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MOBILITY IN THE 21ST CENTURY:
AUTONOMOUS VEHICLES

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Abstract

Purpose and Methodology This study examines the social acceptance of Autonomous Vehicles (AVs) and the challenges surrounding it by (i) researching and analyzing the current status of AVs, (ii) gathering the opinions of consumers by means of an online survey, as well as (iii) interviewing industry experts affiliated with firms involved in the development of AVs, and (iv) assessing the marketability of AVs through an evaluation of internal and external factors.

Findings AVs are likely to be accepted by society, with the attendant loss of control of not only the vehicle itself, but also of the data that it generates. AVs will disrupt traditional car ownership, leading to the emergence of new business models in the sharing economy. AVs are the essential prerequisite for current shared mobility concepts to prevail, although major challenges such as legal regulation and as yet unsolved liability issues can impede the market penetration of AVs.

Keywords Autonomous driving, autonomous vehicle, consumer tastes and preferences, shared mobility

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List of Abbreviations

ABS	Anti-lock Braking System
AD	Autonomous Driving
AV	Autonomous Vehicle
ESP	Electronic Stability Program
MCAS	Maneuvering Characteristics Augmentation System
Nova SBE	Nova School of Business and Economics
NHTSA	National Highway Traffic Safety Administration
OEM	Original Equipment Manufacturer
R&D	Research and Development
SAE	Society of Automotive Engineers
Uber ATG	Uber Advanced Technologies Group
V-to-I	Vehicle-to-Infrastructure
V-to-V	Vehicle-to-Vehicle
WHO	World Health Organization

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1 | Introduction

THE AUTOMOTIVE SECTOR is currently embracing new technologies that promise radical change. The prospect of self-driving vehicles went from being fiction to becoming a prototype at a breakneck speed.

The cutting-edge technologies embedded in AVs can heavily impact road safety. Notably, 95% of road accidents are due to human error (NHTSA, 2016). Road accidents are the eighth most frequent cause of death globally (WHO, 2018) and the increase in delays due to congestion will double by 2050 (Department for Transport, 2018). In this context, AVs have the potential to disrupt the automotive market with their promise of enhanced road safety and more fluid traffic flows.

The mass data collected by cameras and sensors installed in AVs, most of which is processed in real time, will make vehicles an essentially different product from those offered today. This, in turn, will allow ride-hailing service providers to offer an alternative to private vehicle ownership (Herrmann, Brenner and Stadler, 2018). Consumers' experience of riding and "driving" a vehicle will also change markedly. Given the attendant surrender of vehicle control, it is uncertain whether consumers will accept AVs, even though automated technologies are already being tested on the streets of several cities. Moreover, consumers may be concerned about the collection and potential sharing of the data generated through their use of AVs, with the attendant loss of privacy.

All this leads to the following research questions: (i) *Will AVs be accepted by consumers?* (ii) *Will AVs be embedded in the shared mobility economy?* (iii) *Are AVs with the highest level of autonomy already marketable?*

These questions will be approached from four different angles. In Section 2, we will define AVs and differentiate them from other related terms. We will also discuss the current state of the industry and show how AVs might give rise to new business models within the sharing economy.¹

¹ The sharing economy is based on the "idea of sharing things and using them together" (Freese and Schönberg, 2014).

Subsequently, the current market competitors will be examined in detail. After outlining the applied methodology in Section 3, we gauge social acceptance through an online survey targeting a randomly selected sample of potential consumers, whose results we treat in Section 4. This allows us to gauge if there is an actual demand for AVs, as well as identify factors which may hinder their uptake. In addition, by interviewing industry experts affiliated with the creation and introduction of AVs, we are able to determine whether the public's view matches the experts' perception of how the market will evolve. Moreover, in Section 5 we assess the marketability of (fully) AVs by evaluating internal and external factors determining this aspect of the problem. This shows us whether AVs are already able to prevail. Finally, in Section 6, we conclude with a summary of the results obtained, answers to the three research questions posed above, and a critical appraisal of our applied methodology.

Substantial efforts have been made to depict the industry's state of the art, which should thus be accurate at the time of writing.² Yet, this might not be the case at the time of reading due to the accelerated tempo at which change is currently being felt in the automotive industry.

2 | Autonomous Vehicles

2.1 | Definitions

The first automobile was invented in 1886 in Germany by Carl Benz (Herrmann, Brenner and Stadler, 2018). From then onwards, innovations in the automotive industry and consumers' changing lifestyles have led to the evolution of vehicles, namely in what concerns safety. More recently, driver assistance systems have increased in number and features (acronyms such as ABS, ESP and several other are now familiar to most drivers). Very recently, the path towards a fully AV became apparent. According to Techopedia (2019), AVs are vehicles that drive themselves without human intervention. They are also known as self-driving cars, robot cars or autonomous cars.

² Which ended on December 14, 2019.

The terminology surrounding AVs is very often associated with similar terms with a different meaning. One must therefore clearly define and distinguish them.

Automation vs. Autonomy The term automation describes the independent activity of a machine, whereas the term autonomy is broader since it describes the self-control capability of an entire system (Herrmann, Brenner and Stadler, 2018).

Autonomous Driving is defined as the last (more advanced) stage of automation. When this ultimate level is reached, the system automatically takes over all steering, acceleration and braking processes. The car is *always* able to act completely independently from its “driver” – or, more precisely, occupants – in all traffic situations (Herrmann, Brenner and Stadler, 2018).

Sharing Economy is based on the “*idea of sharing things and using them together*” (Freese and Schönberg, 2014). It is an economic model based on peer-to-peer activities involving the exchange of goods and services.

Shared Mobility aims at maximizing the use of mobility resources (e.g. vehicles) while separating their use from ownership. It is defined as short-term access to shared vehicles according to the needs and comfort of the user (Soares Machado, De Salles Hue and Quintanilha, 2018).

The development of driver assistance systems has advanced extensively over recent years. Yet, though whether a fully AV is already available is still disputed, the trend away from human-driven vehicles towards AVs has clearly been established. To distinguish the levels of Autonomous Driving (AD), the Society of Automotive Engineers (SAE) defines five standardized levels with regard to the number and capabilities of driver assistance systems:

Level 0 (No Automation) The driver has total and exclusive control over the steering, brakes, throttle and power.

Level 1 (Driver Assistance) The driver permanently controls most of the functions, but some driver assistance technologies (such as steering or acceleration) can be performed automatically by the vehicle.

Level 2 (Partial Automation) The driver permanently monitors the system but is relieved from the physical operation of the vehicle (hands off steering wheel and foot off pedal simultaneously). He or she must be prepared to take control at any time.

Level 3 (Conditional Automation) The vehicle controls safety-critical functions but informs the driver about conditions which require a transition.

Level 4 (High Automation) Fully AVs perform all safety-critical driving functions in certain areas and under defined weather conditions.

Level 5 (Full Automation) The driver is not expected to be available for control in any driving scenario during the journey. The AV is able to answer complicated, morally ambiguous questions in emergency situations (Brooks, 2017).

The higher the degree of automation, the less the driver has to intervene. Level 5 offers a new way of driving in which the driver himself is no longer required. The terminology of these levels will be used repeatedly in subsequent chapters. We thus ask the reader to bear them in mind.

2.2 | State of the Art

Assessing the state of the art requires an evaluation of the status quo, the increasing number of patent applications and the miles already driven by AVs.

Numerous test projects of AVs involving advanced systems and sophisticated sensors are already in place. Yet, a fully self-driving AV is still not available (Kolodny and Schoolov, 2019). Many automotive technology firms believe solving the first 90 percent of the technical issues raised by AD will be moderately difficult. However, they also expect cracking the “last 10 percent” required for vehicles to achieve Level 5 (see Section 2.1), to be exceedingly hard (Herrmann, Brenner and Stadler, 2018). Some leading AD firms have already developed Level 4 technology (see Section 2.4). Yet, particularly complex traffic situations (e.g. heavy rain, stormy weather, and such like) and urban areas pose significant challenges (Herrmann, Brenner and Stadler, 2018). Nonetheless, autonomous campus shuttles (such as Nova SBE’s shuttle connecting

the campus with *Carcavelos* train station) or employee buses are already being offered by these firms, though almost always with onboard drivers as a human safety precaution (Kaslikowski, 2019).

R&D departments are currently working flat out to get AVs onto the roads quickly. The European Patent Office has received more than 18,000 patent applications for AVs in the past ten years. Almost 4,000 of these were filed in 2017 alone and the 25 leading suppliers account for 40 percent of all patent applications. The remaining 60 percent were filed by about 100 firms. The top five filers in Europe are – in decreasing order of number of patents filed – Samsung, Intel, Qualcomm, LG and Bosch. Regarding company origin, American and European companies led the European patent market in 2017 with approximately 1,400 patent applications each. Europeans dominate the areas of driving behavior, smart logistics, perception, analysis, and decision making, while US companies dominate in communications and IT (VDI, 2019).

In parallel with auto manufacturers, IT firms such as Alphabet and Uber are also involved in the construction and operation of AVs and expect to earn significant profits from them. So far, test vehicles of Alphabet's subsidiary Waymo have already driven more than 10 million miles on the road, and more than 10 billion miles in simulation (Etherington, 2019). All simulated miles as well as miles on the road add up to a considerable training experience for Waymo's self-driving algorithm. Consequently, Alphabet can be considered one of the pioneers in developing self-driving technologies. In turn, Germany's premium car manufacturers – such as Daimler and Volkswagen – anticipate (and fear) IT companies could have advantages due to their significant field experience (Taylor and Wissenbach, 2019). If this were to be the case, traditional car manufacturers would suffer significant future sales losses. Hence, car manufacturers are already looking for ways to accelerate development through partnerships among each other and with tech companies in order to avoid being displaced by large IT firms (Taylor and Wissenbach, 2019).

2.3 | Connection to Shared Mobility

“In just a few short decades, owning a car could be a lot like owning a horse – mostly for hobbyists and really unnecessary for transportation purposes.”

Elon Musk, founder of Tesla Motors

AVs are expected to be integrated into current shared mobility concepts. This subsection shows the disruption of the traditional ownership model by roving fleets of AVs in the future.

Studies outline that cars remain unused for more than 95% of the time (Morris, 2016). Owning a car is therefore fairly expensive, particularly when considering how much it remains underused. In addition to the acquisition cost, maintenance and insurance costs have to be considered and many consumers thus take out a loan in order to buy their own car.

Nowadays, this traditional ownership model is being disrupted. Many consumers no longer buy a car on their own, but instead buy, use or rent one collectively. One potential reason for this may be that the so-called Generation Y does not seem to perceive cars as status symbols anymore (Eliot, 2019). Shared mobility,

together with AD, will change the manner in which consumers purchase mobility services.

In fact, consumers will increasingly purchase a *service* – mobility – rather than a *good*, i.e., a car. Jonas (2015) combines

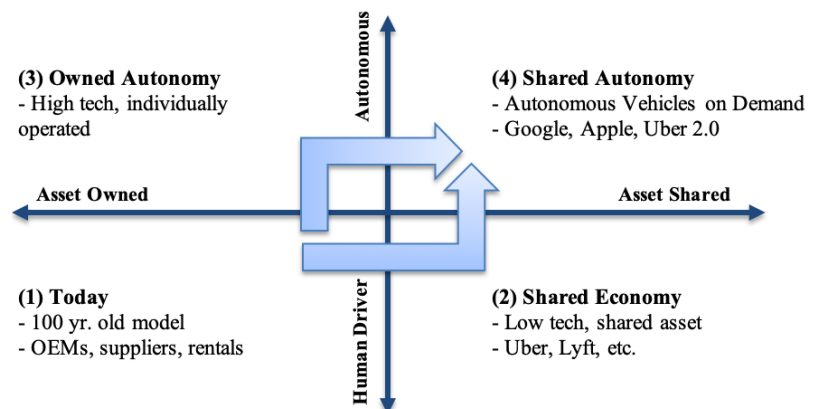


FIGURE 1: The Four Stages of Mobility

Source: own depiction based on Jonas (2015).

these two trends with respect to shared mobility and AD to define the notion of shared autonomy. According to Jonas (2015), four phases will become apparent. The current concept of mobility as practiced (1) *Today* will interact with the concepts of (2) *Shared Economy* and (3) *Owned Autonomy*, leading to the concept of (4) *Shared Autonomy*. Figure 1 summarizes these concepts.

Quadrant (1) represents the most common (and current) paradigm of a car driven by a human being. Key players are OEMs (Original Equipment Manufacturers), suppliers and rental agencies. Car manufacturers have developed comprehensive assistance systems to make driving within this paradigm safer and more reliable.

Quadrant (2) depicts the disruption of the transportation network, which is driven by ride-hailing services such as Uber and Lyft. By exploiting digitalization and offering greater flexibility, they have introduced the *Shared Economy* concept into the mobility sector.³ Doing so allows consumers to renounce car ownership while transferring vehicle control to another person. One could summarize this evolutionary process by stating that “taxis” are now cheaper than ever before, while customers enjoy added flexibility. In urban environments, this development has even led many consumers to forgo public transportation altogether in favor of ride-hailing services (Jonas, 2015).

Quadrant (3) illustrates the initial transfer of control tasks to a computer. The steering wheel and pedals, though still present, are used less often. Privately owned, traditional cars will increasingly find themselves competing with vehicles endowed with automated driving characteristics offered by firms such as Tesla and Mobileye. Driving assistance systems will continuously improve road safety and traffic flow efficiency (Jonas, 2015).

Lastly, **Quadrant (4)** envisages the target state, characterized by the widespread presence of roving fleets of fully AVs available 24/7, which can be ordered through a smartphone. Key players will be technology companies such as Google, Apple and Uber. Vehicles – to a very large extent purely electric or hybrid – are available on request, offering short waiting times and safe as well as comfortable journeys. All vehicles are connected through a hub-and-spoke network and communicate with each other. Public transport is phased out due to lack of cost competitiveness. Many car parks, previously designed to accommodate a large number of vehicles, gradually dis-

³ One could counterargue that traditional taxis had already done so long ago. However, ride-hailing services incremented the introduction of the shared economy concept to a level that traditional taxis never did.

appear from the urban landscape. Quadrant (4) also encompasses deep changes in the way consumers purchase mobility as a result of the development of new digital technologies. As Elon Musk's quote above outlines, owning a car in the future will be mostly for hobbyists and unnecessary for transportation purposes. According to Musk, self-driving taxis will shape the cityscape already in 2020, with over a million robotaxis on the road (Kolodny, 2019).

2.4 | Competitors

Assessing the challenges raised by AVs requires an analysis of the competitive landscape and its current leaders. The corresponding results will now be discussed.

Alongside well-known firms such as Google and Tesla, a variety of automotive firms and other technology giants are investing in autonomous transportation, either by creating their own AV or by developing the software controlling the vehicle. According to Navigant Research (2019), many are already making progress towards creating fully AVs. This report rates manufacturers, suppliers and technology firms according to their Level 3, Level 4 and Level 5 systems (as defined in Section 2.1), as well as their short-term objectives. For this purpose, aspects such as *Go-to market strategy*, *Partnering (with other firms)*, *Production strategy* and *Technology* have been assessed and analyzed. Figure 2 summarizes the results by means of the Navigant Research Leaderboard Grid.

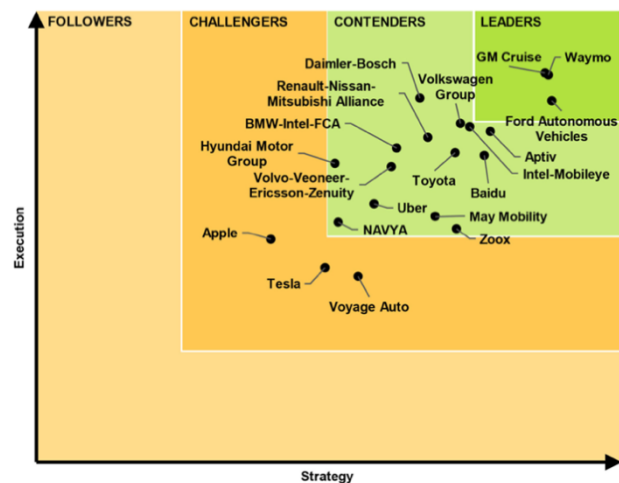


FIGURE 2: The Navigant Research Leaderboard Grid

Source: Navigant Research (2019).

Waymo (Google), GM Cruise and Ford Autonomous Vehicles are the leaders in the field of AVs (see Section 8, Appendix A.1 for sample photos). As such, these will subsequently be discussed in more detail.

Waymo is an American company based in Mountain View, California. The firm develops technologies for AVs and continues the work of Alphabet's Google Driverless Car project, established in December 2016. According to CEO John Krafcik, the firm does not intend to build its own vehicles. Instead, it will license its software and share its experience with other carmakers (Dhawan, 2018). Waymo's first attempts to launch a self-driving taxi service in Phoenix, Arizona, date back to April 2017. On December 5, 2018, again in Arizona, the company launched a commercial self-driving car service called "Waymo One", offering users an app-based platform for requesting a ride (Fingas, 2018). Another success achieved by Waymo was the approval of Level 5 rides in California at the end of 2018, a state with stricter rules than Arizona concerning the operation of self-driving cars. So far, the firm only allows Waymo employees and their guests to ride its vehicles in a limited service area in South Bay (Hawkins, 2019a). CEO John Krafcik has not yet revealed his European expansion plans but has pointed out that the firm has the capabilities to expand into new markets and find additional partners for its technology (DeBord, 2018).

GM Cruise is an American self-driving car company founded in 2013 and based in San Francisco, California. Acquired by General Motors Company in March 2016, the firm develops and tests technologies for its own cars. With a total of 450,000 autonomous miles driven in California last year, GM Cruise ranks second in terms of AVs' mileage (Wiggers, 2019). According to CEO Dan Ammann, the company is partnering with Softbank's Vision Fund and Honda to develop purpose-built AVs (Burns, 2018). Since July 2017, GM Cruise has been testing AVs on public roads in San Francisco, Scottsdale, Arizona and the Detroit metropolitan area (Hawkins, 2017). However, CEO Dan Ammann recently stated that the firm is delaying their commercial launch beyond 2019 as further testing is required (White, 2019).

Ford Autonomous Vehicles is an American multinational company headquartered in Dearborn, Michigan, which was founded in 2018 by Ford Motor Company. Its self-driving software is being developed together with Argo AI, a Pittsburgh-based startup owned by Ford and Volkswagen.

Ford has started testing AVs in Miami and Washington D.C. Further tests have been conducted in Detroit and Pittsburgh. However, none of these vehicles are fully autonomous yet. The firm keeps two security drivers in each vehicle at all times (Hawkins, 2019c). Recently (September 2019), the firm announced it will expand its fleet of AVs to Austin, Texas, where it plans to launch Level 4 autonomous commercial vehicles in 2021 (Hawkins, 2019c).

Further Key Players

Tesla is an American automotive and energy company, headquartered in Palo Alto, California. Since September 2014, Tesla has been equipping its cars with an autopilot providing semi-autonomous driver assistance (Lawler, 2014). Tesla has continuously developed the driver assistance system and its autopilot already includes adaptive speed control, lane departure warning, emergency braking, autosteer and parking (Morris, 2019). Initially, Tesla was expected to achieve full autonomy by the end of 2017. However, this has continually been postponed as further testing is required (Brown, 2018). Though all Tesla vehicles are currently equipped for full self-driving, Tesla's CEO Elon Musk recently made it clear that it is not yet guaranteed that their software will work under all circumstances upon its release in early 2020 (Morris, 2019).

Uber is an American ridesharing company based in San Francisco, California. Self-driving cars are being developed together with Advanced Technologies Group (Uber ATG), a subsidiary of the company, which is minority owned by Softbank Vision Fund, Toyota and Denso (Griswold, 2019). In March 2018, Uber had to temporarily abandon its AV development when an accident with a self-driving car led to the death of a pedestrian in Tempe, Arizona (Sydney and Sage, 2018). According to the police report of the accident, the person was run over by an AV while crossing the road, while the driver watched videos on her smartphone. In response, Uber compensated the victim's family and withdrew its self-driving cars from all public roads in Arizona (Loizos, 2018). However, the tests were officially resumed nine months later in Pittsburgh, Penn-

sylvania (Hawkins, 2019b). The firm recently unveiled the third generation of its vehicles and will begin testing them in Dallas in 2020 (Hawkins, 2019b).

Despite an extensive literature review on AVs, we found that there are currently no vehicles with the highest degree of automation (Level 5) for sale on the market. Hence, our study fulfills unanswered research questions by studying the acceptance of these vehicles by consumers and assessing the challenges faced by (fully) AVs.

3 | Methodology

Various methods were used to answer the three research questions. The data were collected using both a quantitative and a qualitative approach.

