with Audi have been emerging. |
| | 2017 | Technology companies are among the leaders in the market in the Autonomous Vehicle market. | Waymo, a Google company, was launched in 2009 as Google's autonomous. Waymo has announced partnerships with Lyft (ride sharing service), Avis and Intel. Since Waymo's launch, it has logged over 2 million miles autonomously. |

### *3.3 Data Collection and Analysis*

Various factors were considered to examine autonomous technology's degree of disruption in the ridesharing industry. Vehicle operating costs and drivers' income allow for a better understanding of economic factors. Other factors include AVs technology readiness, investments and collaboration activities between major industries, expert predictions, and ethical and societal influences.

### *3.4 Ridesharing and Vehicle Economic Factors*

The economics of the cost of driverless versus driver-operated vehicles were examined to investigate if a substantial cost difference exists. Likewise, to understand the potential lost income due to autonomous disruption, revenue generated by current ridesharing drivers was examined. Litman documented data for both operating expenses and driver income for ridesharing industries in its 2018 article. Report indicates that ridesharing services cost $1.50-2.50 per mile and the median profit drivers earn per mile was $0.59 and $0.29 after operating expenses. According to Zoepf et al. (2018) findings, 74% of the drivers make less than the minimum wage in their state, and after vehicle expenses, 30% of drivers affirm their losing money. The cost of operating an AV per mile is still up for debate, projections from various sources as to when the AVs will start full operation are listed in Table 3. A PERT (Program Evaluation and Review Technique) or three-point estimating technique is a good model to calculate weighted average cost per mile; it is used in this study based on predictions from different authors to calculate a weighted average per mile cost to develop a comprehensive estimate for AV on a cost per mile basis. Equation 1 is the PERT for the weighted average per mile cost.

$$PERT = (O + 4M + P)/6 \tag{1}$$

where; O = most optimistic estimate, M = most likely estimate and P = most pessimistic estimate.

Past predictions were classified into most pessimistic, most likely, and most optimistic and were used to predict the possible AVs per mile cost for the future. According to past authors' predictions from 2018 to 2040, the most pessimistic (P) estimate is $1.20 per mile, most likely (M) is $0.80, and the most optimistic estimate (O) is $0.10. Therefore, using the three-point estimate technique in equation (1), a more comprehensive cost estimate of AVs per mile is $0.75. As reported in Stephens' (2016) and Litman' (2020) articles, human-operated vehicles cost around $0.40 to $0.60 per mile. Therefore, for the next 20 or so years from now, AV's cost per mile will be like that of human-operated vehicles. It seems reasonable to assume that until autonomous vehicles become significantly cheaper than human-operated cars, there is no reason to conclude a dramatic shift towards the replacement of drivers for at least a decade or so.

### *3.5 Societal and Environmental Factors*

Public perception and acceptance are vital for the widespread application of autonomous driving technology. If customer demand rises, energy and investments further accelerate. Since autonomous driving technology is unlike any other technology out there concerning safety, therefore, public acceptance is the key. Table 2 shows a study, which surveyed participants' thoughts on ethical issues facing AVs. Findings from the study show that AVs should sacrifice their passengers when more pedestrians' lives are at risk. Seventy-six percent of the participants feel that it would be morally right for AVs to sacrifice one passenger than killing ten pedestrians. In another study that sampled 451 people opinion, 77% of the participants feel that AVs should not sacrifice its passenger when only one pedestrian can be saved, with a moral approval rate of 23%. However, the moral approval rate increased as the number of lives saved increases. The participants in majority of the studies in Bonnefon, Shariff & Rahwan article feel that AVs should save the lives of the passengers at the expense of a single pedestrian. Although, the studies have small sample size, it still provides an understanding of the complexities and moral dilemmas when programming artificially intelligent driving systems. Another article listed in Table 1 reports findings from a survey of 347 Austinites on autonomous driving technology. Part of the findings indicate the reduction of accidents to be the primary benefit of AVs and mentions equipment failure as the chief concern for people, while 48% are worried about the interaction with conventional vehicles. However, 70% indicate that they would ride AVs on high-speed roads and congested traffic. Autonomous capability during congested traffic or high-speed roads seems to indicate that participants prefer using automated technology during stressful conditions. One can infer based on the findings that participants might be concerned about factors such as pedestrians, which can throw off the autonomous technology. Currently, ride-sharing companies mainly operate on city streets and short distances for convenience. The need for autonomous technology during congestion or high-speed conditions seems to address a desire for drivers wanting more free time or less stress during traveling (Bansal, Kockelman, & Singh, 2016). From 2000 to 2014, New York State saw a 31% drop in automobile registrations. Nationally, the percentage of licensed drivers ages 20-24 is down by 15% from 1983 to 2014 (Henry, 2017). The decline in automobile registrations supports a trend toward shared mobility. The younger generation brought up in the digital age views mobility differently. An increased culture towards urban living, ridesharing and a heightened environmental awareness are factors that seem to support this trend. The younger generation will most likely be the driving force behind how quickly AV ridesharing occurs.

