Understanding Surveys of Public Sentiment Regarding Automated Vehicles

Summary of results to date and implications of past research on the dynamics of consumer adoption

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13. ABSTRACT (Maximum 200 words)

This paper explores the public's outlook on automated vehicles, focusing specifically on attitudes regarding safety, trust, and willingness to try, as well as the factors that influence those opinions. It compiles the results of numerous surveys and studies conducted over the past four years and tracks consumer attitudes over time, against the backdrop of newsworthy events in the development, testing, and early deployment of automated vehicles. This paper also presents an overview of research on the factors that affect consumer technology adoption, particularly in the context of innovative technologies, and identifies implications of this research for future assessments of the public's interest in automated vehicles.

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List of Abbreviations

Abbreviation	Term
AAA	American Automobile Association
AV	Automated Vehicle
DARPA	Defense Advanced Research Projects Agency
HDTV	High-Definition Television
INP	Incrementally New Product
IT	Information Technology
ITS JPO	Intelligent Transportation Systems Joint Program Office
OEM	Original Equipment Manufacturer
RNP	Really New Product
TAM	Technology Acceptance Model
UTAUT	Unified Theory of Acceptance and Use of Technology

Executive Summary

The research presented in this paper was sponsored by the United States Department of Transportation's Intelligent Transportation Systems Joint Program Office (ITS JPO), and conducted by the Volpe National Transportation Systems Center.

This paper explores the public's outlook on automated vehicles, focusing specifically on attitudes regarding safety, trust, and willingness to try, as well as the factors that influence those opinions. It compiles the results of numerous surveys and studies conducted over the past four years and tracks consumer attitudes over time, against the backdrop of newsworthy events in the development, testing, and early deployment of automated vehicles. This paper also presents an overview of research on the factors that affect consumer technology adoption, particularly in the context of innovative technologies, and identifies implications of this research for future assessments of the public's interest in automated vehicles.

The authors reviewed 22 surveys conducted by 15 entities/partnerships, several of which recur annually. The authors noted the following general observations based on this review:

- **Survey results should be assessed cautiously –** Survey methods vary, and in some cases may provide insufficient and/or biased context to respondents. The authors encountered a range of terms used to describe automated vehicles to survey respondents, as well as definitions of those terms that were, in some cases, sparse, incomplete, inaccurate, or potentially biasing. Surveys that present minimal or no descriptions or definitions of the terms used risk respondents interpreting them inaccurately. On the other hand, some surveys that present more thorough definitions risk biasing respondents' views on automated vehicles—for instance, describing them predominantly in terms of their lack of manual controls, without mention of their capabilities or potential benefits.
- **Vehicle automation may be too novel to reveal reliable survey results** – The authors reviewed several studies on relevant considerations for gauging public interest in a novel technology. Prevailing literature suggests that a priori preferences for a "really new product" (in contrast to an "incrementally new product") tend to be unstable and easily changed by small adjustments in the measurement procedure. Specifically in the context of automated vehicles, one study notes: "…due to the lack of wide-scale deployment and use of AVs by the general public, [large-scale surveys] cannot provide survey respondents with an accurate overview of the capabilities and limitations of the new technologies in question. It is also difficult for the surveys to capture an accurate understanding of users' actual use and impression of these vehicles. Results are therefore likely to be influenced by the interviewer's descriptions, or rely on respondents' impressions, which are, for example, shaped by promotional videos."
- **The surveys reviewed suggest that interest in automated vehicles is mixed, and leans negative** – While potentially subject to biases as discussed above, surveys of consumer sentiment regarding automated vehicles still provide useful insight. Across most surveys that asked respondents about their willingness to try riding in an automated vehicle, slightly more than half

of responses were negative (i.e., respondents were not interested in or were concerned about trying automated vehicles). The American Automobile Association (AAA) has been surveying the public since 2016 about their willingness to ride in an automated vehicle, and across five instances of this survey, between 63 and 78 percent of respondents have indicated that they would be “too afraid to ride in a fully self-driving vehicle.” Interest levels in buying or regularly using an automated vehicle are fairly consistent with interest in trying them. Several surveys have provided context to these findings, discovering that more than half of respondents perceive that automated vehicles are not safe.

In order to provide context for the survey results and methodology critiques, the authors reviewed available literature on the factors that influence actual adoption of new technologies. Theories positing specific factors that influence adoption of new technologies have been the focus of research and debate for several decades. Technology adoption research initially focused on IT systems; in recent years, researchers have also been studying consumer adoption of automated vehicles. Key factors that could influence consumer adoption of automated vehicles, discussed in Section 3 of this paper, include the following:

- **Trust in Automated Vehicle Technology:** The degree to which potential adopters perceive automated vehicle technology as safe and reliable.
- **Relative Advantage**: The degree to which potential adopters perceive a new or modified technology as being better than its precursor, including in terms of safety.
- **Enjoyment of Driving**: The degree to which potential adopters enjoy driving conventional vehicles, and would not want to relinquish that role.
- **Perceived Usefulness/Performance Expectancy**: The degree to which an individual believes that using a technology will help him or her improve task performance.
- **Perceived Ease of Use/Effort Expectancy**: The degree of ease associated with the use of a technology.
- **Social Influence**: The degree to which an individual perceives that other people believe he or she should use a technology.
- **Voluntariness of Use**: The degree to which potential adopters perceive the use of a technology as being voluntary or of free will.
- **Facilitating Conditions**: The degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the technology.
- **Image**: The degree to which potential adopters perceive the use of a technology as enhancing their image or social status.
- **Level of Knowledge about Automated Vehicles**: The degree to which potential adopters have knowledge of automated vehicles (e.g., from reading articles about them).