First, a survey of AVs was conducted to gauge their acceptance by the general public.⁴ Prior to its launch, the survey was pre-tested on several individuals and further developed in accordance with their feedback. Subsequently, it was distributed online through social media and career network channels, namely Facebook, XING and LinkedIn. In addition, several potential respondents were addressed via direct messaging. In total, 307 individuals took the survey, of which 281 answered the questionnaire completely. Regarding survey demographics, 65% of all respondents are 23 to 28 years old. Thus, the younger population is somewhat overrepresented. Since 55% of respondents are men, 44% are women, and 1% is diverse, the survey by and large is representative of the whole population. Most participants (86%) hold a Bachelor's or Master's degree. It is thus likely that the sample is biased towards the more educated demographics.

Secondly, in-depth interviews were conducted with experts knowledgeable in the field of AVs in order to measure alignment between the general public's and experts' attitudes towards AVs.⁵ This methodology is based on the rationale that misalignment between consumers and the industry is harmful to the market penetration of AVs. One interviewee is a manager at one of the

⁴ The survey questions and results can be found in Appendix A.5.

⁵ The interview guide can be found in Appendix A.2, the interview analysis in Appendix A.3 and the interview transcripts in Appendix A.4.

world's leading engineering partners. The firm develops the mobility of the future and offers 20 years of research experience with sensors, function development and algorithms for new driver assistance systems right through to fully automated connected driving. The other interviewee is the director of a German car manufacturer. As one of the biggest producers of premium cars and the world's biggest manufacturer of commercial vehicles with a global reach, the firm is a pioneer in AD. Both interviewees thus have a broad knowledge of AV's functionality, challenges and opportunities. However, the views of a single industry expert do not necessarily exactly reflect the views of the whole industry. Despite this caveat, one surmises that they are strongly correlated with the industry's views. Hence, the responses should offer a glimpse into the industry's approach to market developments. The individuals' names as well as their firms have been replaced by industry affiliation for reasons of confidentiality. Both interviews lasted 60 minutes, were conducted by telephone in German and subsequently translated into English.

Thirdly, in order to assess the marketability of AVs as a future means of transport, we discuss the strengths, weaknesses, opportunities and threats faced by these vehicles, i.e. we perform an evaluation of the internal and external factors derived from the literature review, survey findings and expert opinions.

4 | Evaluation of the Acceptance of Autonomous Vehicles

4.1 | Societal Acceptance

A survey regarding AVs was conducted to gauge their acceptance by the general public. The corresponding results will be discussed in this section.

Questions 1–2 The majority of respondents (78% male, 48% female) have already *often* or *very often* heard or read about AVs. Hence, we conclude that awareness of AVs is already widespread and that consumers are conscious of the new (disruptive) technologies pervading the automotive industry. In this regard, most women deem themselves either *slightly knowledgeable* (36%) or

moderately knowledgeable (35%), while the majority of men believe to be already *moderately knowledgeable* (57%) about AVs.

Questions 3–4 Most respondents believe that an AV will be the more reliable “driver”, when compared to an average human driver. In terms of their own driving skills, however, respondents consider *themselves* to be more reliable than an *average human driver*.⁶ Interestingly, although respondents rate their driving skills as above average, they rate themselves as inferior drivers when compared to AVs.

Question 5 Moreover, 81% of all participants (87% male, 74% female) believe that AVs increase road safety. The majority are therefore confident that AVs bring about safety advantages, even though they do not consider *themselves* unreliable drivers. Despite the fact that a lower percentage of women participated in the survey, more women (in absolute terms) mention that they do not expect (or do not know about) improved road safety arising from the presence of AVs. In fact, 9% of women (against only 6% of men) do not expect AVs to yield improved road safety.

Question 6 A large percentage of respondents (81% male, 83% female) are either willing to pay anything between the same amount and up to 30% more for an AV than for a traditional vehicle. This substantiates their recognition of the potential extra benefits of AVs. In this regard, it should be pointed out that only 13% of respondents (12% male, 14% female) are willing to pay a premium *in excess* of 31% for an AV.

Question 7 However, somewhat surprisingly, AD does not have a particularly good image with respondents, with many being still skeptical regarding this technology. Three issues are of particular relevance to consumers: unresolved liability issues (21%), additional cost (20%), and the absence of driving fun (18%). The majority of participants are afraid of incurring high costs, despite being willing to pay the above-mentioned premium. Moreover, they are worried about how liabil-

⁶ This type of bias (i.e. illusory superiority) is well document in psychology (Schuster, 2019). The fact that it is also present in our sample suggests that our respondents are representative of the general population in this regard, which is an important determinant of preferences in the context of our research questions.

ity for future traffic accidents will be apportioned and do not want to sacrifice the driving experience that current vehicles offer.⁷

Question 8 Potential users of AVs also flag ethical issues. One participant mentions that “*if, for example, the car is constructed in such a way that its highest priority is to save the lives of passengers, even at the expense of several other dying people, [he/she] would feel guilty in case of an accident*”. Another participant responds that “*machines cannot act or react like humans out of instinct, but rather based on data*”. Many respondents therefore hesitate to delegate the power of decision to a computer and the programs running on it.

Question 9 Additionally, further interesting aspects with respect to the launch of AVs have been mentioned. One respondent specifies that “*an autonomous car would allow us to redesign the interior. If this were not the case, an autonomous car would not have such a benefit compared to a ‘classical car’*”. Some consumers are therefore already considering new design possibilities for future vehicles and demand-specific improvements over the vehicles currently on offer. Another participant even emphasizes that AVs will be “*more environmentally harming*”. This is based on the idea that use of an AV by several individuals (i.e. sharing of autonomous cars) may have the same effect – more cars in circulation – as today’s ride-hailing platforms such as Uber and Lyft.

Questions 10–11 Strikingly, 46% of respondents (48% male, 44% female) would consider not owning a vehicle in the future. Consumers state that they are likely to use car sharing (i) because of its convenience and (ii) because the existence of reliable public transportation makes owning a car less useful. Other respondents mention cost savings and overcrowded roads as reasons for not owning a vehicle.

Question 12 In contrast, knowing that the average car is parked 95% of the time and is therefore not used efficiently, only 19% of respondents (21% male, 14% female) would still own a car.

⁷ This is consistent with the observation that many respondents rate *themselves* as being above-average drivers.

Consumers state that (i) flexibility still remains an important issue, (ii) that the demand for independent means of transport in rural areas is crucial and (iii) that they do not want to sacrifice the enjoyment of driving. In fact, almost every second woman (42%) does not know whether she should own a vehicle in the future or not.

Questions 13–15 In line with this, 58% of respondents (66% male, 46% female) would consider subscribing to a service for AVs allowing them to access a vehicle when they need it. Once again, women are quite undecided (46%) whether they should subscribe or not. Overcrowded roads are a factor leading respondents to rent a car instead of owning one. This type of subscription is also intended to solve today's parking problems. In addition, comfort, flexibility and cost savings are further reasons that are adduced in favor of (autonomous) shared mobility. The current car-sharing model (exemplified by DriveNow and Car2Go) is based on these consumer preferences. However, the safety of an AV offered by car sharing services is considered crucial for its acceptance.

Question 16 Many respondents (33% male, 41% female) feel neither bad nor happy about a future in which there are exclusively AVs that do not allow driver intervention. Respondents are therefore undecided regarding the advantages and disadvantages that AVs entail, perhaps due to lack of detailed knowledge regarding these vehicles.

Question 17 46% of participants (44% male, 48% female) further indicate that they expect most vehicles (i.e., 80% or more) to be autonomous in between 11 and 20 years (2030 to 2039). However, this forecast differs to some extent from McKinsey's research on the self-driving vehicle revolution, which assumes that AVs will become the fully primary means of transport by 2050 (Bertoncello and Wee, 2015).

Questions 18–20 On the one hand, the majority (59% of respondents) strongly agree with the assertion that AVs will be the means of transport in the future, while concurrently waiving their driving fun. On the other hand, many respondents mention that they are *“concerned about these cars and do not know what the future will look like, especially in small villages”*. However, re-

spondents are aware of the technological advancement that will grant them a more relaxed driving experience.

Questions 21–22 Strikingly, 78% of respondents state that AVs will improve their personal time management so that they can free up time for other tasks (e.g. reading, working). Interestingly, the majority (59%) is irresolute regarding whether a ride in an AV would make them feel safer on the road, considering that 81% of all respondents believe that AVs increase road safety.

Questions 23–24 Additionally, every second participant (53%) states that she or he is undecided regarding whether they would prefer a car with many assistance systems where the driver is still responsible for most of the safety-critical functions rather than riding a fully AV. Once again, this symbolizes their recognition of *themselves* as inferior drivers when compared to AVs. By potentially considering the higher costs for AVs, the majority (57%) would rather use an AV rented from a mobility service provider (e.g. taxi, car sharing) than own one themselves.

Questions 25–27 Many respondents (50%) also strongly agree that consumers would have more confidence in AVs if the car industry was more transparent about their state of development. Likewise, respondents are still uncertain about the current status of these vehicles and require more information from decision makers (e.g. suppliers and government). The survey further shows that respondents are not unduly concerned with the data storage capabilities of AVs. Connected cars collect a mass of information about the driver (e.g. traveling routes and destinations), which firms could make available to third parties. The lack of concern with data protection may correlate with the lack of transparency of the automotive industry regarding AVs. Participants are not yet in a position to quantify the exact extent of the data obtained, as well as to gauge its uses.

In summary, the survey results show that AVs are likely to be accepted by consumers. The majority of respondents, who recognize the advantages of AVs, consider eschewing car ownership and are interested in new autonomous car-sharing opportunities. Women in particular are still undecided whether they should either own a vehicle in the future or consider subscribing to a ser-

vice for AVs, which can be explained by the lack of detailed knowledge about these vehicles. Men, in contrast, tend to be more willing to pay a premium for AVs. In addition, men – on average – are already more involved with these new concepts (i.e., AVs and AD) than women. Overall, respondents point out several issues that hinder their full acceptance of AVs, such as unresolved liability issues, additional costs, the absence of driving fun, system shutdowns, legal issues, lack of control, lack of trust or the trolley problem.⁸

4.2 | Expert Opinions and Comparison with Societal Views

Expert interviews were conducted in order to gain insights on specific aspects of the AV market development and to measure potential discrepancies between society's and the experts' views. The results will be discussed in this section.⁹

Level of Competition According to Supplier (2019), the market for AVs is “*very competitive and it will be difficult for German companies to keep up with the pace of large IT companies*”. Car Manufacturer (2019) notes that there is no market for AVs yet because the highest AV level on the market is currently Level 3, thus implying that the driver still has to intervene in some circumstances. One could describe this stage as being characterized by the dominance of driver assistance systems. In contrast to Supplier (2019), Car Manufacturer (2019) points out that “*large IT companies are [due to motion sickness¹⁰] not able to build an AV without cooperating with a car manufacturer*”. This illustrates the fact that IT companies do not have the comprehensive automotive expertise that car manufacturers have.

Road Safety Supplier (2019) declares that with the growth of AVs, road safety increases; yet “*car accidents cannot be 100% eliminated*”. This is consistent with Car Manufacturer's (2019) state-

⁸ The trolley problem represents an ethical thought experiment, developed by philosopher Philippa Foot in 1967 (Cathcart, 2013). It generally questions whether it is justified to kill one person with the chance to save five lives.

⁹ The interview analysis can be found in Appendix A.3.

¹⁰ Motion sickness is a sensation of wooziness. It is a physical state that occurs when people are subjected to oscillatory movements over which they have no control. In a car, the condition tends to arise when you are a passenger and not a driver (Dobie, 2019).

ment that “*car accidents cannot be eliminated in the future, neither in Level 4 nor in Level 5*”. He further states that improved road safety could be achieved from Level 4 onwards. Improved road safety through AVs is also assumed by 81% of all respondents (see Section 8, Appendix A.5). The majority is therefore confident about the safety benefits of AVs.

Responsibility for Accidents The experts are quite uncertain regarding how the responsibility for accidents should be apportioned. Though Supplier (2019) believes that drivers should not be held accountable, he acknowledges that OEMs will likely go bankrupt when held responsible for software errors. Nevertheless, he concludes that it is most likely that the OEM will be held accountable. This is consistent with the opinion of Car Manufacturer (2019), who outlines that in Levels 4 and 5, the manufacturer (or seller) of the product must definitely ensure that it works due to product liability. However, he is not sure what might happen if the manufacturer excludes product liability for a small percentage of the total number of kilometers in the sales contract. In summary, many open questions remain to be clarified regarding liability and its apportioning among players.

Price Premium for AVs According to Supplier (2019), AVs will have a price premium of approximately 20,000 Euros compared to a conventional car with the same functionality, which would equal a surcharge of approximately 20 to 25%. However, he claims that this percentage is highly dependent on the vehicle price. He further states that “*the more expensive the vehicle model, the less the surcharge [in percentage] will be*”. In contrast, Car Manufacturer (2019) states that no (exact) percentage is possible, because it depends on the vehicle category. According to him, the costs for AD are relatively similar per vehicle. Integration costs of the autonomous systems are, however, lower in a premium car. As already explained in Section 5.1, potential users would be willing to pay a considerable surcharge. This underscores both their awareness of the potential benefits of AVs and their willingness to pay a premium equal or even exceeding the premium forecasted by the experts.

Autonomous Future On the one hand, Supplier (2019) states that in approximately 38 years, most vehicles will be fully autonomous and driven cars will only be allowed on the racetrack. Interestingly, the results of our survey show that the majority of respondents overestimate the progress of AVs. According to them, most (i.e., 80% or more) vehicles will be fully autonomous in 11 to 20 years (see Section 8, Appendix A.5). On the other hand, Car Manufacturer (2019) states that it is not possible to make a precise statement, as it depends strongly on the speed of technological development and the implementation of political, legal and insurance conditions. He forecasts that in 10 years' time, cars will have reached Level 4. However, he further explains "*that an average car is currently driven for 12 years, i.e., if it were possible to drive autonomously in 10 years, the AD technology would have to have a yearly market share of 100% [in order] for 80% of all cars to be autonomous in 10 more years*". This suggests that the majority of respondents overestimate the speed with which AD technology will penetrate the market since they are expecting AVs to be available considerably sooner than the experts predict.

Shared Mobility and AVs The increased purveyance of shared mobility concepts raises the question of whether it will still be necessary to own a car in the future. Supplier (2019) states that the current generation still wants to have their own car. Once the next generation comes of age, however, fewer private cars will be on the road. Nevertheless, according to Car Manufacturer (2019), one car is still required per household. He further emphasizes that a "*100% availability guarantee is an important factor for society and AVs are the essential prerequisite for shared mobility concepts*". 46% of respondents would consider not owning a vehicle in the future and 58% of respondents would even consider subscribing to a service for AVs allowing them to access a vehicle when needed. This means that society – contrary to the experts' opinion – would waive their 100% availability guarantee to a certain extent (see Section 8, Appendix A.4).

Consumers' Acceptance According to Supplier (2019), the majority of consumers will accept AVs because they can save time and use it more efficiently. However, he mentions that some per-

sons do not want to sacrifice the driving experience. Both statements are also supported by Car Manufacturer (2019). He further states that “*without [the use of] AVs, certain groups of people would not be able to drive an own vehicle, e.g. young people, people without a driving license, older people, alcoholics, epileptics*”. The ability to ride independently in an AV gives them the opportunity to (re-)gain mobility to a significant extent. In addition, the survey shows that the majority is already confident as to the safety advantages of AVs. Moreover, respondents point out several additional advantages of AVs, namely flexibility, convenience, comfort, relaxation, no waste of time and less congestion in cities.

In summary, expert opinions also lean towards AVs likely being accepted by consumers. We conclude that society’s view largely corresponds with the perception of the industry’s experts. However, in light of an imminent autonomous future, the results of our survey show that the majority of respondents overestimate the progress of AVs. According to the general public, most vehicles will be fully autonomous in 11 to 20 years. In contrast, experts expect that it will take more than 35 years for this to be the case. In addition, with regard to shared mobility concepts, every second respondent of the survey would renounce their own car, which contradicts the experts’ forecast that most consumers demand a 100% availability guarantee. Lastly, it is concluded that OEM will likely be held liable in case for accidents and that large IT companies are unlikely to be able to build an AV without cooperating with a car manufacturer.

5 | Marketability of Autonomous Vehicles

The marketability of AVs with the highest level (Level 5) is assessed by evaluating the strengths, weaknesses, opportunities and threats faced by these vehicles. Results are based on a comprehensive literature review, as well as the insights gained from the consumer survey and the expert interviews.

5.1 | Internal Factors

Strengths With respect to the strengths of AVs, it should first be noted that ninety-five percent of road accidents are caused by human error (NHTSA, 2016). AVs contribute to the avoidance of these accidents since automated driving largely eliminates the risk of human error (Araya, 2019). Moreover, the “driver” of an AV benefits from a less stressful transportation experience. This is confirmed by our consumer survey (see Section 8, Appendix A.5), from which it can be concluded that technology eliminates the need for a *de facto* driver. The occupant can devote himself to other tasks or hobbies while being transported. This allows for a less stressful experience, which should increase the rider’s comfort. Furthermore, AVs also improve personal time management since they allow the former driver to perform other tasks (e.g. reading, working) while riding. This engenders productivity gains. More crucially, it strongly differentiates AVs from traditional vehicles requiring a driver. Lastly, it should be noted that ninety-five percent of cars are parked at any moment (Morris, 2016). This entails costs for the owner. Owners buy the car and continuously pay for insurance and maintenance as a whole, regardless of whether the vehicle is used much or not (see Section 8, Appendix A.4). In the future, acquiring a vehicle will no longer be necessary since a commercially operated AV is capable of dropping off its passengers at their destination and subsequently offer rides to subsequent users. The vehicle itself is thus used more efficiently, which entails a reduction in the associated costs. These, in addition, are spread over several users rather than being covered by a single one. As a result, vehicle ownership is therefore likely to be disrupted by the advent of fully automated AVs, as predicted by the experts (see Section 8, Appendix A.4).

Weaknesses AVs have several weaknesses. First and foremost, their development is (very) costly (Nunes and Hernandez, 2019). Consumers must cover development costs through the price of an AV. Indeed, the consumer survey confirms that the majority of respondents (87%) are unwilling to pay more than a 30% premium over the price of a traditional vehicle when buying an AV (see

Section 8, Appendix A.5). This will likely hinder market penetration significantly in early stages. Moreover, 69% of respondents state that AVs take the fun out of driving. We infer that this factor significantly impacts the attractiveness of – and thus the willingness to pay for – AVs. According to Car Manufacturer (2019), the investment per AV is more profitable for vehicles that cover long distances (e.g. freight transport). This means that the break-even point is reached faster than with a robotaxi since taxis today operate with a time utilization of only 30–40% as predicted by Car Manufacturer (2019). Furthermore, AVs also pose liability challenges. Who is to blame in a crash? The software developer? The vehicle’s manufacturer? The vehicle’s owner? Insurance companies, plaintiffs and thus the court system will be faced with novel issues, the settlement of which will affect the utilization rate of AVs both in the short as well as in the long run. The assessment of both experts also shows that it is difficult to predict how these challenges can be properly addressed. Moreover, at this stage, AVs cannot operate in all weather conditions without a human driver. Heavy storms, rain, snow or fog disturb the sensors and cameras, implying that a fully accident-free journey is not yet guaranteed (Herrmann, Brenner and Stadler, 2018). Overcoming these issues is a *sine qua non* condition for the commercial viability of AVs. Lastly, roads fully suitable for AVs are not yet fully developed. GPS and other technologies cannot currently detect obstacles such as potholes, recent changes in road conditions and newly erected signs. For AVs to be able to drive unconditionally on today’s roads, the road network and related infrastructure must be significantly improved. The associated costs are presumably significant.

5.2 | External Factors

Opportunities AVs give rise to several opportunities. Autonomous shuttles and buses in particular enable children, the elderly as well as the disabled and the sick to become more independent (Herrmann, Brenner and Stadler 2018), which is also confirmed by Car Manufacturer (2019). Besides, the traffic flow can be optimized. Through communication among vehicles (V-to-V) and between vehicles and the infrastructure (V-to-I), stop-and-go waves caused by human driving

behavior (e.g. bottlenecks, lane changes or other disturbances) can be eliminated (Herrmann, Brenner and Stadler 2018). Furthermore, the smoother (optimized) acceleration of an AV reduces fuel consumption. As a result, a reduction in CO₂ emissions is also achieved. In fact, researchers at the University of Illinois have shown that switching to AVs can reduce overall fuel consumption by up to 40 percent (Stern, 2018). In addition, truck platooning also reduces fuel consumption by up to 10 percent (Banker, 2019). By connecting trucks on highways via V-to-V communication, they can benefit from the slipstream of the following truck.