### *3.6 Predictions*

Table 3 shows the predicted timeline from Table 1 and Table 2 data. This timeline provides a high-level view of different expert's predictions. Many manufacturers have already introduced semi-automated systems in their vehicles. For example, Fasanya et al. (2019) list some of the adaptive features now equipped in the new cars for safety and automated purposes for the drivers. The fast-growing technology and demand for road safety, AVs is expected to be fully commercially available by 2019 as reported by (Keeney, 2017). Around the early 2020s, AV availability is likely to be available in all driving conditions as predicted in (Otto, 2017)'s article. A more agreed upon estimation for significant market share and road use by AVs is projected to happen around the 2030-2040s. Significant benefits such as reduced traffic and safety due to AVs are projected to occur around 2040 to 2050 (Littman, 2020). Good predictions, but why the slow realization of these predictions? Almost all predictions were made without considering some important factors such as cost per mile, change in government policies, and the dynamic reasoning of humans. The slowdown in the process could be a result of the US president Donald Trump's policies on climate changes. This is one of the reasons why it is necessary to consider all factors while predicting the future operationality of AVs on our roads.

**Table 3**
Projected Timeline of AV Disruption

| Projected Timeline | Years |
|---|---|
| German manufacturers introduce initial automated systems (Otto, 2017) | 2018 |
| Fully AV commercially available (Keeney, 2017) | 2018-2019 |
| Manufactures introduce fully AVs for all driving conditions (Otto, 2017) | 2020-2027 |
| Improved mobility for wealthy non-drivers (Litman, 2020) | 2020-2030 |
| Dominant form of door-to door mobility (Keeney, 2017) | 2028-2030 |
| 10% of cars will be used as a shared vehicle (Henry et al., 2017 | 2031-2034 |
| 70% of market share (Johnson and Walker, 2017) | 2035-2039 |
| Major benefits of AV- traffic, safety, middle-class (Litman, 2020) | 2040-2050 |
| 75% of vehicles on road (Henry et al., 2017) | 2040-2050 |
| 33.3% vehicles on road are shared Avs (Henry et al., 2017) | 2050-2060 |

### *3.7 Major Collaborations (Players)*

Data collected on collaborations between ridesharing companies, automotive manufacturers, and tech giants as of 2018 with the financial commitments is shown in Fig. 1. A sample of some critical partnerships and their respective investments adds up to roughly $25.7 billion as at 2018. Although this graph provides a small sample of total investments, it provides an in-depth look at the types of collaborations and the confidence companies across industries place in autonomous ridesharing.