The authors conclude by identifying several implications of these findings for future surveys on the public's interest in automated vehicles, including:

- The use of clear and thorough, but neutrally-presented, terms and definitions;
- Question structure and content that may provide more accurate and stable measurements of the public's interest in automated vehicles;
- Tying surveys to actual automated vehicle demonstrations, pilots, or test deployments in order to gain an understanding of the role of hands-on experience in influencing perceptions of and interest in automated vehicles;
- Incorporating insights from technology adoption models to develop more nuanced surveys of public perceptions of automated vehicles and the factors that influence them.

1. Introduction

The research presented in this paper was sponsored by the United States Department of Transportation's Intelligent Transportation Systems Joint Program Office (ITS JPO), and conducted by the Volpe National Transportation Systems Center.

1.1 Overview and Motivation

Does the public want automated vehicles? While the automotive and technology sectors continue to pour billions of dollars into the development of passenger and freight vehicles that can operate autonomously, survey after survey reveals a public with mixed opinions about automated vehicles—opinions that generally skew toward concern and mistrust rather than optimism and eagerness.

This paper explores the public's outlook on automated vehicles, focusing specifically on attitudes regarding safety, trust, and willingness to try, as well as the factors that influence those opinions. It compiles the results of numerous surveys and studies conducted over the past four years and tracks consumer attitudes over time, against the backdrop of newsworthy events in the development, testing, and early deployment of automated vehicles. This paper also presents an overview of research on the factors that affect consumer technology adoption, particularly in the context of innovative technologies, and identifies implications of this research for future assessments of the public's interest in automated vehicles.

1.2 Background

Notions of automated personal transportation date at least as far back as the 1950s, when automakers envisioned space-age cars powered by jet turbines and guided automatically by magnets or wires embedded in the road surface. Research and demonstrations occurred sporadically during the ensuing decades but rarely progressed beyond the proof-of-concept phase. A series of competitions hosted by the Defense Advanced Research Projects Agency (DARPA) between 2004 and 2007 jumpstarted the current wave of development and testing; advancements in computing power, new sensing technologies, and increasingly capable AI-based computational methods accelerated the progress. Just three years after the final DARPA competition, Google revealed that it had been testing self-driving vehicles on public roads in California, inciting a flood of research activity, investment, and enthusiasm for the future of automated vehicles. Close to 30 states now explicitly allow testing and/or operation of automated vehicles on public roads, with California, Arizona, and Florida allowing vehicles to operate without human occupants. Numerous companies offer rides to the public through pilot deployments, or as part of their on-road testing.

In parallel with the ongoing work on fully automated driving systems, automotive original equipment manufacturers (OEMs) have continued developing advanced driver-assistance systems that automate certain aspects of the driving task while still requiring human driver oversight and an ability to resume control. Tesla's Autopilot and General Motors' Super Cruise are two examples of driver-assistance systems corresponding to Level 2 of SAE International's taxonomy for Automated Driving Systems.[1] Figure 1 provides an overview of the levels of driving automation defined by SAE International.

[1] *SAE International Standard J3016: Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles* defines five levels of driving automation and associated concepts (available at: https://www.sae.org/standards/content/j3016_201806/).