Threats Lastly, there are circumstances that threaten the success of AVs. A technological malfunction can lead to a serious accident that cannot be prevented due to the lack of human intervention. Thus, the embedded technology poses a major risk in itself.¹¹ Moreover, data security as well as privacy are also at stake when AVs are in use (see Section 8, Appendix A.4). The mass of user information such as locations travelled to, routes and destinations that each car continuously stores, raises privacy concerns as predicted by Supplier (2019). In line with this, the possibility of hackers breaking into an AV's system is another major threat that does not apply to traditional vehicles. By targeting the vehicle's software, hackers can interfere with or even fully control the vehicle. According to the experts, this poses a very significant risk. In addition, AVs also raise ethical challenges. How will an AV – or, better still, its software – evaluate difficult ethical dilemmas? How will it decide when facing the inevitability of a major accident, while having to choose between hurting a senior citizen and a child? How should the vehicle ethically decide what to do when a beast suddenly crosses the road? Should it take evasive action even if doing so poses a minor risk to passengers or (human) bystanders, or instead decline to take such an action, thereby sacrificing the animal? Unresolved ethical questions are a major barrier to the market penetration of AVs, which is also confirmed by our consumer survey. Furthermore, current jobs in the

¹¹ Two recent major crashes involving the Boeing 737 Max are insistently attributed to the malfunction of a technological system denominated MCAS (Maneuvering Characteristics Augmentation System). Though involving a different type of vehicle, this shows that heavy reliance on a technology may lead to serious accidents that could likely have been avoided in its absence.

transportation industry could be made superfluous by the widespread introduction of AVs. Truck drivers, taxi drivers and delivery drivers, in particular, will be much affected by the introduction of AVs, as predicted by Car Manufacturer (2019). Moreover, car manufacturers claim that only original repair parts can ensure the safety of the sophisticated systems deployed in AVs. This 800-billion-dollar aftermarket could therefore exclude independent repair shops in the future (Bellon, 2019). Finally, legislation regulating AVs – or, more precisely, their “behavior” – has not yet been devised in most countries. Current written regulations are likely to become outdated (or even inapplicable) once AVs enter commercial use, another issue that threatens the introduction of AVs, as forecasted by Supplier (2019).

In summary, the large number of weaknesses and threats outweigh the strengths and opportunities of AVs. This implies that AVs are not yet fully marketable as a future means of transport. On the one hand, positive factors such as the reduction of road accidents, an enhanced ride experience or an optimized traffic flow militate in favor of AVs. On the other hand, the significant impact of legal regulations, technological maturity and a lack of infrastructure development delays the marketability of (fully) AVs. However, respondents’ positive attitude towards AVs – also supported by the experts – show that the benefits of AVs are valued and can yield high market potential in the future. Given the additional costs of AVs, we conclude that these vehicles are most likely to prevail if they are part of a shared mobility concept.

6 | Conclusion

We sought to assess the social acceptance of AVs and the challenges surrounding it. Three research questions were asked: (i) *Will AVs be accepted by consumers?* (ii) *Will AVs be embedded in the shared mobility economy?* (iii) *Are AVs with the highest level of autonomy already marketable?*

Regarding the first research question, the online survey and the experts’ views indicate that AVs are likely to be accepted by consumers. Nevertheless, many potential users are still skeptical

about this kind of technology. However, AVs allow time to be saved and used more efficiently. In addition, certain groups – such as very young and old people, and epileptics – will benefit from (re)gaining mobility through the launch of AVs. Strikingly, respondents are not overly concerned with the private data storage capabilities of AVs.

With regard to the second research question, we conclude that AVs will play a major role in the urban mobility ecosystem and are the most essential prerequisite for shared mobility concepts in the future. Without AVs, these concepts will likely not prevail. Business models with subscription-based AVs are emerging in the form of robotaxis in urban ecosystems. However, according to the industry experts, consumers will presumably continue to own one car per household to ensure 100% flexibility.

Regarding the third research question, an analysis was performed to determine if AVs are already marketable. In view of the large number of threats and weaknesses, we come to the conclusion that AVs with the highest level are not yet fully marketable. Nevertheless, according to the experts, there is strong potential in the more distant future.

As a future outlook, it is concluded that AVs could be the primary means of transport from 2050 onwards. The prospect of self-driving cars depends on two factors, in particular: (i) How fast is the technology going to evolve? (ii) How quickly can the legal, political and insurance conditions be established so that the technology can gain traction (so to speak)?

An evaluation purely based on an online survey and two expert interviews entails a few limitations. Although the survey was aimed at respondents all over the world, only the opinions of two experts affiliated with firms operating in the German automotive market were obtained. Moreover, the views of a single industry expert do not necessarily exactly represent the views of the whole industry. Hence, they can only offer a glimpse of the industry's approach to market developments. In order to gain a broader perspective, additional expert interviews could be obtained, particularly from the Silicon Valley area, where most AVs are currently being tested.

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Expert Interviews

- Engineering Supplier [Supplier, 2019]:** As one of the globally leading engineering partners, this firm develops the mobility of the future. It has 20 years of research experience with sensors, function development and algorithms for new driver assist systems right through to fully automated connected driving.
- German Car Manufacturer [Car Manufacturer, 2019]:** As one of the biggest producers of premium cars and the world's biggest manufacturer of commercial vehicles with a global reach, this firm is a pioneer in autonomous driving.

8 | Appendices

A.1 Vehicles of Waymo, GM Cruise and Ford AV



Autonomous Vehicle of **Waymo**



Autonomous Vehicle of **GM Cruise**



Autonomous Vehicle of **Ford AV**

A.2 Interview Guide

Interview Guide “Mobility in the 21st Century: Autonomous Vehicles”

Date: November xx, 2019, xx:xx p.m.

Warm-up

“Thank you for agreeing to talk to me today. I am conducting research on the challenges and acceptance of Autonomous Vehicles.

In what follows, there are no right or wrong answers and, of course, everything we talk about today is absolutely confidential. Do you mind if I record this interview? We’re going to cover different topics in the next 45 to 60 minutes. If you have any questions, please don’t hesitate to ask them at any time.”

Background Information

- Could you briefly introduce yourself and describe your responsibilities at (insert company name)?
- For how many years have you been dealing with the topic of Autonomous Vehicles?
- How would you rate the progress that your firm has made up to now regarding Autonomous Vehicles?

Specific questions related to AVs

- Is the market for AVs highly competitive? Why (whatever the previous answer)?
- Do large IT companies, such as Google, develop AVs faster than traditional carmakers?
- Do you believe that AVs will increase road safety in the future? To what extent (slightly, significantly, or to an extent that car accidents will be a feature of the past)?
- What would prevent potential consumers from buying an AV? Please address *all* issues that you find to be relevant.
- How much more (in percentage) would an AV cost you compared to a conventional car with similar features?
- Who will be held responsible if an accident occurs? The driver? The carmaker? Both? A third party that supplied the software? All three?
- Will AVs be accepted by the consumers, i.e., to what extent? Why?
- Do you think the appearance of AVs will be good or bad for sales?
- When do you expect most (i.e. 80% or more) vehicles to be autonomous?

External factors

- Which external factors (political, economic, social, technical, legal, environmental) influence the market for AVs? Please address *all* those aspects and issues that you find to be relevant.

Connection between AV and Shared Mobility

- Will it be necessary to own a car in the future?
- As you may already know, the concept of Shared Mobility, i.e. Car-Sharing, etc., is increasingly being used. Could you imagine that AVs will be embedded in the Shared Mobility concept? How?
- Will this enhance or, to the contrary, hurt the profitability of your firm? Why?

Final open questions

- Can the driver's privacy be an issue? For instance, AVs may collect too much information about the driver (e.g. traveling routes and destinations).
- Will this be a problem affecting the market prospects of AVs?
- Emotionally, how do you feel about a future in which there are exclusively AVs that do not (or almost do not) allow any interventions by the driver?
- If I have an AV, will I be able to drive it by myself?
- Will you lose people that love to drive cars?

Wrap-up

"This brings us to the end of our interview, and I would like to thank you for your time. Do you have any questions or comments you would like to add? Thank you once again."

A.3 Interview Analysis

Cluster	Engineering Supplier	Car Manufacturer	General Public
Level of Competition	Very competitive; It will be difficult for German companies to keep up with the pace of large IT companies	There is no market for autonomous vehicles yet; Large IT companies are not able to build an AV without cooperating with a car manufacturer	n/a
Road Safety	Increasing due to AVs; Accidents cannot be 100% eliminated	Possible in Level 4 (i.e. only limited areas); Car accidents cannot be eliminated in the future, neither in Level 4 nor in Level 5	81% states that road safety will increase due to AVs
Responsibility for Accidents	Driver cannot be held responsible; OEM will go bankrupt if e.g. a software error happens; However, most likely that the OEM will be held responsible	In Level 4 and 5, the manufacturer or seller of the product must definitely ensure via product liability that it works	n/a
Price Premium for AVs	Depending on vehicle price; The more expensive the vehicle model, the less the surcharge will be; Approx. 20,000 Euros surcharge, on average 20-25% more expensive	No percentage possible, depends on vehicle category; The costs for autonomous driving are relatively similar per vehicle; Integration costs of the autonomous systems are, however, lower in a premium car	22% would be willing to pay the same 22% would be willing to pay 1% to 10% more 22% would be willing to pay 11% to 20% more 16% would be willing to pay 21% to 30% more 13% would be willing to pay in excess of 31% more
Autonomous Future	Approx. in 38 years 80% of all vehicles are autonomous; In the long run, driven cars will only be allowed on the racetrack	No precise statement possible, depending on the speed of technological development and the implementation of political, legal and insurance conditions	Within 5 years (2%) In between 6 and 10 years (17%) In between 11 and 20 years (46%) More than 21 years (33%) Never (2%)
Shared Mobility and AVs	Current generation still want their own car; With the next generation, cars on the road are strongly reduced	One car is required per household; 100% availability guarantee is an important factor for society; AVs are the essential prerequisite for shared mobility concepts	46% would consider not owning a car 58% would consider subscribing to a service that allows to access AVs every time you demand it
Consumers' Acceptance	The majority of consumers will accept AVs because they can save time and use it more efficiently; However, some people don't want to sacrifice the driving experience	Definitely, because time is saved and can be used more effectively; Some customers, however, do not want to sacrifice the driving experience; Without AVs, certain groups of people would not be able to drive an own vehicle, e.g. young people, people without a driving licence, older people, alcoholics, epileptics	Flexibility; Convenience; Comfort; Time in the car can be used for work, relaxation and is not wasted; Less congestion in cities

Legend:

Compatible

Neutral

Contrary

A.4 Interview Transcripts

Interview: Engineering Supplier

Interview Guide – Engineering Supplier “Mobility in the 21st Century: Autonomous Vehicles”

Date: November 12, 2019, 06:00 p.m.

Warm-up

“Thank you for agreeing to talk to me today. I am conducting research on the challenges and acceptance of Autonomous Vehicles.

In what follows, there are no right or wrong answers and, of course, everything we talk about today is absolutely confidential. Do you mind if I record this interview? We’re going to cover different topics in the next 45 to 60 minutes. If you have any questions, please don’t hesitate to ask them at any time.”

Background Information

- Could you briefly introduce yourself and describe your responsibilities at (*company name*)?
 - Master’s in Engineering, Major Automotive
 - Responsible for a project with autonomous trucks with (*company name*) & (*company name*), which is dedicated to travel autonomously around the port of Hamburg, as well as on the highway
- For how many years have you been dealing with the topic of Autonomous Vehicles?
 - 2.5 years
- How would you rate the progress that your firm has made up to now regarding Autonomous Vehicles?
 - Very confidential, but very far ahead

Specific questions related to AVs

- Is the market for AVs highly competitive? Why (whatever the previous answer)?
 - Very competitive, everyone wants to show AVs as a core competency, there are only a few outsourcing projects
 - Very profitable environment
- Do large IT companies, such as Google, develop AVs faster than traditional carmakers?
 - It will be difficult for German companies to keep up with the pace of large IT companies
 - IT companies have a lot of software skills → Big challenge but still possible to keep up with
- Do you believe that AVs will increase road safety in the future? To what extent (slightly, significantly, or to an extent that car accidents will be a feature of the past)?
 - In any case, there is a significant increase in road safety, but car accidents cannot be 100% eliminated
 - Many situations can be tested in simulation, yet the world is too complex to test everything
 - Companies can protect themselves against many things, e.g. by only allowing AVs on roads
- What would prevent potential consumers from buying an AV? Please address *all* issues that you find to be relevant.
 - Most people do not want to rely on a machine
 - Many people think that they can drive better than average
 - Approx. 10 % can drive very well, 90 % overestimate their driving skills
 - Older people are not used to it, so they may not prefer AVs
 - The next generations perceive AVs as an alternative, they will accept it directly
 - In the near future you may not need a driver's license anymore

- Cost factor (expensive)
 - Example: People drive in a low sun, the camera is overexposed, so that all other sensors still have to perceive the environment. This quickly makes it very expensive.
 - Nowadays cameras are inexpensive, radars are also inexpensive, but lidar (laser) is partly priceless.
 - Continental will soon release a new lidar, so that it might become more affordable
- How much more (in percentage) would an AV cost you compared to a conventional car with similar features?
 - Depending on vehicle price
 - The more expensive the vehicle model, the less the surcharge will be
 - Approx. 20k surcharge, on average 20-25% more expensive
- Who will be held responsible if an accident occurs? The driver? The carmaker? Both? A third party that supplied the software? All three?
 - Difficult to say how it can be meaningfully implemented
 - An OEM (i.e. Original equipment manufacturer) will never say that he will be held liable
 - OEM will go bankrupt if e.g. a software error happens
 - The driver cannot be responsible anyway
 - Example: A customer will not buy an AV if he can be held liable in the event of an accident
 - However, most likely the OEM is responsible for it
 - If the AV can be intervened by the driver, there will be disputes as to who ultimately led the AV to the accident.
- Will AVs be accepted by the consumers, i.e., to what extent? Why?
 - The majority of consumers will accept AVs, because they can save time and use it more efficiently
 - However, some people don't want to sacrifice the driving experience
- Do you think the appearance of AVs will be good or bad for sales?
 - For car manufacturers rather bad: people will "only" use cars to get from A to B (Shared Mobility)
 - This makes OEMs more likely to become service providers by renting a car fleet
 - (Company name) will benefit from this, as the OEMs will receive the functionality from (company name)
- When do you expect most (i.e. 80% or more) vehicles to be autonomous?
 - Approx. in 38 years 80% of all vehicles are autonomous

External factors

- Which external factors (political, economic, social, technical, legal, environmental) influence the market for AVs? Please address *all* those aspects and issues that you find to be relevant.
 - Politics/foreign trade: E.g. Presidents, like Donald Trump, sanctions from China → sales decrease → economic capacity shrinks
 - Legal: Question of guilt to be clarified, very complex
 - A legal hurdle was cleared a year ago

Connection between AV and Shared Mobility

- Will it be necessary to own a car in the future?
 - No absolutely not, yet some of our generation still want their own car
 - With the next generation it is strongly reduced, since these people want to get only from A to B

- Will be a cost question, whether one can afford to drive with only AVs (i.e. Shared Mobility)
- Robotaxis → Makes it cheaper → only needs a battery and no driver anymore, so it can be offered cheaper
- As you may already know, the concept of Shared Mobility, i.e. Car-Sharing, etc., is increasingly being used. Could you imagine that AVs will be embedded in the Shared Mobility concept? How?
 - Shared Mobility is a huge issue because the society don't want a car in the city anymore, they are more relying on concepts such as DriveNow
 - A rented fleet of AV can be used if someone has drunk alcohol → Convenience
- Will this enhance or, to the contrary, hurt the profitability of your firm? Why?
 - Profitability will only be slightly affected as fewer cars are sold
 - However, cars currently park 95% of its time. If cars are continuously on the road with simultaneous maintenance, it will last for one year and will achieve approx. 200,000 kilometers. Therefore, this will not have a big impact as most fear

Final open questions

- Can the driver's privacy be an issue? For instance, AVs may collect too much information about the driver (e.g. traveling routes and destinations).
 - Customer data is very sensitive
 - OEMs will handle the customer data with care and will not pass it on to third parties. Otherwise there will be a loss of trust and they will no longer use this service
- Will this be a problem affecting the market prospects of AVs?
 - Yes, huge topic: Everything is getting smarter and more connected, therefore greater potential for hackers (cybersecurity)
 - V-X communication is the biggest point of attack for hackers
 - Hackers can load a virus on your AV, because your car is just a "big computer"
- Emotionally, how do you feel about a future in which there are exclusively AVs that do not (or almost do not) allow any interventions by the driver?
 - Negative because I am a candidate who says that I can drive better than the average
 - Just because an AV can drive better than 90% of people, it doesn't mean it reacts better in different situations
 - In the long run, "driver cars" will only be allowed on the racetrack
 - Because we grew up with a driver's license, this situation is unimaginable for us
- If I have an AV, will I be able to drive it by myself?
 - Still able to intervene in the next 5-10 years (completely autonomous as an additional function)
 - In the long run, it is no longer possible to intervene and there will be no possibility of obtaining a driving license
- Will you lose people that love to drive cars?
 - Yes, but only a small percentage
 - The biggest proponents of AVs are *baby boomers*, who will retire in the near future
 - 10% of people will not buy a car if they are not allowed to drive themselves
 - The people need to be convinced that an AV drives better than a human being

Wrap-up

"This brings us to the end of our interview, and I would like to thank you for your time. Do you have any questions or comments you would like to add? Thank you once again."

Interview: Car Manufacturer

Interview Guide – Car Manufacturer “Mobility in the 21st Century: Autonomous Vehicles”

Date: November 20, 2019, 2:00 p.m.

Warm-up

“Thank you for agreeing to talk to me today. I am conducting research on the challenges and acceptance of Autonomous Vehicles.

In what follows, there are no right or wrong answers and, of course, everything we talk about today is absolutely confidential. Do you mind if I record this interview? We’re going to cover different topics in the next 45 to 60 minutes. If you have any questions, please don’t hesitate to ask them at any time.”

Background Information

- Could you briefly introduce yourself and describe your responsibilities at (*company name*)?
 - Management background (MBA), 23 years of experience in the automotive industry, much experience abroad
 - Responsible for “CASE” sales (Connected, Autonomous, Shared, Electric) for 3.5 years with about 400 employees
- For how many years have you been dealing with the topic of Autonomous Vehicles?
 - 3 years
- How would you rate the progress that your firm has made up to now regarding Autonomous Vehicles?
 - Difficult to define, (*company name*) has made huge advances in technology as well as in evaluating the mobility of the future
 - Since products are not yet on the market, comparison is difficult

Specific questions related to AVs

- Is the market for AVs highly competitive? Why (whatever the previous answer)?
 - There is no market for autonomous vehicles yet
 - The maximum level of autonomous vehicles is currently level 3 (i.e. driver still has to intervene in certain situations) → rather driving assistance systems
 - Demand in the industrial sector is very high → Long-distance transport / goods transport but not yet in car business
- Do large IT companies, such as Google, develop AVs faster than traditional carmakers?
 - No, not possible without an automotive partner → Cooperation necessary
 - The ability to build algorithms is only one capability, but this is not sufficient to bring autonomous vehicles fully onto the road
 - The link with the systems in the vehicle is the second capability that large IT companies cannot create without a car manufacturer
 - Motion Sickness is very important: E.g. How does the car react to a brake?
 - IT companies (alone) could only produce cars for parcel delivery, since no persons are involved (they do not have the competence for motion sickness)
 - Car manufacturers can produce autonomous vehicles even without the expertise of large IT companies
- Do you believe that AVs will increase road safety in the future? To what extent (slightly, significantly, or to an extent that car accidents will be a feature of the past)?
 - Possible in Level 4 (i.e. only limited areas)

- Car accidents cannot be eliminated in the future, neither in Level 4 nor in Level 5
- What would prevent potential consumers from buying an AV? Please address *all* issues that you find to be relevant.
 - 1. Security, 2. Comfort, 3. Cost
- How much more (in percentage) would an AV cost you compared to a conventional car with similar features?
 - No percentage possible, depends on vehicle category
 - The costs for autonomous driving are relatively similar per vehicle
 - Integration costs of the autonomous systems are, however, lower in a premium car
- Who will be held responsible if an accident occurs? The driver? The carmaker? Both? A third party that supplied the software? All three?
 - In Level 4 and 5, the manufacturer or seller of the product must definitely ensure via product liability that it works
 - Example from the USA: Who pays for the damage?
 - Criteria are laid down for the examination and if these are met in the event of an accident, liability is transferred to a state institution, which then bears this liability for everyone
 - What happens if the manufacturer excludes product liability for a small percentage (e.g. 0.4%) of the total mileage in the sales contract?
- Will AVs be accepted by the consumers, i.e., to what extent? Why?
 - Definitely, because time is saved and can be used more effectively (e.g. trips to work)
 - Some customers, however, do not want to sacrifice the driving experience
 - Certain groups of people are not able to drive an own vehicle, e.g. young people, people without a driving licence, older people, alcoholics, epileptics
 - This would change with the launch of autonomous vehicles
- Do you think the appearance of AVs will be good or bad for sales?
 - Depending on the degree of regulatory intervention
 - If the advent of autonomous driving is accompanied by some entry restrictions for types of individual traffic (e.g. only robotaxis are allowed), this would damage car sales. At the same time, however, it would increase sales of vans
- When do you expect most (i.e. 80% or more) vehicles to be autonomous?
 - No statement possible, depends on two core questions:
 - 1. How fast is the technology developing? (e.g. computing power and energy consumption)
 - 2. How quickly will the legal, political and insurance conditions be developed so that the technology can prevail?
 - Technologically, in 10 years cars will be ready to drive in Level 4
 - An average car is currently driven for 12 years, i.e. if it were to be possible to drive autonomously in 10 years, the technology of autonomous driving would have to be sold 100% each year, in order to have 80% of all cars autonomous in 10 more years
 - Level 5 is very far away, as the car would have to be able to drive autonomously everywhere, e.g. from point A to point B in the Sahara

External factors

- Which external factors (political, economic, social, technical, legal, environmental) influence the market for AVs? Please address *all* those aspects and issues that you find to be relevant.

