

Acceptance of Automated Driving Across Generations: The Role of Risk and Benefit Perception, Knowledge, and Trust

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Abstract. The eventual adoption of automated vehicles seems inevitable. With the potential to reduce traffic accidents caused by human error [1], decrease congestion, increase mobility, and yield more efficient use of commuting time, most major automakers as well as several technology companies have invested in their development. Policymakers and manufacturers need to understand people's risk and benefit perceptions around automated vehicles in order to understand their likelihood of adoption, as well as to communicate about vehicles' potential benefits and to address risks effectively. This study draws on data from a survey of 1,765 adults in the United States with an embedded experiment to examine risk and benefit perceptions around automated vehicles across different generations to understand how factors such as people's generational age, knowledge and trust affect attitudes toward acceptance and use. Generations differed in driving behaviors and perceptions of driving-related technologies. Participants' attitudes toward automated vehicles were predicted by age group and gender, but not by experimental condition. Independent of condition, however, exposure to the intervention did have an effect on attitudes: participants' risk perceptions decreased after viewing an informational video, while their benefit perceptions increased. Consistent with earlier research, trust, knowledge, and risk and benefit perceptions are related to acceptance of automated vehicles. Our results also show, however, that informational materials that may enhance positive feelings about the technology can increase people's benefit perceptions. This work provides a basis for further research into the acceptance of automated vehicles and the risks associated with them as they approach consumer markets.

Keywords: Automated driving · Technology acceptance · Risk perception · Traffic safety · Survey research

1 Introduction

For the first time in fifty years, the number of traffic fatalities in the U.S. is increasing, claiming 35,092 victims in 2015 [2]; 94% of these fatalities were caused by driver errors [3]. Automated vehicles, vehicles that perform all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver

[4], have the potential to reduce traffic accidents caused by human error [1]. They may also decrease congestion, increase mobility, and yield more efficient use of commuting time. Many major automakers as well as several technology companies are currently invested in their development. If the successful adoption of automated vehicles is to occur, policymakers and manufacturers need to understand people's risk and benefit perceptions around automated driving as well as their knowledge about and trust in automated vehicles in order to communicate about their potential benefits and to address risks effectively. Little is known, however, about the interplay of these factors concerning automated driving. Thus, continued efforts are needed to explore people's risk perceptions and attitudes toward the future of driving and automated vehicles. A better understanding of the public's view of automated driving may provide policymakers and automakers with valuable information in developing regulations, technologies, and education to maintain and enhance public safety and to educate consumers about the choices available to them.

2 Literature Review

2.1 The Real Risk of Driving

Motor vehicle crashes are a leading cause of death and harm in the United States. In 2015, there were over 35,000 automobile-related fatalities [2], with traffic accidents the leading cause of death among 15–29 year olds [5]. In addition, in 2014, over 2.3 million people were injured by cars, causing property damage, lost earnings, medical costs, legal costs, and lost quality of life [1]. Despite these sobering statistics, the American Automobile Association (AAA) reports that Americans have become less concerned about hazardous driving behaviors such as drunk, aggressive, and drowsy driving [6].

The primary reason that driving is so dangerous is the drivers themselves. Ninety-four percent of all traffic accidents occur as a result of human driver errors [3]. Most of these were recognition errors such as inattention and inadequate surveillance of surroundings (41%) and decision errors such as driving too fast or too aggressively (34%) [7]. Alcohol impaired drivers were involved in 31% of all fatalities [2].

Despite these data, people tend to overestimate their own driving skills and underestimate the risks, leading many to fail to take adequate precautions (e.g., [8, 9]). By removing human error, it is anticipated that increased automation, and eventually automated driving, will have the potential to reduce traffic accidents and traffic fatalities dramatically. The Insurance Institute for Highway Safety estimates that if all vehicles on the road today had forward collision and lane departure warning systems, blind spot detection, and adaptive headlights, nearly a third of crashes and fatalities could be prevented [10]. However, advanced vehicle technologies and automated driving tend to be viewed as risky. How will factors such as risk and benefit perception, knowledge, and trust affect the acceptance of automated vehicles as they approach consumer markets?