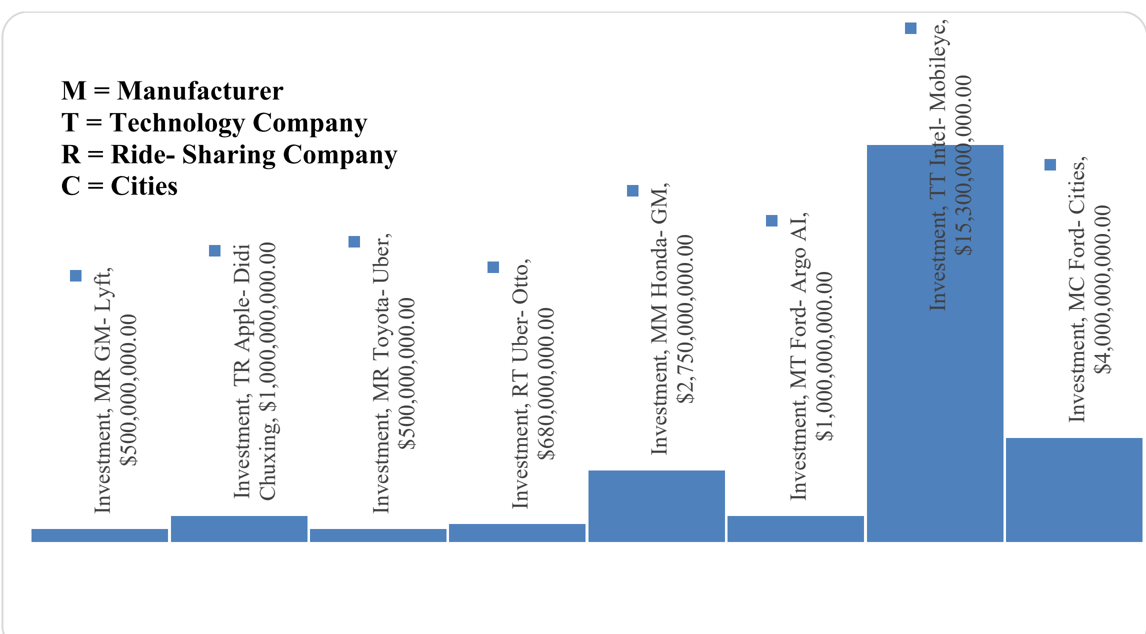


**Fig. 1.** Sample Size of Investments toward Shared AV's (Collaborations across Industries)

## 4. Discussion

There is no debate about the technological readiness of autonomous driving capabilities around the world. Autonomous vehicles are already being tested on roads, millions of tested miles data have been collected and more data collection are still in progress to strengthen autonomous driving capabilities able to adapt to all types of road and weather conditions. The purpose of this research is to examine the extent to which autonomous driving is going to disrupt the ridesharing industry. There are many biases in current estimates and projections because many predictors mainly focus on the issues from one viewpoint, which is advancement from technology availability. Others base their predictions on historical data from previous disruptive technologies such as smart phones. However, risk management professionals (RMPs) have warned about prediction with historical data because this might not give realistic results. This paper took a comprehensive approach by assessing different/diverse independent factors. Scholarly research journals, news reports, and conference proceedings were reviewed and analyzed for future operation of the AVs. Further analysis was conducted using the estimates from various experts across industries to develop a comprehensive high-level timeline. The timeline accounts for many of the biased forecasts from other sources. For example, some projections only factored in the readiness of the AI technology, disregarding infrastructure or legal issues that could delay implementation. The sustainability of ridesharing drivers in the future does not look favorable. As discussed earlier, many drivers are earning less than their states minimum wage. Some drivers sometimes lose money when vehicle operation expenses are factored into the total expenses. It is safe to assume that the likely cost per mile of AVs to be around \$0.75 in the next 20 years using the PERT estimation technique. Therefore, for the next couple of decades, AV's cost per mile will be close to that of human-operated vehicles (\$0.40 to \$0.60 per mile). It seems reasonable to assume that until autonomous vehicles become significantly cheaper than human-operated cars, there is no reason to conclude a dramatic shift toward entirely replacing drivers for at least a decade or so. Ridesharing companies earn money by charging booking and service fees on top of the passengers' fare (Helling, 2020). Consequently, ridesharing companies profit more off lower prices because they can accumulate more booking and service fees per trip. This model hurts the drivers because of constraints on the total number of rides they can offer each day; at the same time, their operating expenses are rising. Thus, when the cost of fares decreases, the driver suffers the loss. This might be a potential for early operation for the autonomous vehicles for the ridesharing industries. If the cost of operating AVs becomes significantly less, this is favorable for ridesharing companies because they will still accumulate booking and service fees. Cheaper rides make it more attractive for passengers; although, negatively impacting drivers' wages. In addition, ridesharing companies do not have to pay commissions to their drivers, if operating autonomous vehicles. However, the question remains, who is going to own, operate, and maintain these autonomous shared vehicles. Through further research, ridesharing companies seem to be collaborating and partnering with manufacturers and technology companies to bridge this gap. Collaborations across industries are a significant finding in this research. The development of a classification system on collaboration data provided great insight into the many groupings across industries. For example, technology companies joining with manufacturers or ridesharing companies. The investments between these companies are organized accordingly to show different pairings and their respective investments. The graphical representation of the collaboration shown in Fig. 1 could be updated and analyzed to further track the trends across different industries looking to invest in automotive autonomy.

## 5. Conclusion

The main drive for the fast development of AVs is Artificial intelligence (AI). This research examines the impact, rate of disruption on the ridesharing industry and their drivers and factors that could affect full operation of AVs. Autonomous vehicles will negatively impact the ridesharing drivers, changing the very business model that ridesharing companies currently operate on today. Its full acceptability might be over two decades to come. If this autonomous technology proves to be as reliable as experts predict, drivers are in for trouble. Autonomous ridesharing will open many exciting opportunities and present new problems, which will need to be solved. Thus, if drivers can adapt and re-tool themselves to meet the future challenges ahead, there will be plenty of opportunities for them. As shown in the research, ridesharing companies are collaborating with other companies to adapt to this shift in their current business model. Automotive manufacturers, technology companies and ridesharing companies are all partnering and heavily investing in one another to accelerate the public acceptance of the AVs on our roads. These collaborations reveal their confidence that autonomous driving and shared mobility will undoubtedly occur at some point in the future. As is shown, there were many independent variables that will impact the rate of this disruption. The most challenging are the legal barriers. As no one can quite predict an exact timeline, this research provides a timeline, which pooled estimates from various sources to give a more comprehensive picture of how the disruption may unfold in the coming years. There are still many hurdles not discussed in this paper. For AVs to operate effectively, a robust infrastructure is needed. Figuring out what to do with all the cars currently on our road is another challenge in which there is no clear solution. Further, issues such as maintenance costs of AVs are not going to be known until they are widespread. Autonomous technology and AI are surely disrupting the ridesharing industry; however, the exact extent of this disruption is difficult to predict. Nevertheless, many challenges and opportunities will arise from autonomous ridesharing. Those that can adapt will prosper, and those that are not will be displaced. Additional groupings with entertainment and service companies should further be investigated since autonomous ridesharing might provide unique services and experiences to consumers while traveling. More study in this area of research is required to understand all that is at stake in the AVs.