- Predominantly regulatory factors, i.e. political and legal factors
- Technical infrastructure: Is a 5G network necessary? Will the car stop directly if it cannot connect to a network for a short moment?

Connection between AV and Shared Mobility

- Will it be necessary to own a car in the future?
 - One car is required per household
 - The individual freedom that you get from a car is very important
 - 100% availability guarantee represents an important factor for society
 - Peak dilemma (e.g. New Year's Eve)
 - Car-Sharing options are far too expensive for longer individual journeys
 - Many empty runs necessary. This relativizes the cost of owning a car
 - For cities with less than 400,000 - 500,000 inhabitants, shared concepts are more expensive than owning a car per person
- As you may already know, the concept of Shared Mobility, i.e. Car-Sharing, etc., is increasingly being used. Could you imagine that AVs will be embedded in the Shared Mobility concept? How?
 - Autonomous vehicles are the essential prerequisite for shared mobility concepts. Without autonomous vehicles, the concept will never prevail.
 - Because the car drives to the person, the acceptance of shared concepts is much higher than when the person has to look for an available car himself
- Will this enhance or, to the contrary, hurt the profitability of your firm? Why?
 - Depending on the sales volume of the future → Car sales vs. van sales (see answer of sales forecast)

Final open questions

- Can the driver's privacy be an issue? For instance, AVs may collect too much information about the driver (e.g. traveling routes and destinations).
 - No, it won't. Scepticism about data transparency is declining sharply
 - Example: In China, proposals are expected to be made on the basis of customer data
 - Especially the younger generation does not see any major limitations due to the data transfer
 - Companies are expected not to disclose data to third parties
- Will this be a problem affecting the market prospects of AVs?
 - Absolutely not, see answer to previous question
- Emotionally, how do you feel about a future in which there are exclusively AVs that do not (or almost do not) allow any interventions by the driver?
 - Neither happy nor bad → Comfort gain
 - Uncertain whether he wants to sacrifice the driving experience
 - Ethical debate is not comprehensible
 - If a driver could rationally think about which group of people could be "worth less", he would have enough time to bring the car to a standstill
- If I have an AV, will I be able to drive it by myself?
 - Depends on the system: Do I want to drive a robotaxi fully autonomously or do I want a hybrid solution (i.e. autonomous vehicle that can also be driven by a person) that asks for it before starting the journey?
 - For a certain period of time, hybrid solutions will be necessary until vehicles can drive fully autonomously in all areas
- Will you lose people that love to drive cars?
 - No, as hybrid options still have to be offered up to a certain point in time

- In the future, it will be necessary to switch to a fully autonomous car if there is no other option

Wrap-up

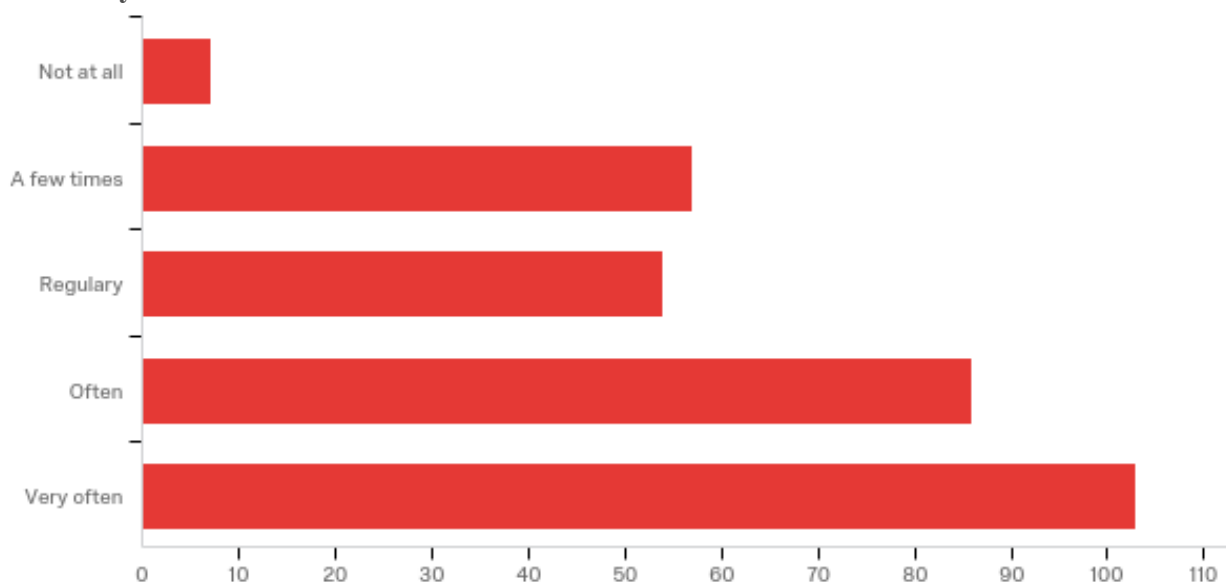
“This brings us to the end of our interview, and I would like to thank you for your time. Do you have any questions or comments you would like to add? Thank you once again.”

A.5 Survey Questions and Results

Autonomous Vehicles Survey

October 26th, 2019, 7:12 am MDT

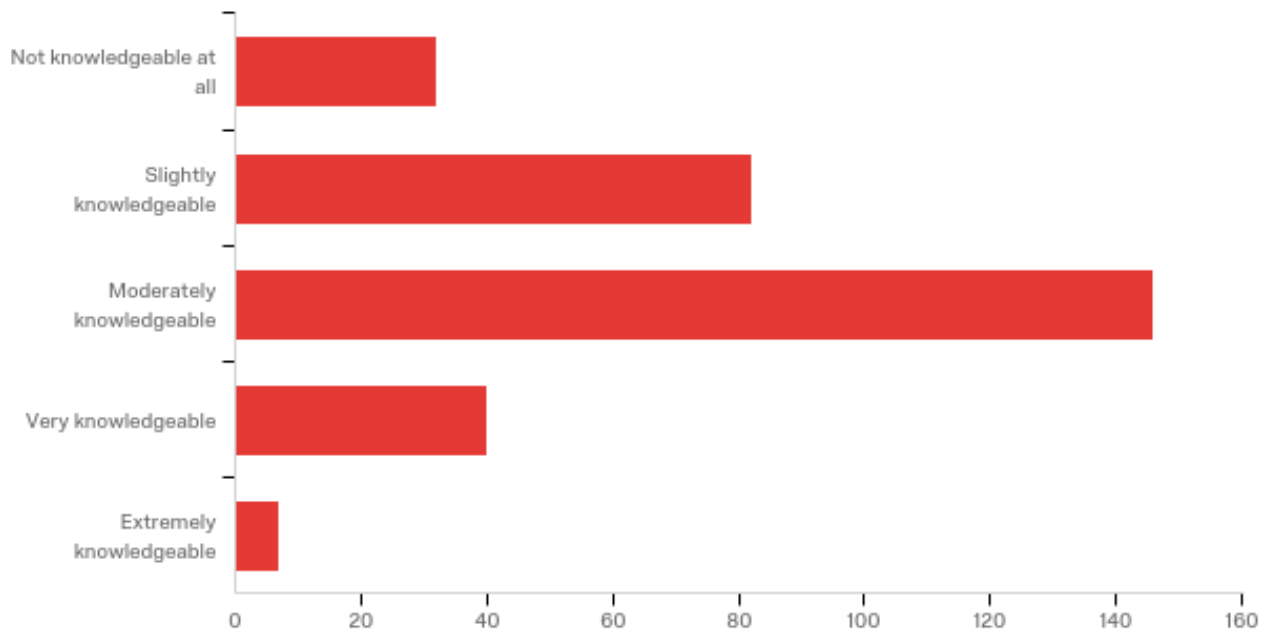
Q1 - Have you ever heard or read about Autonomous Vehicles?



#	Field	Minimum	Maximum	Mean	Std Devia- tion	Variance	Count
1	Have you ever heard or read about Autonomous Vehicles?	1.00	5.00	3.72	1.18	1.38	307

#	Answer	%	Count
1	Not at all	2.28%	7
2	A few times	18.57%	57
3	Regularly	17.59%	54
4	Often	28.01%	86
5	Very often	33.55%	103
	Total	100%	307

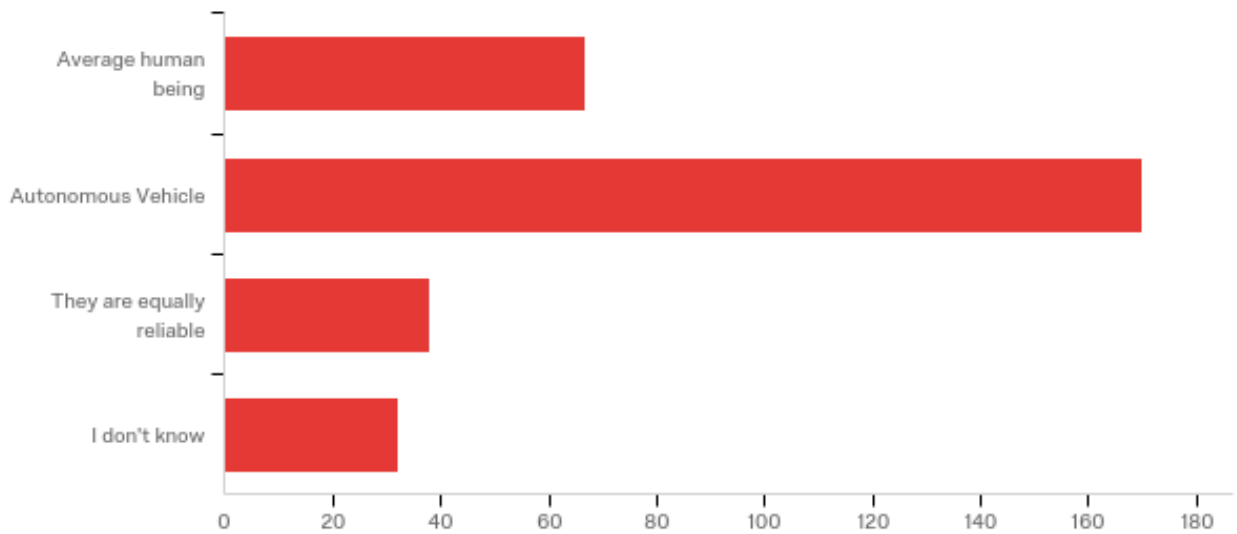
Q2 - How knowledgeable do you rate yourself to be regarding the subject of Autonomous Vehicles and Autonomous Driving?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	How knowledgeable do you rate yourself to be regarding the subject of Autonomous Vehicles and Autonomous Driving?	1.00	5.00	2.70	0.90	0.82	307

#	Answer	%	Count
1	Not knowledgeable at all	10.42%	32
2	Slightly knowledgeable	26.71%	82
3	Moderately knowledgeable	47.56%	146
4	Very knowledgeable	13.03%	40
5	Extremely knowledgeable	2.28%	7
	Total	100%	307

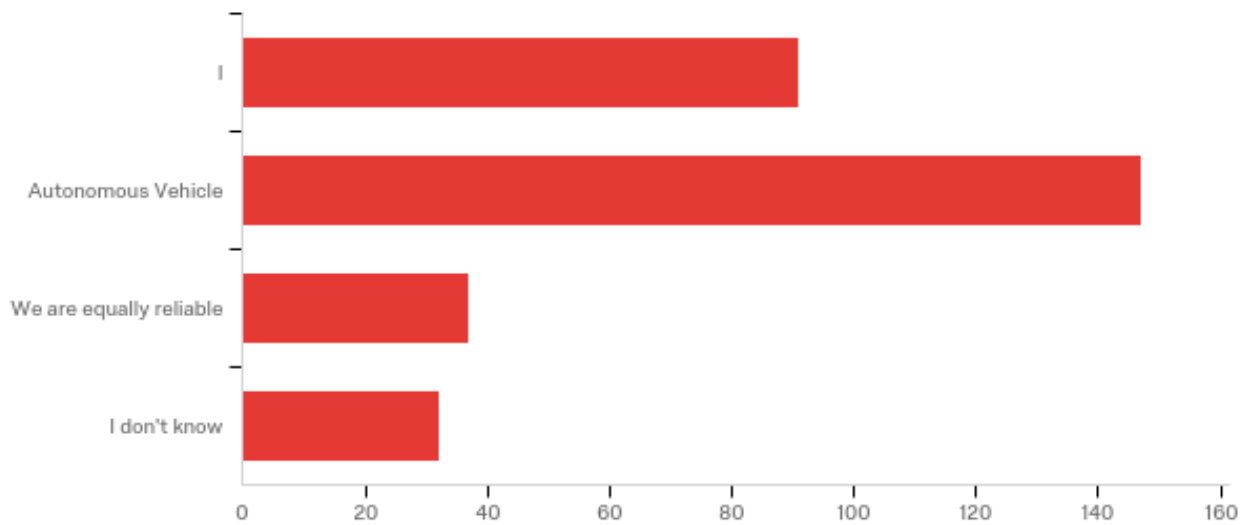
Q3 - Who do you think is the more reliable driver: the average human being or an Autonomous Vehicle?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Who do you think is the more reliable driver: the average human being or an Autonomous Vehicle?	1.00	4.00	2.11	0.86	0.75	307

#	Answer	%	Count
1	Average human being	21.82%	67
2	Autonomous Vehicle	55.37%	170
3	They are equally reliable	12.38%	38
4	I don't know	10.42%	32
	Total	100%	307

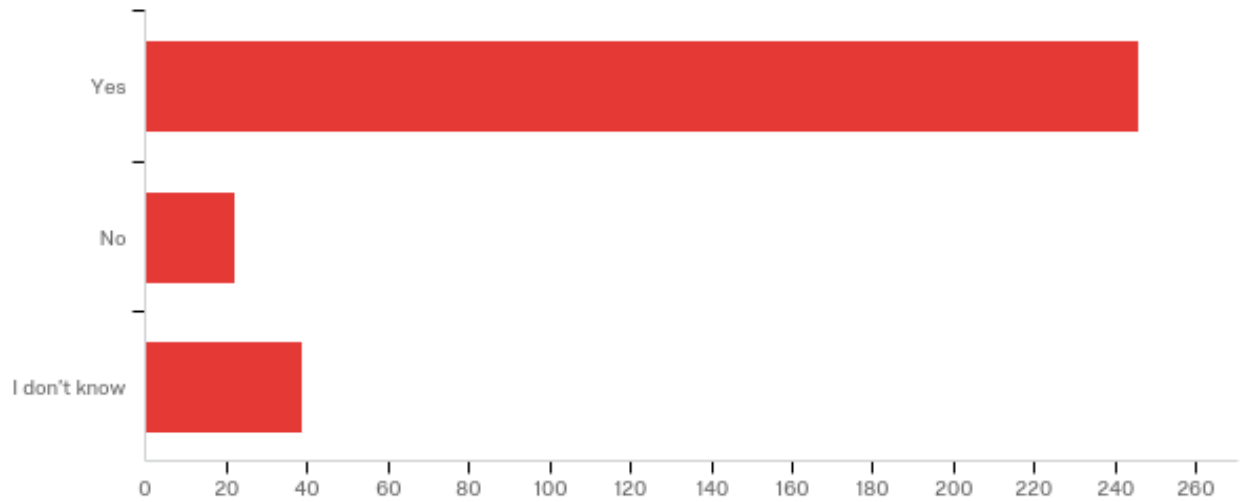
Q4 - Who do you think is the more reliable driver: you or an Autonomous Vehicle?



#	Field	Minimum	Maximum	Mean	Std Devia- tion	Variance	Count
1	Who do you think is the more reliable driver: you or an Autonomous Vehicle?	1.00	4.00	2.03	0.91	0.83	307

#	Answer	%	Count
1	I	29.64%	91
2	Autonomous Vehicle	47.88%	147
3	We are equally reliable	12.05%	37
4	I don't know	10.42%	32
	Total	100%	307

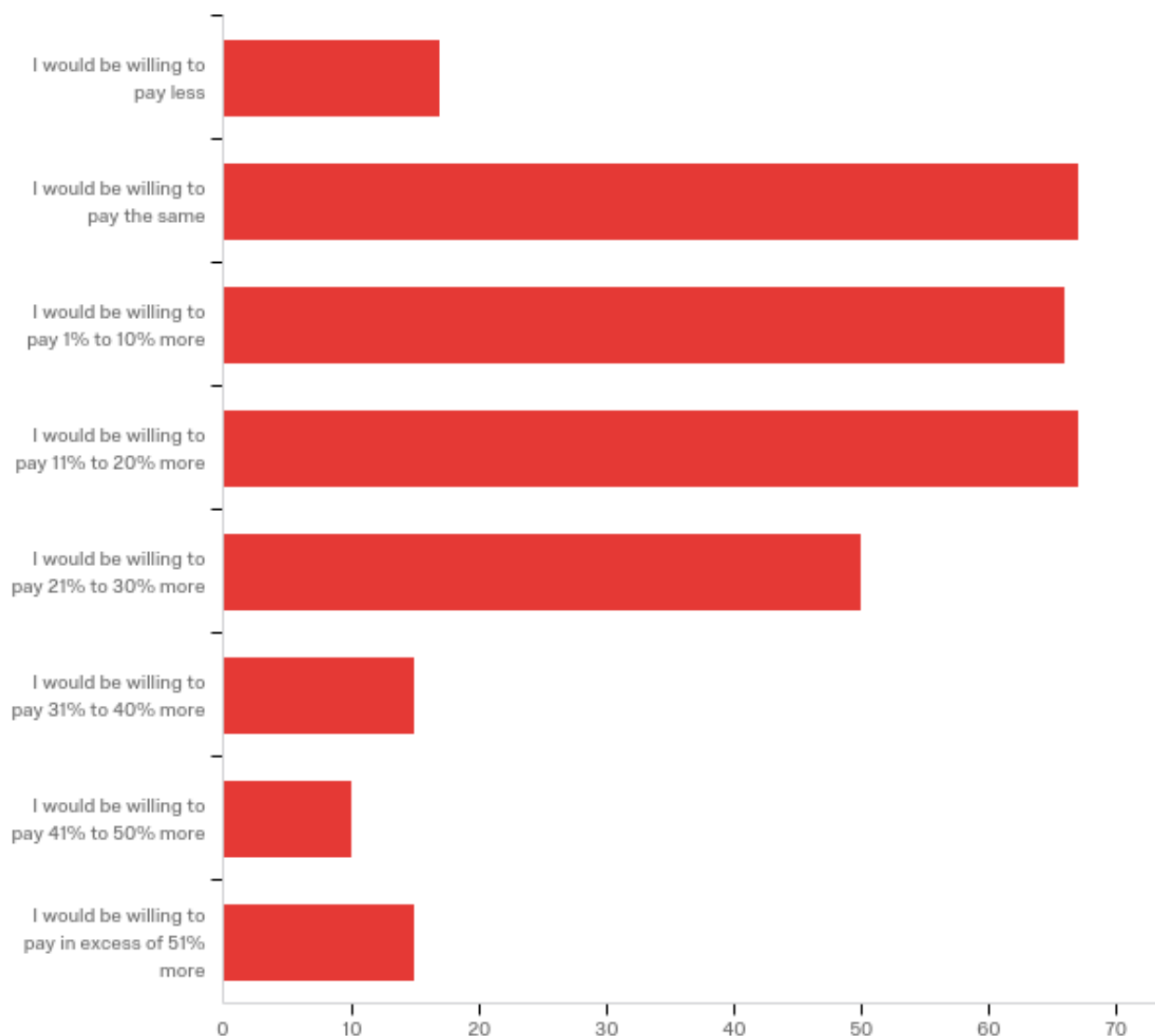
Q5 - Do you believe that Autonomous Vehicles will increase road safety in the future?