2.2 Factors Involved in Technology Acceptance

Though some research has explored acceptance and use of public transit with automated vehicles [11], there has been minimal exploration into the attitudes and acceptance of privately owned automated vehicles for personal use. Research suggests that risk and benefit perception are important predictors of acceptance of emerging technologies (e.g., [12–14]). When evaluating new technologies, risk and benefit perceptions are often negatively correlated [15–17]. This may occur because people assess hazards as general attitudes and affect, as people experience negative affect with high risks and positive affect with high benefits [15]. Also, people prefer consistency among their beliefs to reduce cognitive dissonance, so they may evaluate risks as fewer and benefits as greater for technologies perceived as favorable [15]. Despite common belief, risks and benefits are often positively correlated.

Perception of risk of technologies and artificial intelligence increases with more novelty [18] and less familiarity [19] of the technology. As such, people accept lower levels of risk around technologies that are unfamiliar, as well as those that evoke a feeling of dread, or are thought to be poorly understood by scientists [20]. For example, the limited research in automated driving indicates that risk perception of automated vehicles systematically varies by subgroups. One study found that men tend to anticipate higher levels of pleasure and lower levels of anxiety using automated vehicles than women do [21]. This suggests that men may view automated vehicles as having more benefits and lower risks while women may view them as having fewer benefits and higher risks. This is consistent with König and Neumayr's [22] findings that older people and women are more concerned about automated driving than younger people or men. The biggest concerns people reported overall were attacks by hackers and the general safety of the automated systems.

In addition, acceptance is often influenced by trust in the manufacturers, software developers, and others involved in the technology's development [23]. For example, in one study, those who trusted the companies and scientists involved in gene technology perceived fewer risks and more benefits associated with it than those who did not trust them [12]. This confidence and trust is particularly important for technologies people do not have much knowledge about [24]. The more knowledge people have about a technology, the more accurately they may be able to evaluate it. Knowledge leads to a more accurate understanding of small risks and large benefits [25]. With the exception of early adopters and technology enthusiasts, however, most people have few resources to obtain up to date information on automated driving, other than the media, which tends to focus more on risks than benefits, for example, by reporting on accidents, legal or ethical issues.

If people view a new technology as highly risky, do not know much about it, and do not trust the company that produces it, they are much less likely to adopt it. However, risk perception, knowledge level, and trust are not included in the Technology Acceptance Model [26], which is used to predict the likelihood of acceptance of new technologies by examining perceived usefulness, perceived ease of use, and behavioral intentions. Therefore, as automated vehicles approach consumer markets,

we set out to examine whether these factors play a role in their acceptance and what measures of acceptance may be most appropriate.

2.3 The Present Research

In the midst of a national epidemic of traffic accidents, the rapid development of automated vehicles may offer some relief. However, for the successful integration of these vehicles into mainstream traffic, it is imperative for policymakers and manufacturers to be aware of the public's understanding of the risks and benefits associated with automated driving. This study explores risk and benefit perceptions, knowledge, and trust of automated driving affect attitudes toward acceptance and behavioral intentions. The Massachusetts Institute of Technology AgeLab conducted a national survey to assess factors (risk and benefit perception, knowledge, and trust) that influence acceptance of automated driving. We also included a video experiment that aimed at manipulating participants' feelings towards traditional driving (positive vs. negative).

3 Methods

In this study conducted by the MIT AgeLab, an online survey was fielded with a U.S. national sample of adults.

3.1 Participants

Participants were 1,765 (46.2% female, 52.9% male, and .9% other or did not respond) self-selected adults from all 50 states, recruited from Qualtrics Panels. Participants self-identified as 79.9% White, 8.3% Black, 4.3% Asian American, 3.2% Latino, and 4.0% other or multiracial. Our sample ranged in age from 18 to 91 years old ($M = 49.3$, $SD = 17.9$). A breakdown of participants by generation is shown in Table 1. Participants took a median of 26 min to complete the survey. Twenty participants were excluded from analyses because they failed the manipulation check and could not report what the video manipulation was about.