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**References**

Bansal, P., Kockelman, K. M., & Singh, A. (2016). Assessing public opinions of and interest in new vehicle technologies: An Austin perspective. *Transportation Research Part C: Emerging Technologies*, *67*, 1-14.

Bonnefon, J. F., Shariff, A., &Rahwan, I. (2016). The social dilemma of autonomous vehicles. *Science*, *352*(6293), 1573-1576.

Crayton, T. J., & Meier, B. M. (2017). Autonomous vehicles: Developing a public health research agenda to frame the future of transportation policy. *Journal of Transport & Health*, *6*, 245-252.

Fasanya, B. K., Anand, S., &Kallepalli, G. S. (2020, July). Researchers and Public Views on Electronic Sideview Mirror System (ESMS) in the 21st Century Cars. In *International Conference on Applied Human Factors and Ergonomics* (pp. 99-106). Springer, Cham.

Fasanya, B. K., Avula, Y., Keshavula, S., Aragattu, S., Kurra, S., & Kummari, B. (2019, July). Human Factors Concerns: Drivers' Perception on Electronic Sideview System in 21st Century Cars. In *International Conference on Applied Human Factors and Ergonomics* (pp. 556-563). Springer, Cham.

Fleetwood, J. (2017). Public Health, Ethics, and Autonomous Vehicles. *American Journal of Public Health, 107*(4), 532-537. Doi:10.2105/ajph.2016.303628.

Goodall, N. J. (2017). From Trolleys to Risk: Models for Ethical Autonomous Driving. *American Journal of Public Health*, *107*(4), 496-496.

Johnson, C., & Walker, J. (2016). Peak car ownership: the market opportunity of electric automated mobility services. Rocky Mountain Institute and Mobility Transformation.Retrieved [Nov. 30, 2020). Available from: https://rmi.org/wp-content/uploads/2017/03/Mobility_PeakCarOwnership_Report2017.pdf

Keeney, T. (2017). Mobility-as-a-service: Why self-driving cars could change everything. *ARK Investment Management Research*.

Litman, T. A. (2020). Autonomous Vehicle Implementation Predictions: Implications for Transport Planning. 2015. Retrieved [Nov. 20. 2020]. Available from: https://www.vtpi.org/avip.pdf

US Department of Transportation. (2016, September 01). Federal Automated Vehicles Policy: Accelerating the Next Revolution in Roadway Safety. Retrieved [Nov. 10, 2020]. Available from https://www.hsdl.org/?abstract&did=795644.

Hahn, R., & Metcalfe, R. (2017). The ridesharing revolution: Economic survey and synthesis. *More equal by design: economic design responses to inequality*, *4*.

Hensley, R., Padhi, A., & Salazar, J. (2017). Cracks in the ridesharing market—and how to fill them. *The McKinsey Quarterly*.

Henry, A., Barone, R. E., Pichardo, A., Roach, E., Keegan, T., Simons, D., ... & Oldenburg, B. (2017). New Mobility Autonomous Vehicles and the Region. *Regional Plan Association (RPA), New-York*Otto, P. (2017). The future of mobility – on the road to driverless cars. Retrieved [July 2, 2020]. Available from: https://www.ipsos.com/sites/default/files/ct/publication/documents/2017-10/The_Future_of_Mobility.pdf

Helling, B. (2020, November 27). Uber Fees: How Much Does Uber Pay, Actually? (With Case Studies). Retrieved [December 2, 2020]. Available from https://www.ridester.com/uber-fees/

Stephan, M. Lalancette, P. Regalla, A, Stoddart, M, & Quinian, M. (2018, March 14). Autonomous vehicles: The race is on. Retrieved [October 20, 2020]. Available from: https://www.accenture.com/fi-en/insights/communications-media/autonomous-vehicles-data-challenges

Swayne, M. (2018, March 01). A.I. better predicts demand for taxis and ride-shares. Retrieved [August 10, 2020]. Available from: https://www.futurity.org/taxis-and-ride-shares-demand-1692412-2/

Zoepf, S. M., Chen, S., Adu, P., & Pozo, G. (2018). The economics of ride-hailing: Driver revenue, expenses and taxes. *CEEPR WP*, *5*.