#	Field	Minimum	Maximum	Mean	Std Devia- tion	Variance	Count
1	Do you believe that Autono- mous Vehicles will increase road safety in the future?	1.00	3.00	1.33	0.69	0.47	307

#	Answer	%	Count
1	Yes	80.13%	246
2	No	7.17%	22
3	I don't know	12.70%	39
	Total	100%	307

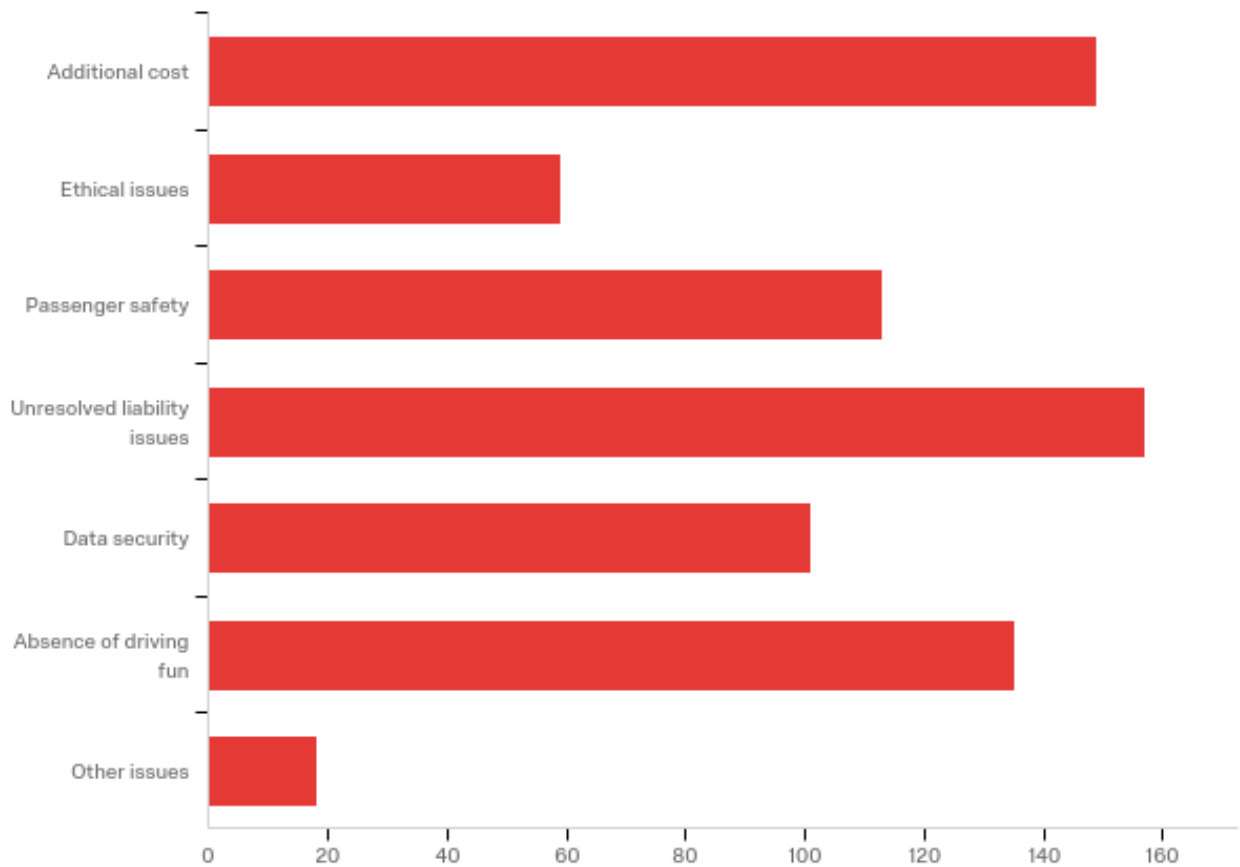
Q6 - How much more would you be willing to pay for an Autonomous Vehicle compared to a conventional car with similar characteristics?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	How much more would you be willing to pay for an Autonomous Vehicle compared to a conventional car with similar characteristics?	1.00	9.00	3.79	1.85	3.41	307

#	Answer	%	Count
1	I would be willing to pay less	5.54%	17
2	I would be willing to pay the same	21.82%	67
3	I would be willing to pay 1% to 10% more	21.50%	66
4	I would be willing to pay 11% to 20% more	21.82%	67
5	I would be willing to pay 21% to 30% more	16.29%	50
6	I would be willing to pay 31% to 40% more	4.89%	15
7	I would be willing to pay 41% to 50% more	3.26%	10
9	I would be willing to pay in excess of 51% more	4.89%	15
	Total	100%	307

Q7 - What would prevent you from buying an Autonomous Vehicle? (Multiple choices are allowed)



#	Answer	%	Count
1	Additional cost	20.36%	149
2	Ethical issues	8.06%	59
3	Passenger safety	15.44%	113
4	Unresolved liability issues	21.45%	157
5	Data security	13.80%	101
6	Absence of driving fun	18.44%	135
7	Other issues	2.46%	18
	Total	100%	732

Q8 - Ethical issues: Please describe them.

Who should the car protect in case a crash is not preventable? The driver or someone on the street?

If you cannot avoid a crash between 2 persons, how would the automatic driver choose

Questions about reliability in terms of accidents

Ethical dilemma's such as which person to hit when left with no choice

Construction in an unethical way

In case of dilemma - who decides who to hit and who to save?

The decision making of the system. Animal or human? Young children or old lady?

If, for example, the car is engineered in a way that its highest priority is to save the passengers life, even at the expense of multiple other people dying, I would feel guilty in case of that happening.

Responsibility for death by an autonomous vehicle if an accident with one of two persons (old lady or child) cannot be prevented and the machine must decide which person is to be hit by the car.

If an accident happens and you are in the car, even though you are not "driving", are you responsible? If not, who is?

Responsibility of the autonomous driving system can't compare with a human, who is driving a car. Especially, if there is an accident, the question of the fault isn't clear.

Machines cannot act or react like humans and judge out of instinct, only based on data

Balance the safety of others

Decisions to be made by the AI whom you harm

Child vs. old person dilemma

Deciding in a situation whose death is less painful

Trust

Moral machine. Decision making in case of accident

If an accident is about to happen and the car can't avoid it anymore, it has to decide who is being injured. Weighing up a human life against these of others is difficult

E.g. Software programmed to secure passengers but no humans in general

Problem coming from viruses that might end up in killing people

You're transferring a lot of decision power to the vehicle

What happens when someone gets hurt? Maybe, just maybe if there was a human in there, we could understand what transpired. But what about a machine? We would have no clue regarding why someone was hit or why something failed.

How does the vehicle react in extreme situations, will the source code be open, reviewed and verified?

If an autonomous car, which is driving with me being passive, commits an accident, would it be my responsibility?

Balancing the safety of others; trolley problem

The problem in which an AV has to decide whether to crash into an oncoming car or swerve and crash into, say, a preschool.

In case the autonomous car could either kill men or 3 children the decision-making process is not transparent to me. There are ethical questions left open such as have three human beings more value than a single one.

In case of accidents

For insurance, reaction time, the decision between a child or an adult when it comes to collision

In case of accidents who would the machine rather run over a child or an old person how would the machine make the decisions. Especially in the case of AI, we will not be able to influence how machines will make the decisions

Who is guilty for mistakes?

The vehicle does not (so far) differentiate whether it endangers a child or an old person in an unavoidable situation, for example.

The question on how the car will decide in case of accident circumstances when somebody (driver, passengers, other road users or pedestrians) will be hurt for sure

In case of unavoidable accidents there could be a decision between killing an old person or a young person

Accidents

Decision in an inevitable crash: Securing the life of the people in the car or the life of pedestrians/older or younger people

Differentiation between humans and animals, old and young humans, "good" and "bad" humans

Man vs machine. I don't want computerized choice of death.

What happens if there is a decision to be made, if to crash in a wall or crash a human

Concerns about the liability in case of road traffic accidents

Baby vs grandma

Lack of trust

Environmental issues

Car deciding what happens in case of an accident

Q9 - Other issues: Please describe them.

Automation will only be fully successful when all (or almost all) cars are automated. Computers have a tendency of not being able to keep up with humans being unpredictable.

Still too many reliability issues; not clear when they can be resolved

What is important is a complete and safe autonomous infrastructure in which NOT autonomous vehicles make up a fraction. Only in this way can the algorithms make reliable statements about road traffic. Furthermore, footpaths, pedestrians and cyclists would have to be integrated into this ecosystem and the roads made intelligent.

The average safety might be higher with autonomous systems, especially in common situations, while the reaction of a trained driver in unusual situations can be more accurate and safer for all involved. Resulting, the autonomous systems need to prove these skills first.

An autonomous car would allow us to redesign the interior. If that's not the case, an autonomous car would not have such a benefit compared to a "classical car"

No interest in buying a new car at the moment.

I would use a mobility service and buy the route instead of buying the vehicle.

Accidents due to system errors

Owning a car is not required with autonomous vehicles in my opinion

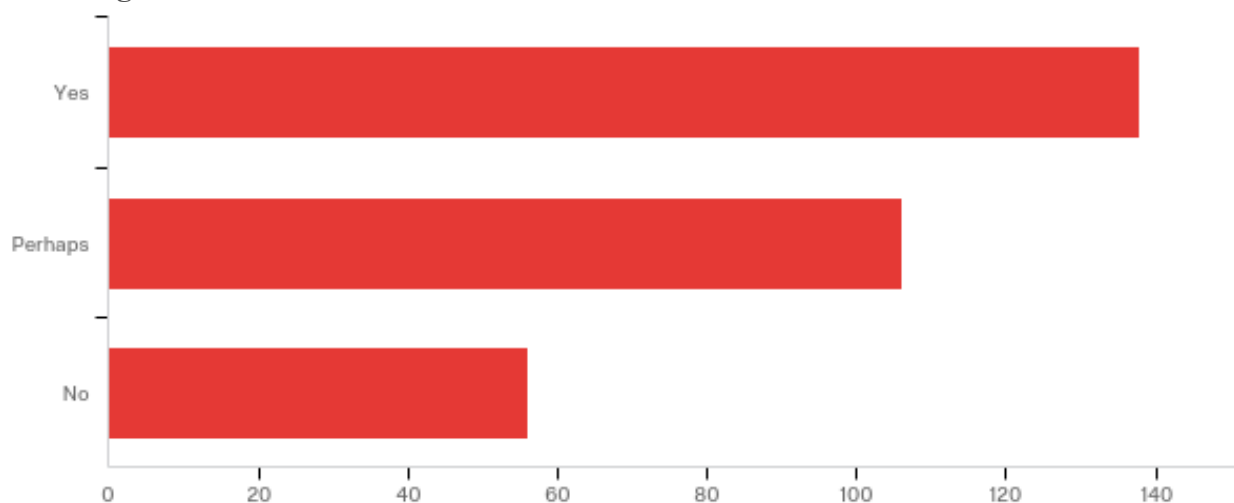
Lack of control. Nervousness of other non-autonomous cars around.

What happens in case of a system shutdown due to a bug/hack/whatever

Legal issues

More environmentally harming

Q10 - Given the increase in mobility services (e.g. shared mobility), would you consider not owning a car in the future?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Given the increase in mobility services (e.g. shared mobility), would you consider not owning a car in the future?	1.00	3.00	1.73	0.76	0.57	300

#	Answer	%	Count
1	Yes	46.00%	138
2	Perhaps	35.33%	106
3	No	18.67%	56
	Total	100%	300

Q11 - Why? (consider not owning a car)

Living in the city, parking is difficult, public transport is good, environment

Convenient and useful

By new structures, owning a car might be irrelevant.

Less costs, environment

Because it's not too expensive

Cost savings. Convenience

I'm not a big fan of cars to be honest. I use my bike in the city. I think cars can be useful for a road trip, but then you don't have to have one, you can rent it.

Pollution, costs, convenience

Won't need it

I've always believed a sharing economy to be a good thing which is why I support public provision of services (e.g. libraries)

No need for an own car, if there is good transport in cities and enough car sharing for outside trips

In bigger cities, there is already no need for an own car. Public transport, shuttle pools and shared mobility services are more than enough. Already too many cars in cities

Due to cost savings

I don't need an own car if the alternative is available and cheap

Owning is too costly compared to today's rent models

I would only consider buying a car, if I'm reliant on using one every day.

I personally don't see cars as an object of desire. If shared economies will improve in a way that I can have access to a car whenever I want and wherever I want to go to, I consider that to be more valuable than owning a car.

To save costs and the environment

Never owned a car so far; increased amount of service offerings will even facilitate that in the future

There are plenty of options such as sharing a car owned by a 3rd party (sharing economy)

Sharing economy is more sustainable and there might be limited space for parking.

If such services are cheap enough, no need for a car

Nature

Don't need it

I don't need to own a car if there are better options.

Especially in cities, where driving with the car is more a hassle than fun, I can definitely imagine going for a car sharing option.

I am basically using public transportation

Unnecessary costs, hassle, environmental issues

Not important

Costs, usage

Because I would like to try the innovation and actively engage into having a safe risk-free driving environment

Not necessary as there are many other means of transportation

In the future, I would like to have a job that I can reach by train or bike. For trips where the car would be indispensable, I would use car sharing.

Especially if living in a big city with reliable public transportation, I do not think there is the necessity to own a car. Mostly it is possible to move around the city with busses or metro, and in case of organizing a trip or an excursion, is always possible, and quite cheap, to rent a car or to do car sharing

Convenient

Don't like driving

Because there is no need for a car, people will share cars

Huge expense of the service offer is given in a city

Convenience

It would be getting easy for driving

Don't need it

Renting a vehicle when needed makes more sense to me

Sometimes it isn't always necessary to own a car, it is much easier relying on public transport and also it is better for the environment.

Saving money, sharing a car is better for the environment

Environment, money, increased public transport infrastructure

Because mob serve make cars unnecessary in big cities

With good general mobility and sharing, you do not need a car

Sharing is caring

Environmental thoughts and good public transport

There is no need for having an own car. The average car in Germany spends 95% of its time parking. The streets are too packed and car sharing e.g. will make cars available for everyone, at least in the case of Cities.

I am living in a city with a well-working public transport system which is both, cheaper and faster. Besides that, I am using car sharing/rental apps such as Car2Go/DriveNow or Miles if I do need a car once in a while.

I don't even use a car often today, and I think there will be enough public transportation/mobility offers that make it possible to not own a car

Less congestion in cities, saving the environment

Costs and space

Better for the environment. If I can walk places I usually do. A car is a luxury.

Environmental reasons

Because I already don't have a car

I hope that in the future we will try to reach most of our destinations by bike, bus and train (and improve the infrastructure accordingly).

For the environment, the additional costs and safety reasons

Cars in the future will be shared

Cheaper and easier. Comfort.

Convenience

Less acquisition and possession costs

Need of mobility satisfied

Better for the environment and multimodal mobility offers additional convenience

Saving money, economy

Data security is very important

If there are greener options and my daily commute does not require it.

Costs and I don't need it regularly

Too high cost driver, which will not be necessary anymore in the future

It is more comfortable If you don't own it. The overall vehicle effectiveness will increase and that is good for all of us.

Not ecological

Unnecessary costs

Environmental reasons and increased challenges associated in urban environment

Sustainability purposes

First of all, it may decrease the traffic jams, secondly - the journey may be less stressful when you are not driver (e.g. Blabla car service)

I would expect this to be cheaper due to higher utilization rates of the cars.

Less pollution

Waste of money. I already don't own a car today and don't need one.

I don't need it really, also for ecological, environmental, social reasons (less parking space in cities, more space for parks, bikes etc.)

I live in a city and do not need one

No need on a daily basis, especially in urban areas with efficient public transport and shared mobility. Owing an own car means paying insurance, maintenance and parking costs for a vehicle I rarely use.

If there would be an adequate urban or country-wide infrastructure a car is no longer needed.

Sufficient alternative offerings in the market (especially in cities) and substantial savings of not owning a car

Because the depreciation of the vehicle has a big impact on the value of it year over year and because I plan on living in a city that will be hopefully be well connected

No need for ownership of cars in the future, shared mobility and increased urbanization

I like cars

A car is very expensive, it needs a parking slot etc... Do not owning a car can even be a relief, if you live in the city

Additional costs without need to use it on a daily basis; live in the city where I don't need it for mobility

I feel I don't need one, especially not in urban areas, where a car would mostly represent a burden in terms of parking and traffic. Furthermore, concepts like mobility as a service would still give me the freedom to drive a car when I need one

Carsharing can be used

Ecological footprint

Costs

I want to contribute to a better world / planet. I don't necessarily need a car, so why owning one? Also, I don't have an emotional attachment to it. As long as I can get from point A to B with no problems, I don't necessarily need to own a car.

To reduce gas emissions

Not necessary - shared mobility services are extending, and it is than still cheaper to here and then rent a car for a day

If the transport optional will increase and improve (negative example: Deutsche Bahn), then there is no need of using air polluting options

In case I will live in a city, I don't need a car as I can use the public transport. If not, I am willing to share a car.

In most bigger cities you don't need a car and if you needed you can easily choose one of the shared cars. For casual usage it is much cheaper

If it is not necessary for my daily tasks & there are enough other options to have a comfortable life without - I do not know why I should pay more for an own car.

In big cities there is no need to have a car. You can get everywhere with the train/bike/bus

Don't want to incur the capex, prefer a Vehicle/Mobility-as-a-Service system

Environmental issues

Environmental reasons and the existing need for it

Easier, more effectively, I can use my time during the ride

Because I'm already used to not owning a car and I don't think it's a problem when you live in a big city with good public transportation

Public transport is sufficient

Not needed in the city

Costs, parking situation, environment

Never owned nor needed one

Increase in public transport opportunities (I hope)

As I live in a big city and won't change this circumstance in near future there is no issue for me to own a car as I use my bike most of the time and do have other transportation opportunities like shared cars etc.

More flexible

Savings, communication, better/faster public transportation

Not a big fan of driving

Useless

I don't think I need a car nowadays

Saving costs

In the city I would not need it, many problems with parking, ecologically responsibility

It depends on where I will live, but if the public transportation is good enough, I would consider not owning a car.

Environment

I do that when I travel

I would not have a car now if I could order an autonomous vehicle any time and would pay not more than with owning a car. I use a car to get easily, fast and comfortable from A to B and those attributes will also be covered by an autonomous vehicle that I order via app.

Most of the cars contain only one person, the driver. This is simply inefficient.

Costs and environment

Flexibility, on demand life

I want to live in a city and owning a car is unnecessary

Financial issues

Total cost of ownership is lower without owning a car

Living in the city - no car needed

Q12 - Why? (consider owning a car)

I think an own car is especially in the suburbs important. Moreover, on a daily use it is cheaper. Car sharing offers usually just small cars.

I need my flexibility especially because I live in a rurally shaped area and I personally prefer independence and prefer ownership more to rental models

I think this is different regarding to the circumstances you have. (e.g.: the place you live)

I want my car

Family lives in a village (no shared cars and bad public transport)

I love driving

I love driving, feeling of independence and freedom

Because I live in a rural area which requires independent transport

Because I want to be as flexible as possible.

I need a car for my job

I want to own a car and don't share it with other people

Unsure

I live on the county side

Flexibility

I am a vet student who needs to be able to get to placements individually so will need a car

Just to be independent

Need it

I love driving, I travel a lot, love to be independent and spontaneous, in smaller towns there aren't such services

Independence

I enjoy driving a car myself

I like cars and the independence

I love to drive, and I don't like when someone or something else has the control

I want to have my one car to be independent.

Because I love cars

I would not consider not owning a car

I want a car

Independence

I love driving

More flexible way of travel

I need a car

Live in the village no possibilities to share a car

I do not want my mobility to be dependent on somebody else besides myself. I believe that I, as an individual, should have the right to own and use a vehicle for my mobility however if possible, without having to login, sharing it or asking for permission. As I found out in research for a paper I did back in 2018, the average consumer doesn't profit financially from car-sharing (at least not in Switzerland).

I like to drive by myself, feeling of freedom

Car = flexibility

I like driving by car.

Status symbol

Like driving my own car with my own settings

When the last driver operated car goes down the freeway, I will be driving it.