Table 1. Participants by generation

Generation	Year of birth	Percent of sample
Silent Generation	1945 or before	13.7%
Older baby boomers	1946–1954	17.2%
Younger baby boomers	1955–1964	19.3%
Generation X	1965–1980	18.8%
Older millennials	1981–1989	17.4%
Younger millennials	1990–1998	13.7%

3.2 Measures and Procedure

We conducted an online national survey of attitudes and perceptions of automated driving with an embedded experiment to explore predictors of the acceptance of automated vehicles. Participants answered items about trust in general and level of knowledge of automated vehicles (from *no knowledge* (1) to *a great deal of knowledge* (5)). They were then provided with a definition of a self-driving car: “For the purpose of this study, we define self-driving cars as those in which operation of the vehicle occurs without the driver controlling the steering, acceleration, and braking; the driver is not expected to constantly monitor the roadway.” They were then asked about their trust in automated vehicles to work reliably, in poor weather, and on old roads in need of repair (from *no trust* (1) to *high trust* (5)), under which conditions they would anticipate using an automated vehicle, how they believe automated driving will affect safety on the roads, how risky and beneficial they perceive automated vehicles to be (on a scale of *not at all* (1) to *very much* (5)), technology adoption habits, current driving behaviors and driving history, and vehicle ownership and transportation alternatives.

Near the end of the survey, participants were introduced to the experiment. Participants then viewed a short (2-min) video about driving safety in general and automated driving. They were randomly assigned to listen to one of two versions of audio that accompanied the video. In one condition, participants heard a description of how driving has become increasingly safer in the past four decades, during the beginning of the video. In the other condition, participants heard that driving is a leading cause of death and the driver is usually to blame for such crashes, during the beginning of their video. All participants listened to the same description of automated driving at the end of the video.

Finally, they were again asked about perceived risks and benefits of automated vehicles, how they believe automated driving will affect safety on the roads, and intentions to use or purchase an automated vehicle automated in the future. Demographic questions were asked at the end of the questionnaire. This questionnaire was run on the Qualtrics platform (<http://qualtrics.com>).

4 Results

4.1 Knowledge, Trust, and Risk and Benefit Perception

Generations differed in driving behaviors and perceptions of driving-related technologies. Older participants perceived driving as being more risky and perceived more human error while driving ($F(5, 1759) = 3.23, p = .006, \eta^2 = .009$). Younger generations also reported taking more risks when driving (e.g., texting and driving) ($F(5, 1568) = 44.54, p < .001, \eta^2 = .124$) and being stopped more frequently by police ($F(5, 1568) = 15.03, p < .001, \eta^2 = .046$). Younger generations, however, felt that safety features in new vehicles were more important than older generations did ($F(5, 1568) = 2.78, p = .017, \eta^2 = .009$), and they reported feeling safer with the latest technologies installed in their vehicle ($F(5, 1568) = 7.62, p < .001, \eta^2 = .024$). They had greater knowledge of automated vehicles ($F(5, 1759) = 37.77, p < .001, \eta^2 = .097$) (see Fig. 1), which was positively correlated with trust in the technology ($r = .369, p < .01$) and in companies working to produce automated

vehicles (e.g., automobile manufacturers such as BMW, Volvo, Toyota, etc., and technology companies such as Google, Apple, etc.) ($r = .288, p < .01$) In line with this, younger generations trusted the automated vehicles to work ($F(5, 1759) = 28.12, p < .001, \eta^2 = .074$), and companies involved in manufacturing them more than older generations ($F(5, 1512) = 16.09, p < .001, \eta^2 = .051$).

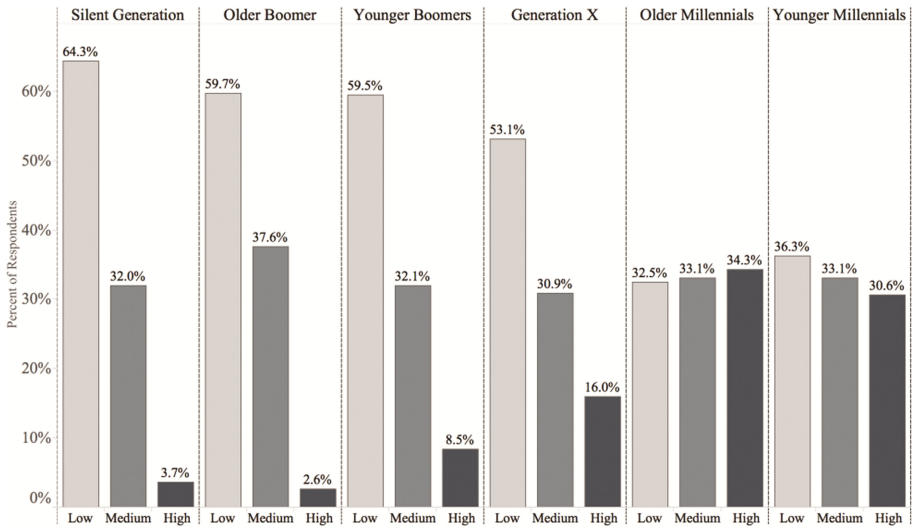


Fig. 1. Level of knowledge by generation

There was general interest to engage in automated driving. Overall, 38% of respondents reported they were quite or very much interested in using an automated car, and 17% indicated they would be quite or very likely to purchase one in the future. Clearly,

Table 2. Most favored benefits of automated vehicles

Benefits	Percent ranked in top three
Impact on safety	63.9%
Ability to do other things while driving	48.8%
Impact on convenience	42.9%
Impact on speed	25.2%
Driver control	24.7%
Impact on mobility	24.3%
Impact on congestion	24%
Impact on environment	17.5%
Impact on costs	11.7%
Liability	10.5%
Impact on data privacy	3.2%

Note: Because participants could choose up to three benefits, percentages do not add up to 100%.

participants saw many of the benefits that automated driving may offer. The three things that people liked most about automated driving across generations were impact on safety (64%), ability to do other things while driving (49%) and impact on convenience (43%) (see Table 2). However, many still harbored concerns, and 23% considered using an automated vehicle quite or very risky.

4.2 Measuring Acceptance of Automated Driving

There are many ways to measure acceptance. However, because automated vehicles are not yet available to consumers and manufacturers have not announced a definite sales model, it is challenging to decisively say which is the best way to measure acceptance of automated driving. This research examines four acceptance measures using ordinary least squares regression. Predictors were: knowledge of automated driving, trust in automated vehicles, risk and benefit perception of automated driving, and generation.

After viewing a short video with information about driving safety and automated driving, they were then asked how interested they are in using an automated vehicle (Measure 1). A regression model for Measure 1 was fitted to the data on N = 1,765 participants to predict interest based on knowledge, trust, risk and benefit perception, and generation. It was found that knowledge of automated vehicles, trust of automated vehicles, risk and benefit perception, and generation were all significant predictors of interest in using an automated vehicle ($F(9, 1755), = 17.87, p < .001$, with $R^2 = .68$). See Table 3 for regression coefficients for all models.

Table 3. Results of fitted multiple regression models predicting automated vehicle acceptance (unstandardized coefficient B)

	Measure 1	Measure 2	Measure 3	Measure 4
Level of knowledge	.032***	.048***	-.008	-.001
Trust	.296***	.310***	.059	.130***
Risk perception	-.017**	-.007	-.090***	-.020***
Benefit perception	.168***	.138***	.092***	.114***
Silent generation	-.179***	-.125***	.044	.059**
Older boomers	-.138***	-.108***	.040	.019
Younger boomers	-.074***	-.066**	.061*	.038*
Generation X	-.054**	-.019	.022	.007
Older millennials	-.022	-.006	-.017	.019
(Intercept)	-.182***	-.271***	.347***	.314***
R ²	.680	.602	.318	.427
Std. error of estimate	.208	.221	.279	.199

Notes: * $p < .05$, ** $p < .01$, *** $p < .001$

Measure 1 examines interest in using an automated vehicle, Measure 2 examines anticipated likelihood to purchase an automated vehicle, Measure 3 examines maximum level of automation comfortable with, and Measure 4 examines features participants want in their next vehicle.

Participants were also asked how likely they would be to purchase an automated vehicle (Measure 2). A regression model for Measure 2 was fitted on $N = 1,765$ participants to predict anticipated likelihood to purchase based on knowledge, trust, risk and benefit perception, and generation. It was found that knowledge, trust, risk perception, and generation were significant predictors of anticipated likelihood to purchase an automated vehicle if one were made available ($F(9, 1755) = 294.54, p < .001$, with $R^2 = .60$). Risk perception was not a significant predictor of purchase intentions.