A car brings freedom. I prefer individual mobility.

I want to be independent

I live in a small village. There is no public transportation

It is important to have a stand-by mean of transportation without having to rely on others even if it's my last choice of preference

Flexibility

Need it for work, no time to wait for a free car

Freedom

To run my hobbies and to feel independent in questions of mobility

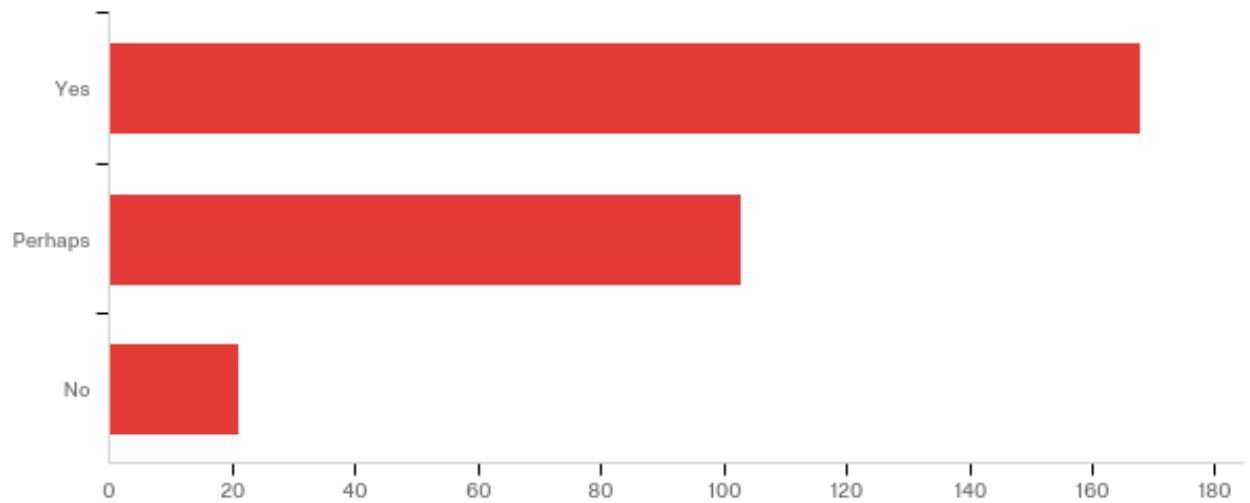
I'm the boss in my car

I want one

We can reduce the number of cars per family but at least one fixed car per family is necessary

Love my car

Q13 - Would you consider subscribing to a service for Autonomous Vehicles that allows you to access an Autonomous Vehicle every time you demand it?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Would you consider subscribing to a service for Autonomous Vehicles that allows you to access an Autonomous Vehicle every time you demand it?	1.00	3.00	1.50	0.63	0.39	292

#	Answer	%	Count
1	Yes	57.53%	168
2	Perhaps	35.27%	103
3	No	7.19%	21
	Total	100%	292

Q14 - Why? (consider subscribing to a service for Autonomous Vehicles)

No need to drive/park on my own in the city, but no need to have fixed costs for my own car

That seems to be quite convenient.

Flexibility

To learn

Convenience, I can spend my time doing other things rather than drive

Convenience

Good possibility to try it

Shared cars are already very helpful, why not with autonomous cars?

This would be the best solution

Because I would get the chance to get used to autonomous vehicles without being forced to buy an own one

Same reason as for using general car sharing models

Then one has more flexibility than with using public transport services. Especially if one is not owning a car.

Because you can be productive while driving and don't need to park the car etc...

Simplicity and comfort

Time in the car can be used for work, relaxation etc. and is not 'lost'

I don't drive a lot by myself and would make my life easier this way especially traveling outside.

Makes living in a city more comfortable (if too expensive, I would still prefer public transport)

At times when I don't want to drive.

Because it could solve many issues such as parking

Need it if I don't own a car

In urban areas this would be more cost effective than owning a car

I rather pay for a car when I really need it instead of a car which I rarely used and where I would be in charge of maintenance etc.

For instance, instead using Uber with a driver I could imagine using an autonomous vehicle

More flexibility, lower immediate costs, lower risk (moving away, having to transport car etc.)

Convenience

Convenience

Having access to cars that will fit to my current use case

It will be safer and easier

Convenience

The same as my last answer and SAFETY.

A concept similar to streaming services, where the service on demand would be available, sounds very promising to me.

Convenient

Prefer not to drive myself

Flexibility and interest

Convenience

Mobility whenever I need it

It's what I do already

Flexibility

It is convenient having a driver whenever I need a ride

Because I don't need to own it.

Might be an alternative to calling a taxi.

That's the idea of not owning a car anymore

Environmental thoughts

Comfortable and it saves money as I won't need to buy an own car. But it should be more reliable than public transport.

Can share a car, not having to buy it

Reduce costs (e.g. car insurance)

Easier and more convenience

Convenient

Because I believe superior demand planning algorithms will be available in the future so that I will be able to drive conveniently from A to B while being able to do something good for the overall traffic situation

Same reasons as shared services

Don't need my own car

In case I do not have my own car, there is less cost involved for me (tax, maintenance, and walking to my car, which is parked about 10-15 minutes from my home, etc.)

Because it would allow me e.g. to work while driving

Easy

Practically

Because I think it would allow people to use AV when they need them without paying the price of such a car

Cheaper than buying your own car

Flexibility

Like Uber

Convenience and low cost

I would be interested to try it

Would allow me to travel independently in a flexible manner

Convenience

Because I don't have to buy a car on my own

Sounds easy

I would use it for long ways

Cheaper, great mobility

Don't have to own a car, additional free time and cheaper than human driver

It's easy

Convenience of using the car on demand and not having the costs of ownership

Makes more sense than owning one at the moment, I would say

Increasing flexibility and decreasing fix costs

To be more flexible and use the driving time for managing other tasks

It is convenient

Comfort

If I have the needed flexibility to drive whenever I want, I don't have to own a car.

Costs are easy to calculate. No risk of high costs because of damages which need to be fixed.

Gives me flexibility and I can try it without a need to buy one

Convenient and green solution

Comfortable with the idea of getting driven every time I want to

To try it out and learn more & build an opinion

Convenience and flexibility

That would be convenient :) own car requires a space and taking care of it, a service is kind of out of your concern

Once the permanent availability is given, it is a perfect substitute to your own car

It mixes flexibility with the feeling of autonomy

If I would like that at one point, then an app/service would be useful.

Increased flexibility

Independence

Flexibility

Increase quality

Because that sounds good, convenient

Convenience

It could be cost effective and you do not need to buy your own car.

It would save a lot of time, and enable you to spend some personal time in transportation, where you can choose to sleep, work or relax

Independence

Convenience

Cheap and fast

It is the future; more convenient (since I can do something else while being in the car)

I don't like to drive myself. Public transit sucks.

Sharing platforms are ideal in the 21st century

Flexibility of using a car when I need one without the burden of owning one (insurances, parking)

It's convenient

Costs & environmental issues

For convenience

Flexible

Fast transportation & working at the same time

Easy to handle, less time or responsibility for buying an own car or to take care about it.

Very convenience

Easy to use

So hopefully I can reduce my costs & it will maybe be also positive for the ecological footprint.

I think it would be okay to learn

I think for city trips (in town) it's a good opportunity to go shopping or sightseeing

Convenience

Flexibility

Easy way to drive from A to B

Practical reasons, sharing is caring

I think it would be practical and if I don't need a car often, it would probably make sense

If frequent usage is required, and usage on demand is possible, this appears to be a fair model

Very convenient and in the end cheaper

It's quick and on demand

Flexibility

This service would reduce the number of vehicles on the road.

Very convenient.

Same as I do now (carsharing / bike sharing)

It would make it more flexible

Flexible offer

It is fun

I am a mother; I have to be very flexible. Also, I don't like to drive with lots of people

Convenience

Flexibility, savings

It might be cheaper; I don't have to care about TÜV, insurance, inspection etc.

Because right now shared vehicles are all different and sometimes you get one that where driving is not smooth. With autonomous driving I would just put my next location in the navigation and the vehicle would do the rest which is very convenient.

Sounds like a better uber if subscription

Comfort

In case they are available, there is no need to own a car and it would save spaces for parking that can be used for housing in metropolitan areas

Would not need time for searching a parking slot, many people can share a car

In order to make a judgment about it

Environment

Lower cost and risk

Because it makes sense and it's comfortable

You're not what you own. So why not use public transport?

Convenience

Would be a perfect way to get a car if you need one and don't have to pay the normal costs

Since we have a stream service like Spotify or Netflix, it would be a good idea to pay a fixed value and a super low price that lets you access an autonomous car. Could you imagine how much time you'll save, doing your work... how cool it would be...?

Safer, reliable

It can improve the omnichannel experience

Lower investment

Convenient, cheap, safe, good for environment

Easier

Q15 - Why? (consider not subscribing to a service for Autonomous Vehicles)

Not interested in autonomous driving

I don't like the idea of a car that drives itself

This is basically UBER which isn't always reliable

I don't know enough to be sure it is safe

Maybe too expensive

I'll wait and see how this develops in terms of safety

Those vehicles are dubious.

There's no reason.

Simply

Unsafety way of transport

I don't like subscriptions like that.

If not, every car is autonomous, I don't trust the system.

No trust

I have owned many computers. I don't want a computer making my decisions.

Nobody will provide this service in small villages

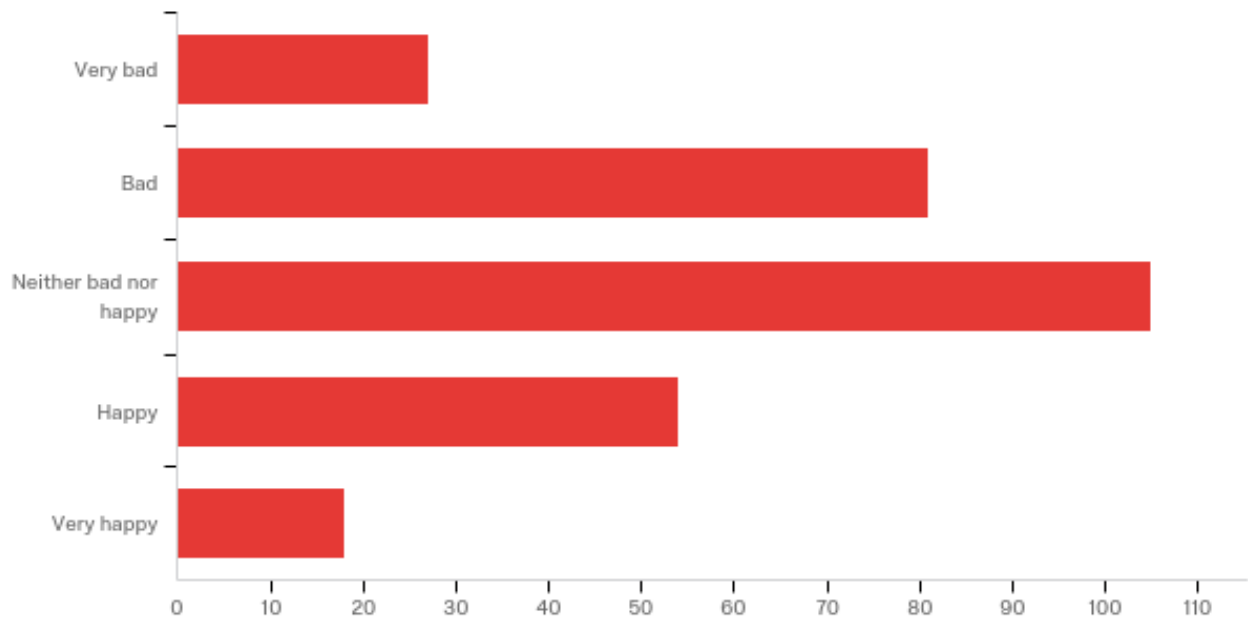
Not sure

I would rather have a standard car

I want to drive the car by myself as it is fun and safer

There are better alternatives

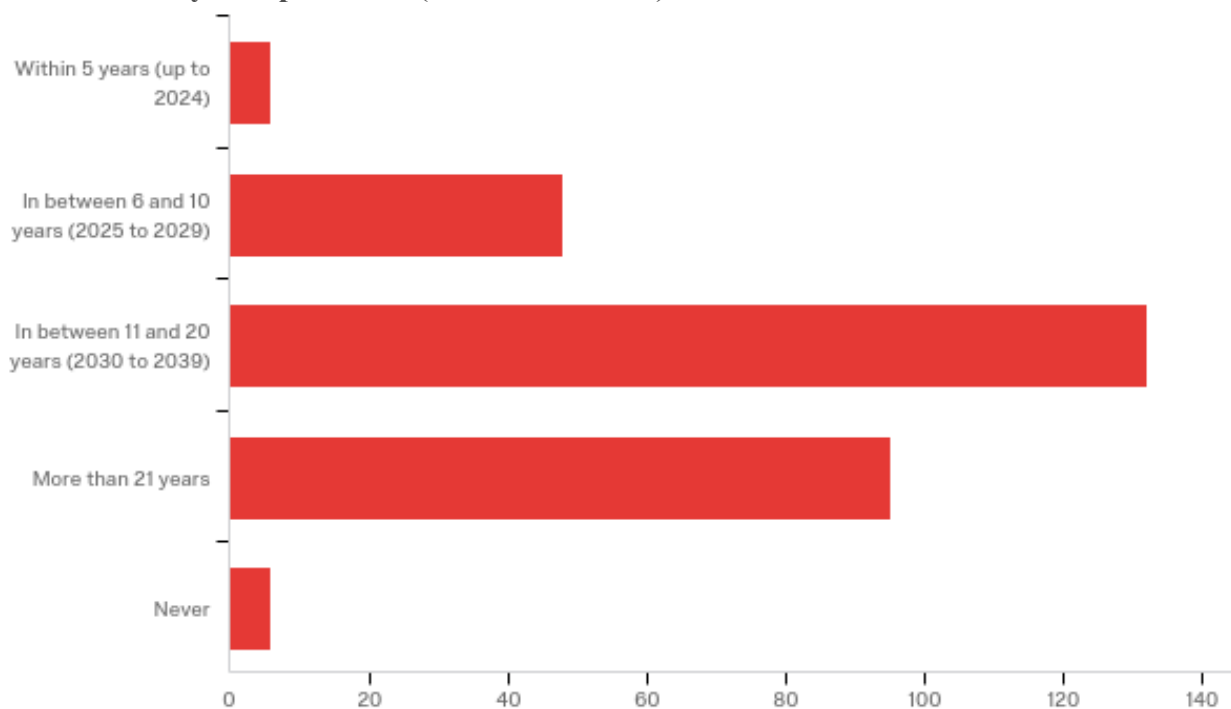
Q16 - Emotionally, how do you feel about a future in which there are exclusively Autonomous Vehicles that do not allow interventions by the driver?



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Emotionally, how do you feel about a future in which there are exclusively Autonomous Vehicles that do not allow interventions by the driver?	2.00	11.00	8.80	1.13	1.29	287

#	Answer	%	Count
7	Very bad	9.47%	27
8	Bad	28.42%	81
9	Neither bad nor happy	36.84%	105
10	Happy	18.95%	54
11	Very happy	6.32%	18
	Total	100%	285

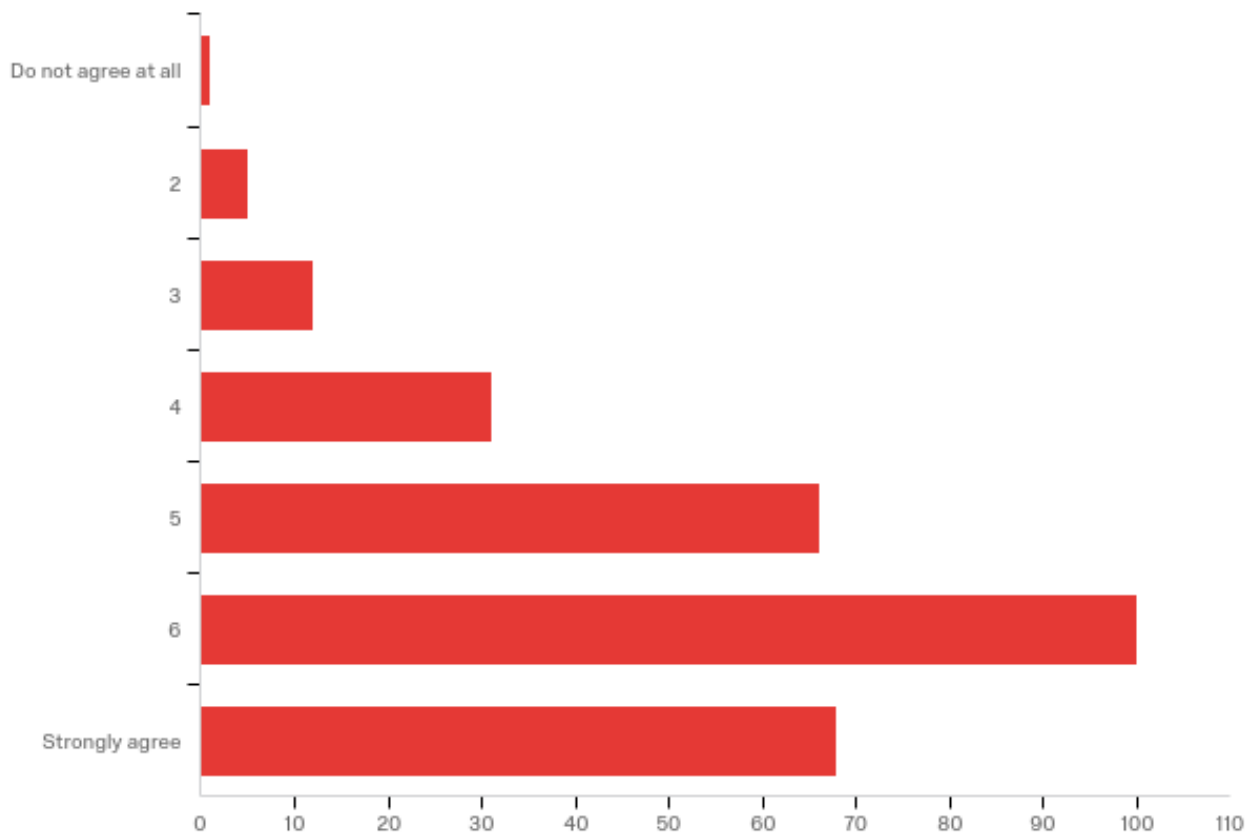
Q17 - When do you expect most (i.e. 80% or more) vehicles to be autonomous?



#	Field	Minimum	Maximum	Mean	Std Devia- tion	Variance	Count
1	When do you expect most (i.e. 80% or more) vehicles to be autonomous?	1.00	5.00	3.16	0.80	0.64	287

#	Answer	%	Count
1	Within 5 years (up to 2024)	2.09%	6
2	In between 6 and 10 years (2025 to 2029)	16.72%	48
3	In between 11 and 20 years (2030 to 2039)	45.99%	132
4	More than 21 years	33.10%	95
5	Never	2.09%	6
	Total	100%	287

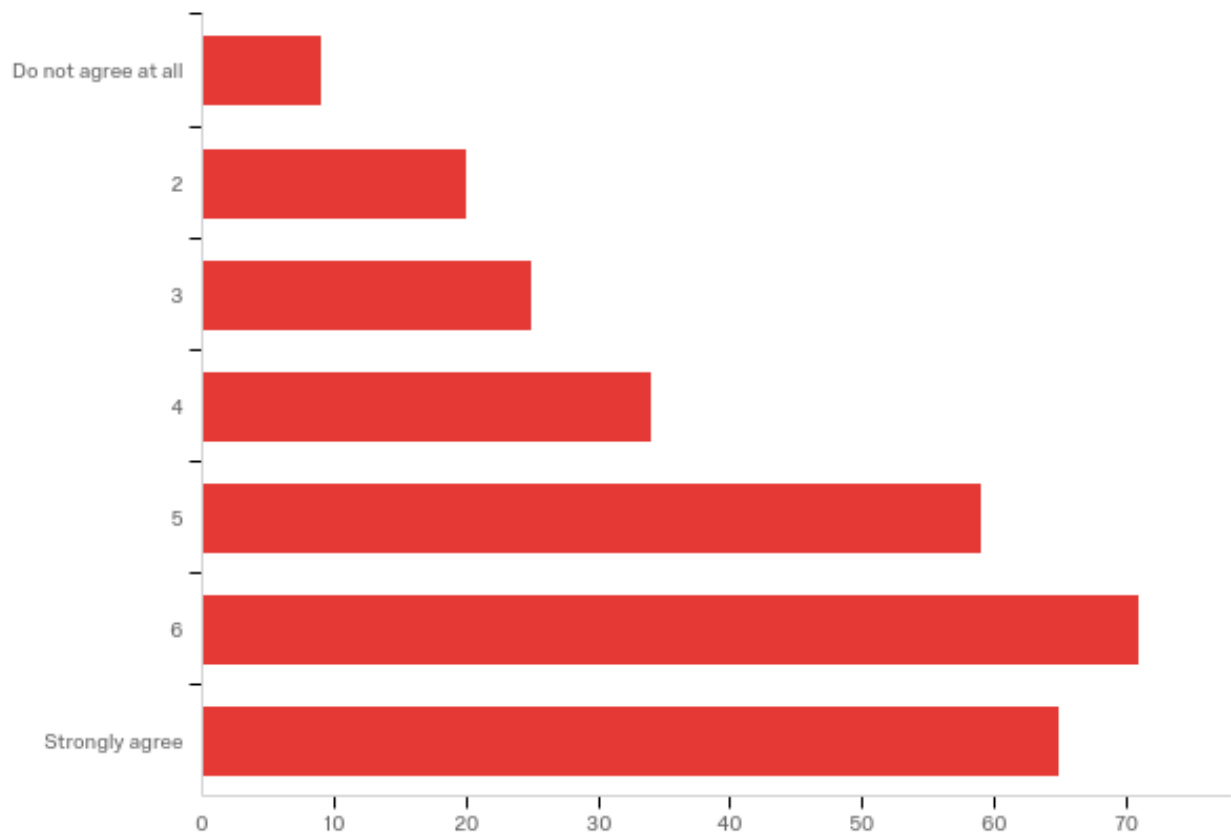
Q18 - Autonomous Vehicles are the means of transport of the future.