Another way of exploring acceptance of autonomous driving is to ask participants more concretely what kinds of technology they would want in their vehicles using familiar terminology. Participants were presented with four statements ranging from “the driver is in complete control of the vehicle at all time” to “the car preforms all driving functions and monitors roadway conditions for an entire trip. This includes both occupied and unoccupied vehicles.” They were asked to indicate which best describes the maximum level of automation they would be comfortable with in their car (Measure 3). A regression model for Measure 3 was fitted to the data on $N = 1,765$ participants to predict the maximum level of automation they would feel comfortable with based on knowledge, trust, risk and benefit perception, and generation. It was found that risk and benefit perception were significant predictors of level of comfort with automation ($F(9, 1755) = 90.90, p < .001$, with $R^2 = .32$). Knowledge, trust, and generation were not significant.

Participants were then asked how much they would want a variety of features in their next vehicle on a scale from “do not want” (1) to “want very much” (5). The features were: those that reduce the potential or severity of a collision, those that help with speed control, those that help with steering, and those that periodically take control of driving. These items were highly correlated and summed into one variable ($\alpha = .862$) (Measure 4). A regression model for Measure 4 was fitted to the data on $N = 1,765$ participants to predict how much participants desire highly automated features in their vehicle based on knowledge, trust, risk and benefit perception, and generation. It was found that risk and benefit perception and trust were significant predictors of desire for highly automated features in their next vehicle ($F(9, 1755) = 145.02, p < .001$, with $R^2 = .43$). Knowledge was not a significant predictor.

4.3 Experimental Manipulation

We also examined the effect of the experimental manipulation. We conducted repeated measure ANOVAS with experimental conditions, age group, and gender as between-subject variables to examine how risk and benefit perception as well as automated driving acceptance were affected by the manipulation.

Risk perception decreased ($F(1,1724) = 302.61, p < .001, \eta^2 = .15$), but neither condition ($p > .05$) nor age group ($p > .08$) had an effect on this decrease (see Fig. 2). Women had higher risk perceptions ($p < .001$) and the decrease was stronger among women than men ($F(1,1724) = 12.70, p < .001, \eta^2 = .007$). Benefit perception increased ($F(1,1724) = 245.28, p < .001, \eta^2 = .13$), but there was no interaction with condition ($F < 1, p > .99$) (see Fig. 3). However, both age group ($F(5,1724) = 2.48, p = .03, \eta^2 = .007$) and gender ($F(1,1724) = 11.70, p = .001, \eta^2 = .007$), affected the increase in benefit

perception. While benefit perception increased among all age groups, it was generally lower for older than younger participants ($p < .001$). Men’s benefit perceptions were absolutely higher than women’s ($p < .001$), but perceived benefits increased more for women than men.



Fig. 2. Pre- and post-manipulation perception of risks of automated driving by gender and generation (asked on a 5-point scale from 1 = not at all risky to 5 = very much)

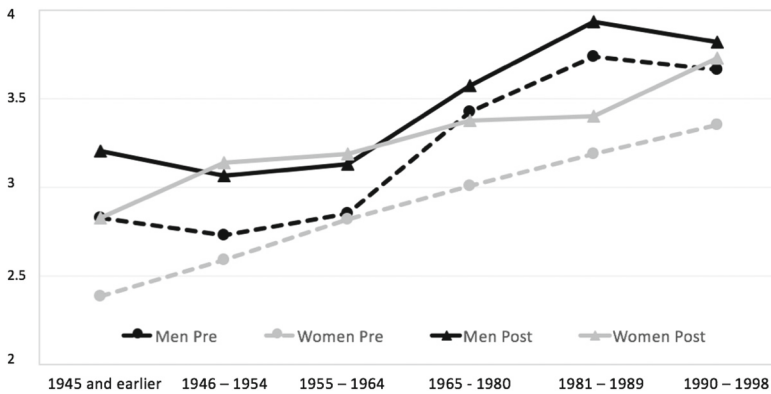


Fig. 3. Pre- and post-manipulation perception of benefits of automated driving by gender and generation (asked on a 5-point scale from 1 = not at all beneficial to 5 = very much)

General interest in use increased ($F(1,1724) = 234.37, p < .001, \eta^2 = .12$), but this was not affected by condition, age group or gender ($F < 3.68, p > .06$). Anticipated likelihood of purchase also increased ($F(1,1724) = 138.45, p < .001, \eta^2 = .07$); there was no inter-action with condition or age group ($F < 1, p > .77$), but gender affected the

increase ($F(1,1724) = 4.76, p = .03, \eta^2 = .003$). Likelihood of purchase was higher for men than for women ($p < .001$), but increased more for women than men.

The maximum level of automation one would be comfortable with increased ($F(1,1724) = 133.45, p < .001, \eta^2 = .07$), but there was no interaction with condition, age group, or gender ($F < 3.74, p > .05$). Additionally, the amount of highly automated features participants wanted in their next car increased ($F(1,1724) = 103.83, p < .001, \eta^2 = .06$), but there was no interaction with condition, age group or gender ($F < 2.14, p > .06$).

5 Discussion and Conclusion

This research sought to examine the factors that influence the acceptance of automated driving, including knowledge, trust, risk and benefit perception, and generation, by conducting an online national survey and experiment.

5.1 Measuring Acceptance

Consistent with earlier research, knowledge, trust, risk and benefit perceptions, and age were found to be related to acceptance of automated driving. Benefit perception in particular seems to be important as it was a significant predictor across all four measures of acceptance.

All five predictors, knowledge, trust, risk perception, benefit perception, and generation, had a significant impact on interest in using an automated vehicle. However, when examining if participants would want to purchase one, risk perception was no longer significant. It is interesting that trust remained significant when risk was not. It seems that when evaluating automated vehicles for purchase, perceptions of safety may not be as important as the benefits it may bring to one's life. Generation was also a significant predictor for these two acceptance variables.

Interestingly, when asked specifically about the level of automation one would feel comfortable with and the types of features one would want on their next vehicle, knowledge of automated vehicles was not significant. Perhaps this is because the items themselves gave participants specific information in easy to understand terms. Participants did not require any preexisting knowledge of automated vehicle technology to make an informed decision. In addition, in examining the level of automation one would be comfortable with, trust was also not significant. This may be because this measure of acceptance is more abstract: the other measures ask about what respondents would want, this asks what respondents would be comfortable with. Using a different measure of trust may yield different results. The effect of generation was less clear for these acceptance variables. This could be because whereas the acceptance variables in Measures 1 and 2 ask specifically about automated vehicles, those in 3 and 4 ask more generally about advanced vehicle technologies.

5.2 Effects of the Experiment

In the experiment, we did not find a statistically significant difference by condition (where people heard audio describing how driving has become increasingly safer or how driving is very risky). Perhaps the lack of an effect of the manipulation was because the two conditions were too similar. The differences in the audio participants heard may have been too subtle or were not attended to carefully with the more stimulating video footage that accompanied it.

However, exposure to the information on automated vehicles provided in both of the experimental conditions seemed to lead participants to report fewer risks and more benefits of automated driving. Providing participants with more information about automated driving in the second half of the video, which were the same in both conditions, may have informed participants about some of the potential benefits of automated driving. Our findings are consistent with [22], who also found that the more people know about automated driving, the more positive their attitudes toward automated driving tend to be.

Providing interested individuals with accurate, easy to understand information about the expected risks and benefits of automated driving may be key in helping people make informed decisions about automated vehicle acceptance and adoption. These informational appeals may want to specifically target women and older adults who generally have less favorable views of this technology. Older adults especially have the potential to lead consumers in purchasing automated vehicles as they have a great deal of buying power and will be reluctant to give up their independence as they age. Baby boomers, for example, control 70% of all disposable income in the U.S. [27].

In addition, all four of the acceptance measures, interest in using automated vehicles, anticipated intention to purchase an automated vehicle, level of automation respondents would be comfortable with in their next vehicle, and the extent to which participants desired highly automated features in their next vehicle, increased after the manipulation. This may be because risk and benefit perception also increase after the manipulation, and the information in the video may have increased participants' knowledge of automated vehicles. Knowledge, risk perception, and benefit perception were significant predictors in several of the acceptance measures presented.

This work provides a basis for further research into the acceptance of automated driving and the risks associated with them as they approach consumer markets. More research is needed to track how these attitudes and intentions to use highly automated vehicle technology and engage in automated driving evolve as these vehicles approach and eventually enter markets around the world. Policymakers and vehicle manufacturers require up to date consumer information to understand road users' concerns and develop vehicles and policies to effectively meet their needs. If they are successful as we enter this new era of transportation, widespread adoption could lead to a plethora of benefits for society including saving thousands of lives each year by taking human error out of driving.

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