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Do not agree at all: Strongly agree	1.00	7.00	5.57	1.22	1.48	283

#	Answer	%	Count
1	Do not agree at all	0.35%	1
2	2	1.77%	5
3	3	4.24%	12
4	4	10.95%	31
5	5	23.32%	66
6	6	35.34%	100
7	Strongly agree	24.03%	68
	Total	100%	283

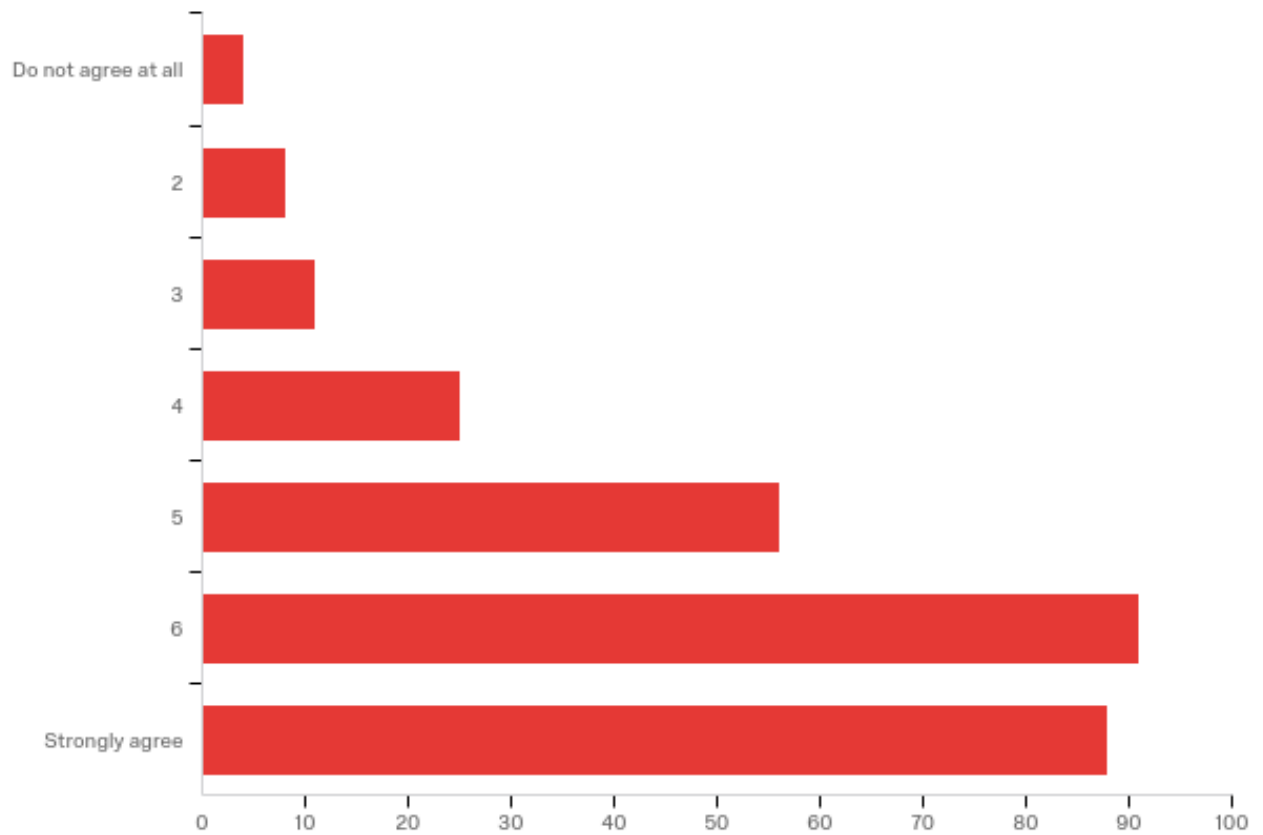
Q19 - Autonomous Vehicles take the fun out of driving a car.



#	Field	Minimum	Maximum	Mean	Std Devia- tion	Variance	Count
1	Do not agree at all: Strongly agree	1.00	7.00	5.07	1.67	2.78	283

#	Answer	%	Count
1	Do not agree at all	3.18%	9
2	2	7.07%	20
3	3	8.83%	25
4	4	12.01%	34
5	5	20.85%	59
6	6	25.09%	71
7	Strongly agree	22.97%	65
	Total	100%	283

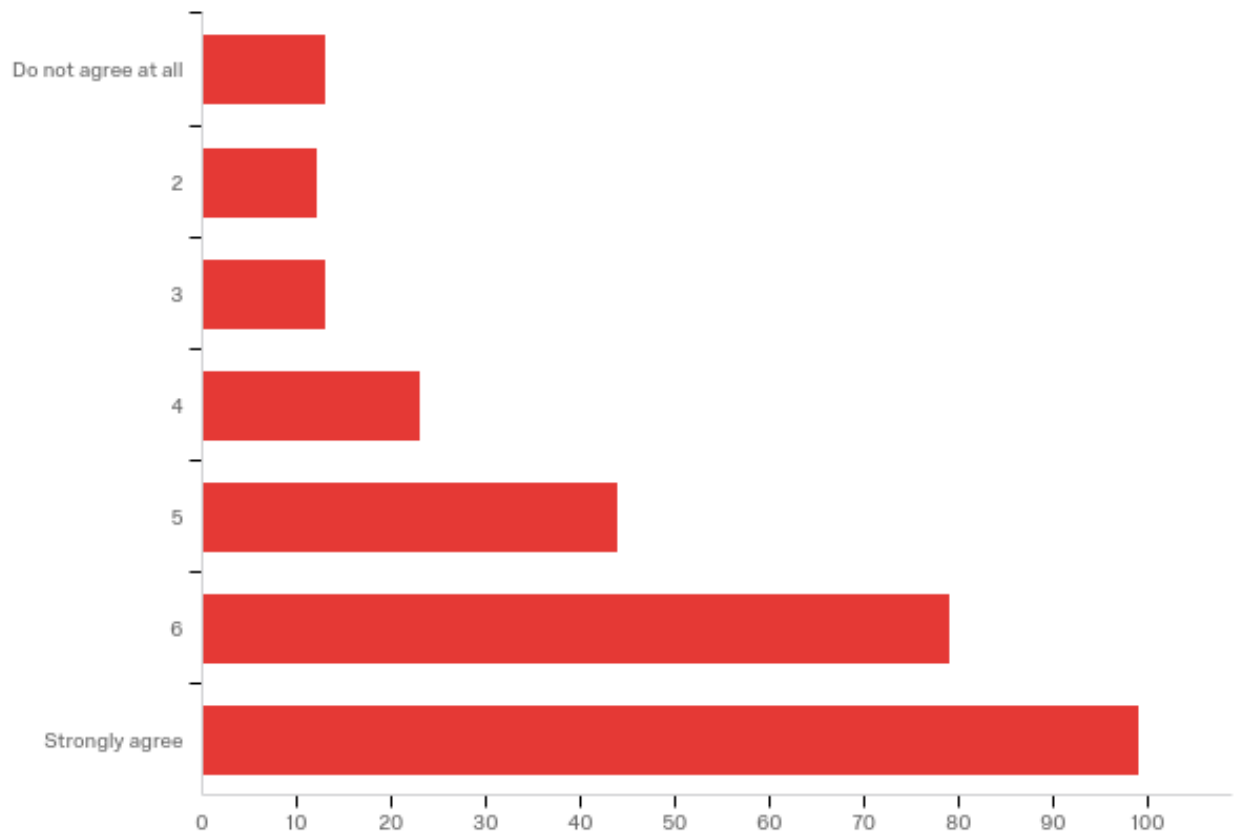
Q20 - Autonomous Driving is a technological advancement that will give us a more relaxed driving experience.



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Do not agree at all: Strongly agree	1.00	7.00	5.64	1.37	1.89	283

#	Answer	%	Count
1	Do not agree at all	1.41%	4
2	2	2.83%	8
3	3	3.89%	11
4	4	8.83%	25
5	5	19.79%	56
6	6	32.16%	91
7	Strongly agree	31.10%	88
	Total	100%	283

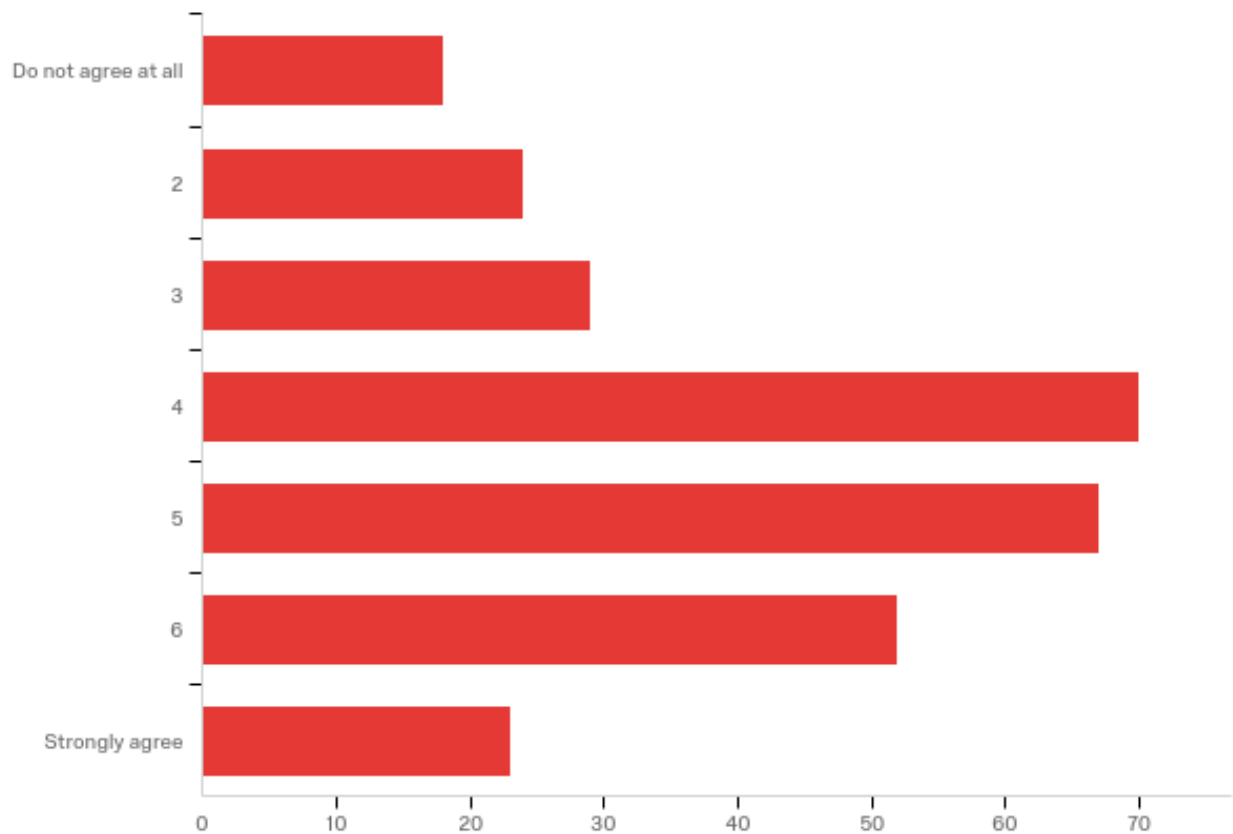
Q21 - Autonomous Vehicles will improve my personal time management so that I can free up time for other tasks (e.g. reading, working).



#	Field	Minimum	Maximum	Mean	Std Devia- tion	Variance	Count
1	Do not agree at all: Strongly agree	1.00	7.00	5.49	1.68	2.82	283

#	Answer	%	Count
1	Do not agree at all	4.59%	13
2	2	4.24%	12
3	3	4.59%	13
4	4	8.13%	23
5	5	15.55%	44
6	6	27.92%	79
7	Strongly agree	34.98%	99
	Total	100%	283

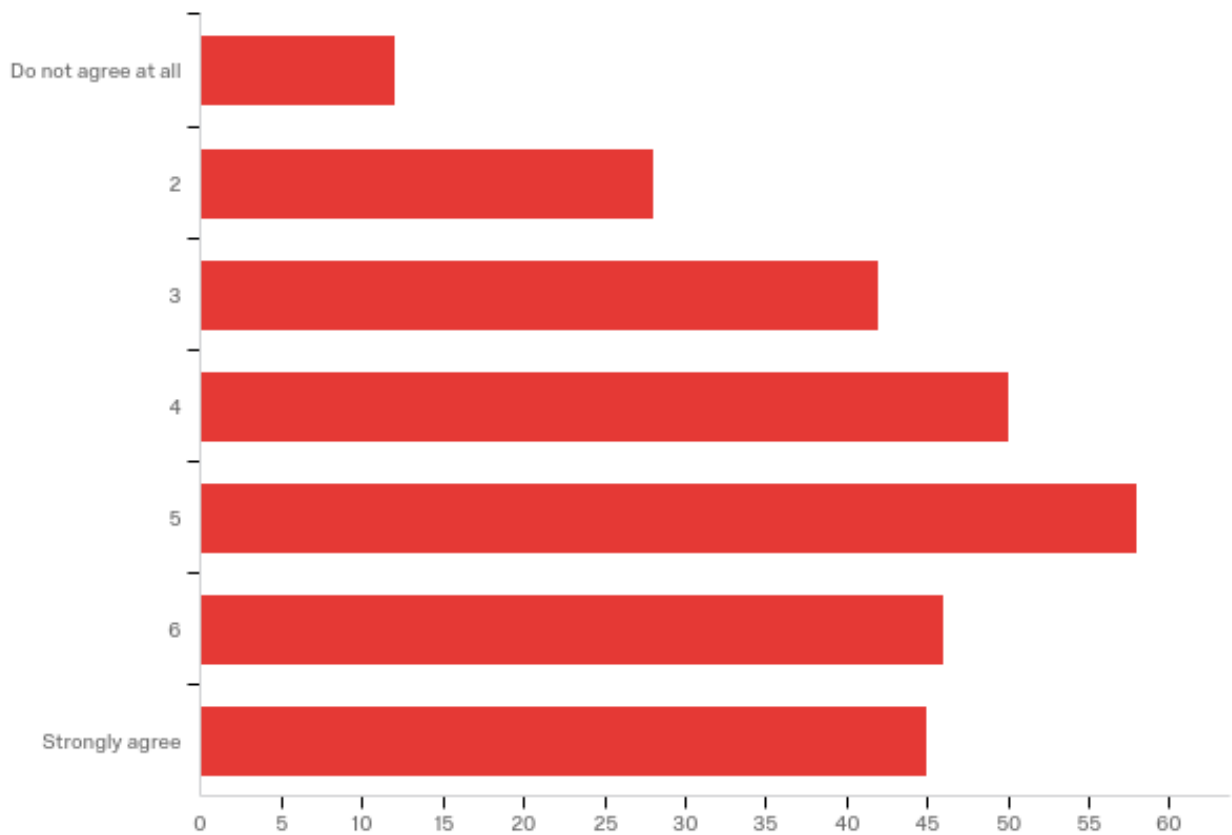
Q22 - Riding in an Autonomous Vehicle would make me feel safer on the road.



#	Field	Minimum	Maximum	Mean	Std Devia- tion	Variance	Count
1	Do not agree at all: Strongly agree	1.00	7.00	4.39	1.60	2.57	283

#	Answer	%	Count
1	Do not agree at all	6.36%	18
2	2	8.48%	24
3	3	10.25%	29
4	4	24.73%	70
5	5	23.67%	67
6	6	18.37%	52
7	Strongly agree	8.13%	23
	Total	100%	283

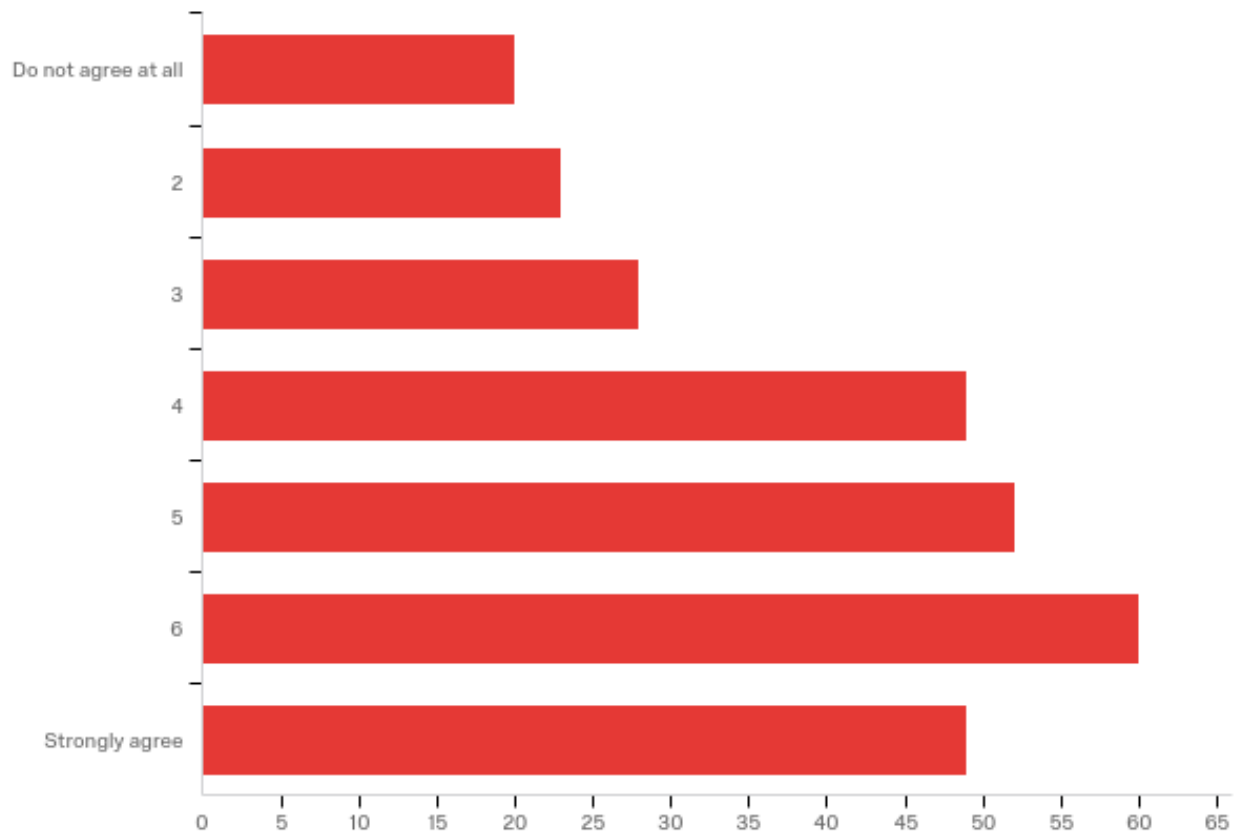
Q23 - I would prefer a car with many assistance systems where the driver is still responsible for most of the safety-critical functions rather than having a fully Autonomous Vehicle.



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Do not agree at all: Strongly agree	1.00	7.00	4.54	1.72	2.95	281

#	Answer	%	Count
1	Do not agree at all	4.27%	12
2	2	9.96%	28
3	3	14.95%	42
4	4	17.79%	50
5	5	20.64%	58
6	6	16.37%	46
7	Strongly agree	16.01%	45
	Total	100%	281

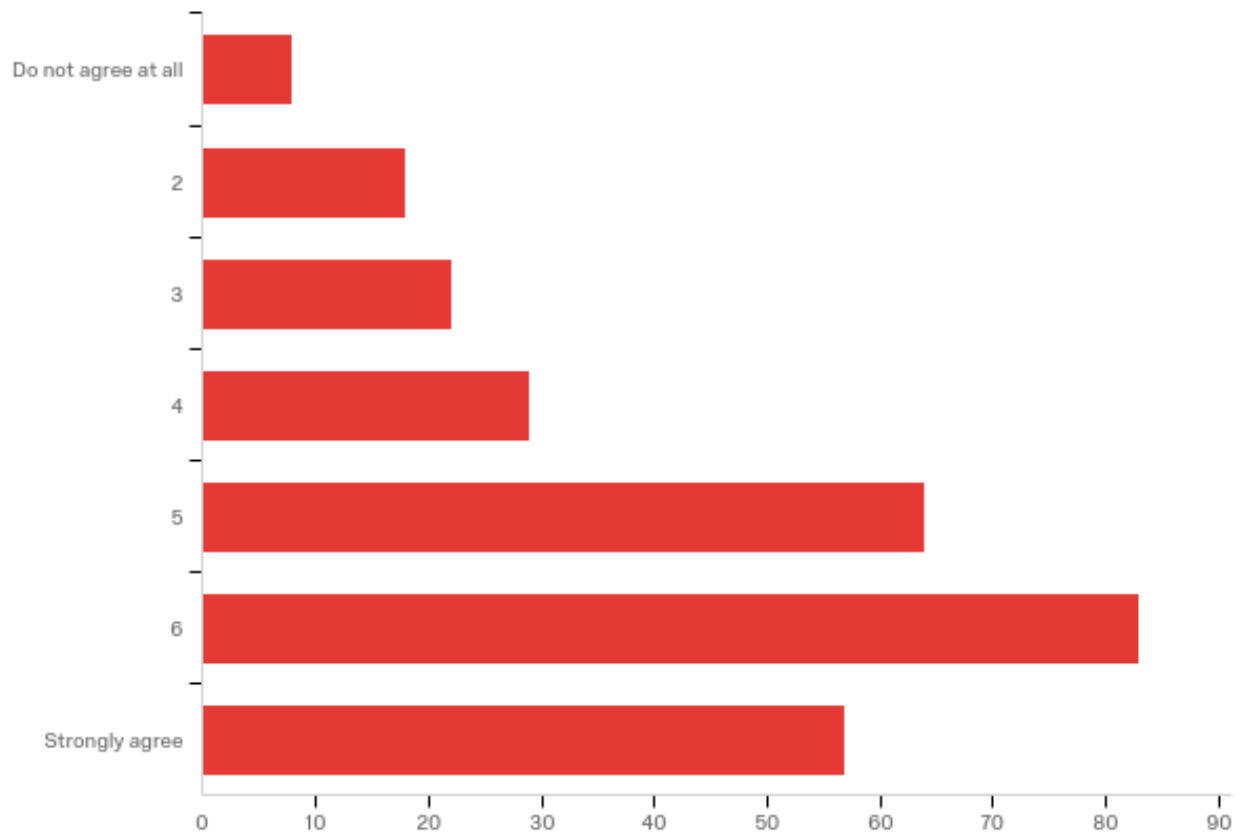
Q24 - I would rather use an Autonomous Vehicle rented from a mobility service provider (e.g. taxi, car sharing) than own one myself.



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Do not agree at all: Strongly agree	1.00	7.00	4.66	1.80	3.24	281

#	Answer	%	Count
1	Do not agree at all	7.12%	20
2	2	8.19%	23
3	3	9.96%	28
4	4	17.44%	49
5	5	18.51%	52
6	6	21.35%	60
7	Strongly agree	17.44%	49
	Total	100%	281

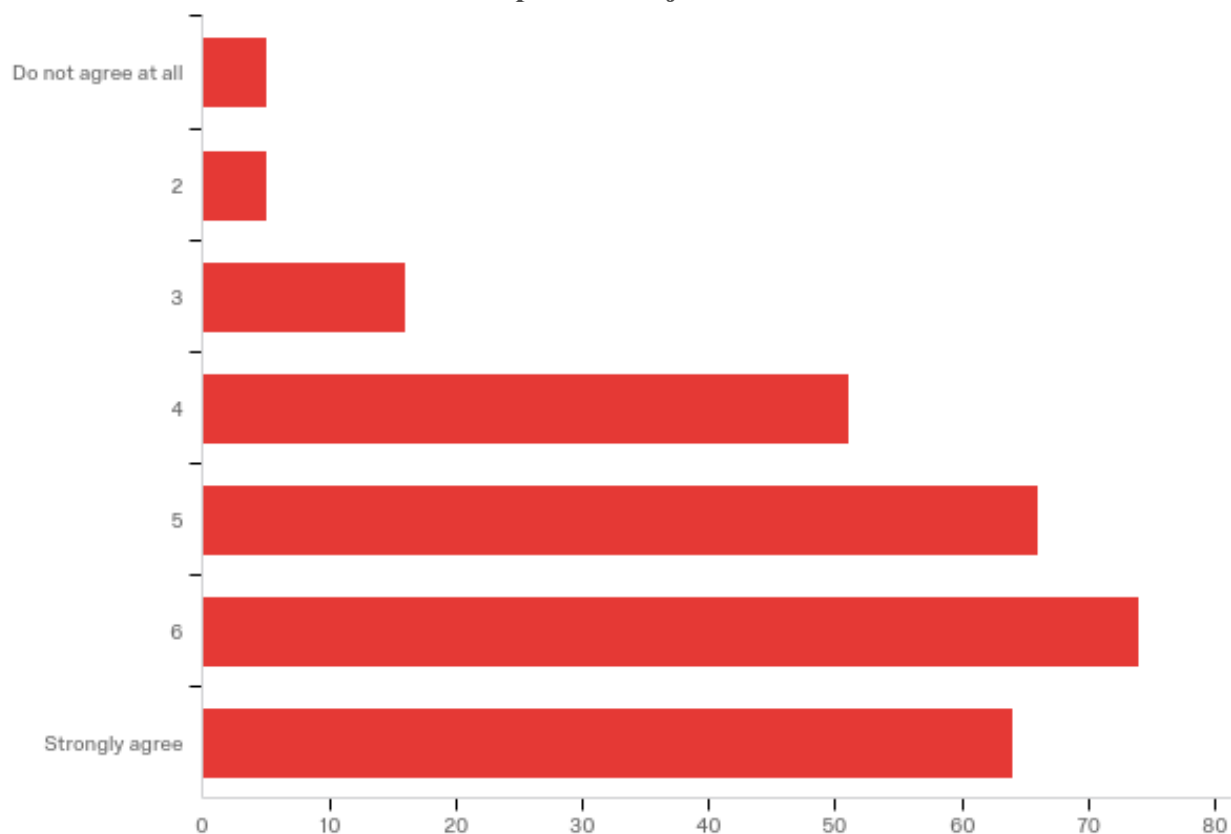
Q25 - I would have more confidence in Autonomous Vehicles if the car industry were transparent about the state of development of these vehicles.



#	Field	Minimum	Maximum	Mean	Std Devia- tion	Variance	Count
1	Do not agree at all: Strongly agree	1.00	7.00	5.14	1.59	2.54	281

#	Answer	%	Count
1	Do not agree at all	2.85%	8
2	2	6.41%	18
3	3	7.83%	22
4	4	10.32%	29
5	5	22.78%	64
6	6	29.54%	83
7	Strongly agree	20.28%	57
	Total	100%	281

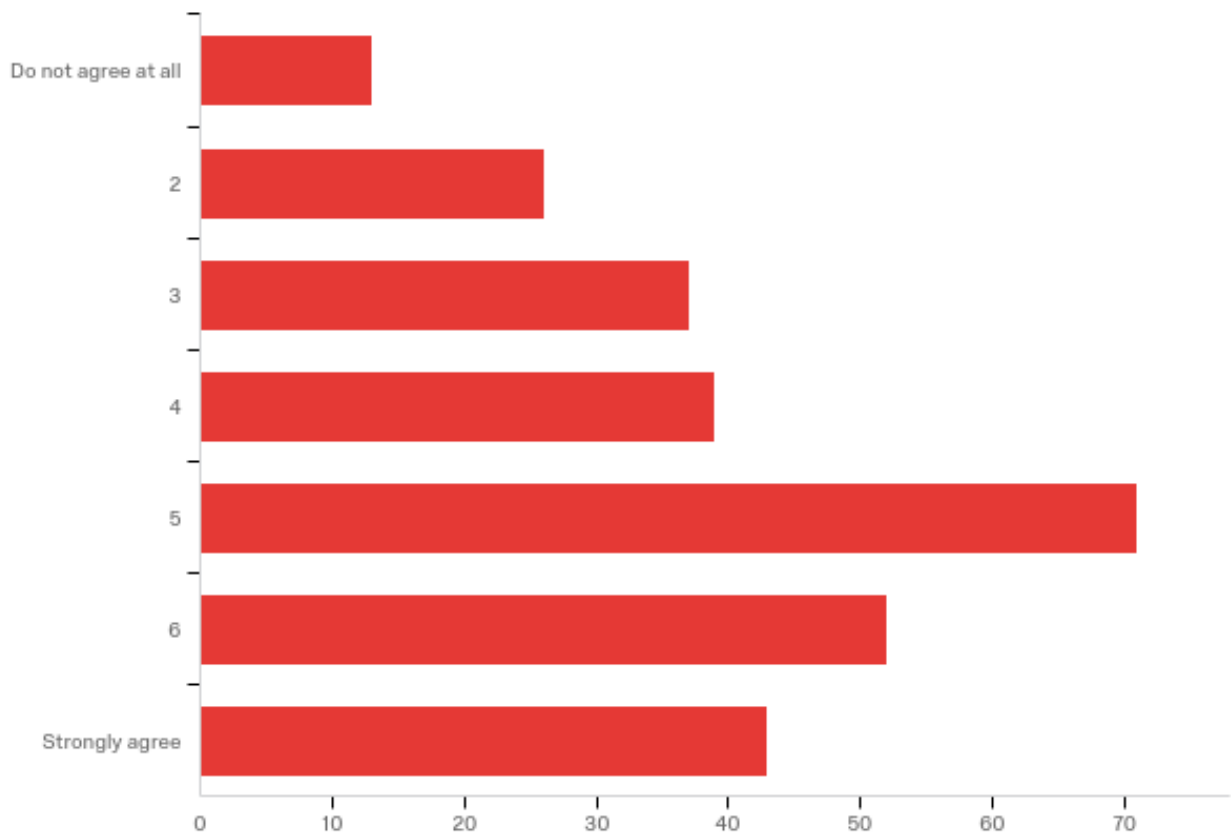
Q26 - Autonomous Vehicles will reduce personal injuries in the future.



#	Field	Minimum	Maximum	Mean	Std Devia- tion	Variance	Count
1	Do not agree at all: Strongly agree	1.00	7.00	5.30	1.39	1.94	281

#	Answer	%	Count
1	Do not agree at all	1.78%	5
2	2	1.78%	5
3	3	5.69%	16
4	4	18.15%	51
5	5	23.49%	66
6	6	26.33%	74
7	Strongly agree	22.78%	64
	Total	100%	281

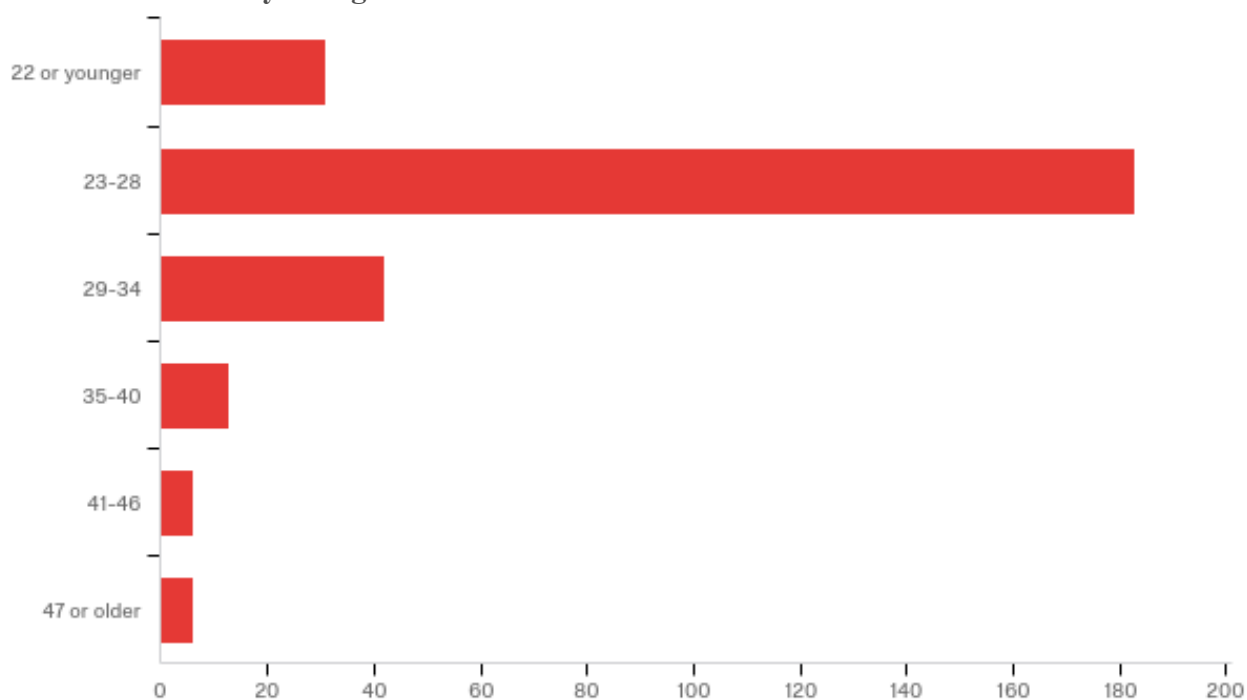
Q27 - Autonomous Vehicles will collect too much information about the driver (e.g. traveling routes and destinations), which they will make available to third parties without the driver's consent.



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Do not agree at all: Strongly agree	1.00	7.00	4.63	1.70	2.90	281

#	Answer	%	Count
1	Do not agree at all	4.63%	13
2	2	9.25%	26
3	3	13.17%	37
4	4	13.88%	39
5	5	25.27%	71
6	6	18.51%	52
7	Strongly agree	15.30%	43
	Total	100%	281

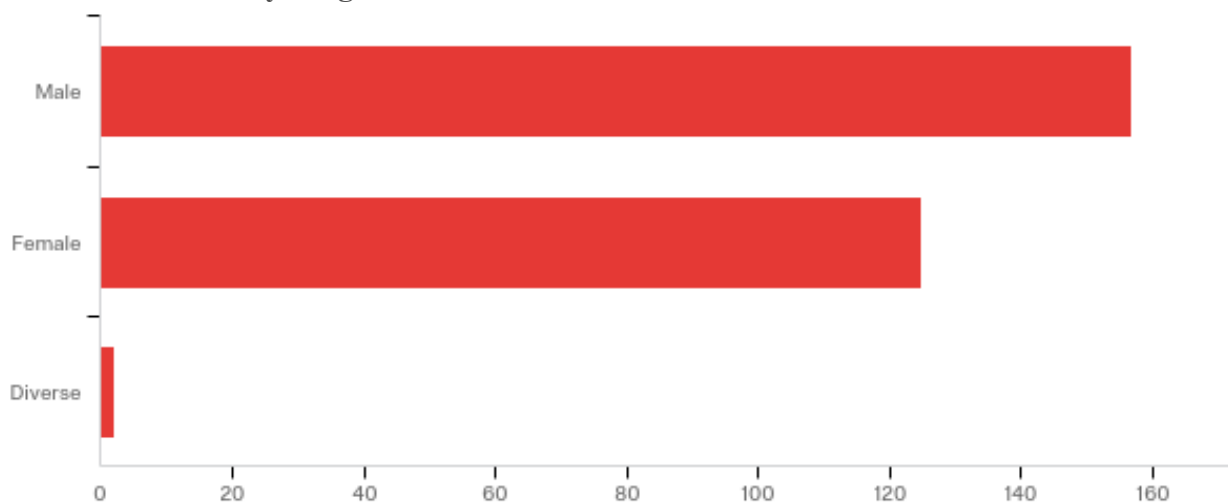
Q28 - Please indicate your age:



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Please indicate your age:	2.00	12.00	6.28	1.22	1.48	284

#	Answer	%	Count
5	22 or younger	11.03%	31
6	23-28	65.12%	183
7	29-34	14.95%	42
8	35-40	4.63%	13
9	41-46	2.14%	6
12	47 or older	2.14%	6
	Total	100%	281

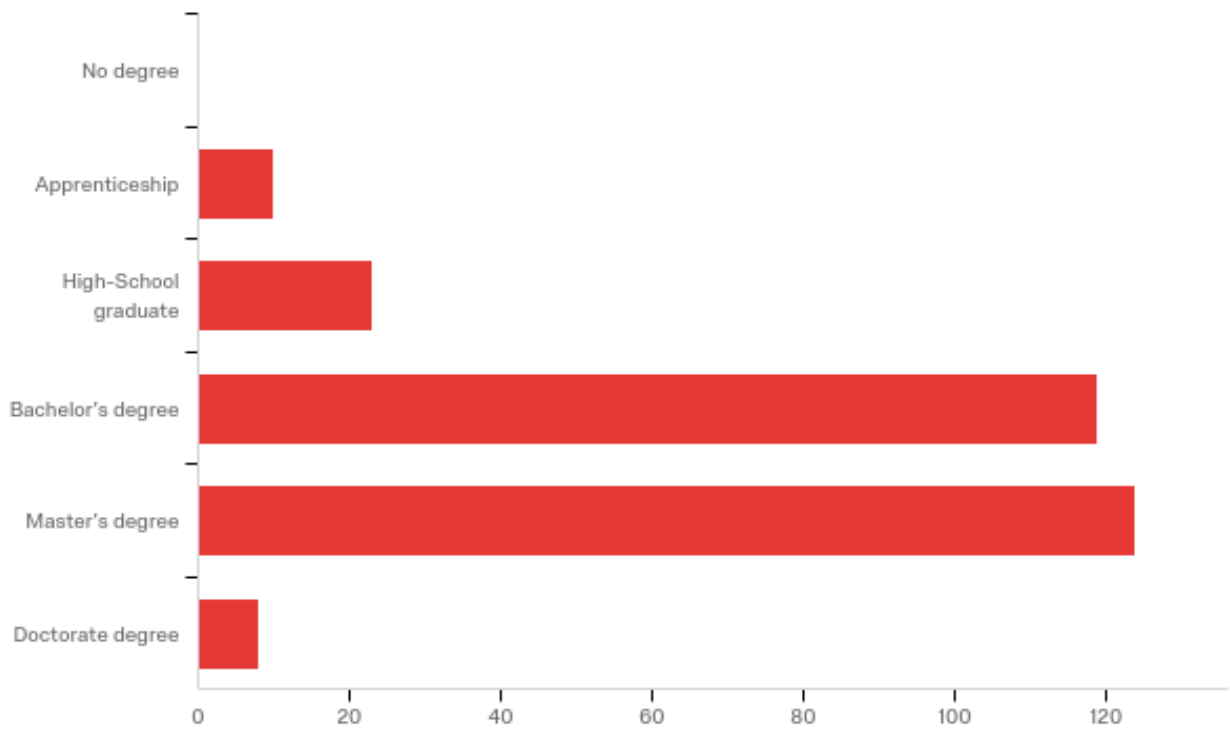
Q29 - Please indicate your gender:



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Please indicate your gender:	1.00	3.00	1.45	0.51	0.26	284

#	Answer	%	Count
1	Male	55.28%	157
2	Female	44.01%	125
3	Diverse	0.70%	2
	Total	100%	284

Q30 - What is your highest level of education?



#	Field	Minimum	Maximum	Mean	Std Devia- tion	Variance	Count
1	What is your highest level of education?	2.00	6.00	4.34	0.81	0.65	284

#	Answer	%	Count
1	No degree	0.00%	0
2	Apprenticeship	3.52%	10
3	High-School graduate	8.10%	23
4	Bachelor's degree	41.90%	119
5	Master's degree	43.66%	124
6	Doctorate degree	2.82%	8
	Total	100%	284