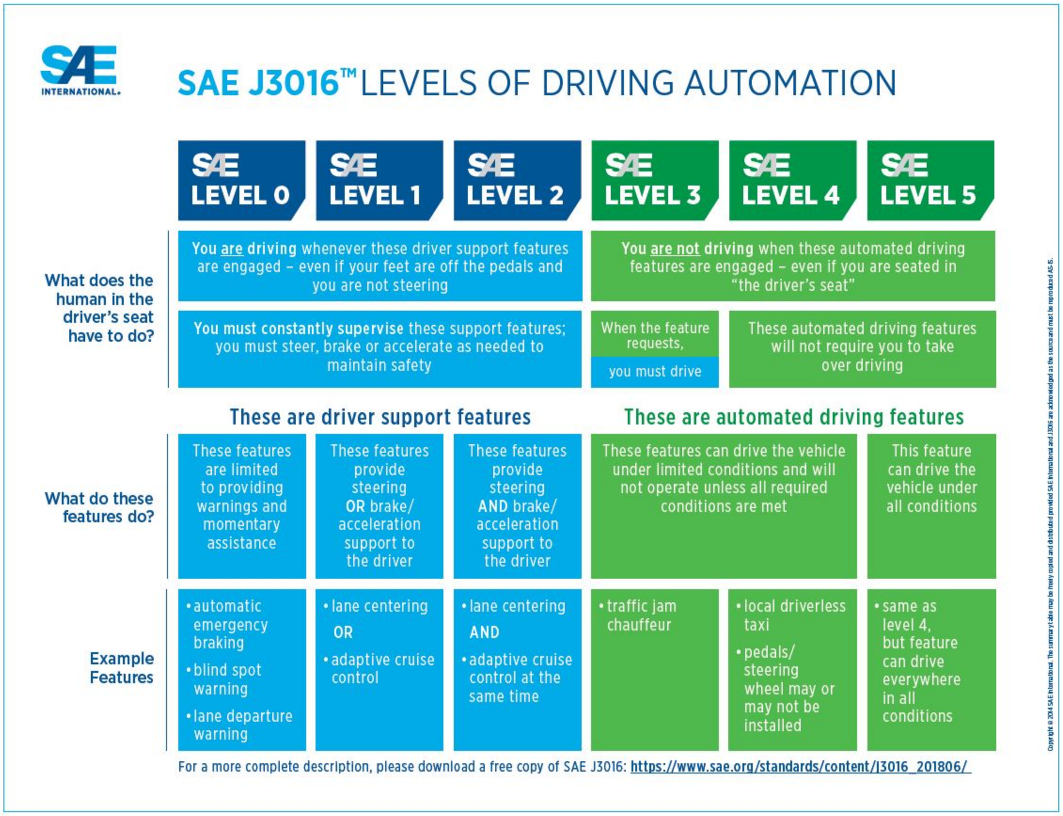

Figure 1: Summary of SAE International's *Standard J3016: Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles* (Source: SAE International)

2. Public Opinion toward Automated Vehicles

Industry research firms, think tanks, and academic researchers have conducted numerous surveys over the past four years to gauge the public's interest in automated vehicles. Each has asked a different, but related, array of questions and presented respondents with different framing, terminology for the technology, and use cases of interest. This section summarizes published survey results, including the questions and terminology used when available.[2]

2.1 Methodology

The authors reviewed summaries of previous surveys on consumer perceptions of and willingness to try automated vehicles. They also conducted general searches to capture new survey results reported through news outlets, as well as searches of academic sources. In the case of results reported via news outlets, the authors identified original source publications in order to provide a more comprehensive view of the reported results, as well as the questions asked and terminology used. Finally, they reviewed these sources and compiled survey results by source, date, and question type.

2.2 Sources

The results presented in this section reflect surveys fielded by the following entities:

Table 1: Sources consulted and summarized[3]

Source	Report/Survey Title	Survey Month/Year	Sample Size	Survey Method/Format
AAA	Automated Vehicle Survey	January 2016	1,832	Telephone/Mobile
AAA	Automated Vehicle Survey	January 2017	1,012	Telephone/Mobile
AAA	Automated Vehicle Survey	December 2017	1,004	Telephone/Mobile
AAA	Automated Vehicle Survey	April 2018	1,014	Telephone/Mobile
AAA	Automated Vehicle Survey	January 2019	1,008	Telephone/Mobile

[2] Some survey summaries present specific wording of questions asked, while others simply present results with highly simplified phrasing. Moreover, some survey summaries explicitly identify the terminology used to describe automated vehicles, while others use terms interchangeably in their summaries. In the latter case, the authors of this paper assume that terms used in summary graphics or presented alongside results align with those used in the survey instrument.

[3] In some cases, results from multiple surveys are reported in a single publication; in these cases, surveys are listed in separate lines.

Source	Report/Survey Title	Survey Month/Year	Sample Size	Survey Method/Format
Brookings	Public Opinion Survey on Artificial Intelligence and Emerging Technologies	July 2018	2,066	Online
Cox Automotive	2016 Cox Automotive Emerging In-Vehicle Car Technology	September 2016	1,334	Online
Cox Automotive	2018 Cox Automotive Evolution of Mobility Study	May 2018	1,250	Online
Deloitte	A Reality Check on Advanced Vehicle Technologies	October 2017	1,634	Online
Deloitte	A Reality Check on Advanced Vehicle Technologies	October 2018	1,730	Online
Deloitte	A Reality Check on Advanced Vehicle Technologies	Spring 2019	1,720	Online
Gallup	Americans Expect Driverless Cars to Be Common in the Next Decade; Driverless Cars Are a Tough Sell to Americans	April 2018	1,503	Telephone
Gallup/Northeastern University	Americans Hit the Brakes on Self-Driving Cars	October 2017	3,297	Mail
HERE Technologies	Consumer Acceptance of Autonomous Vehicles	June 2016	2,000[4]	Online
HNTB	HNTB's America THINKS Survey, The Road to Autonomous Vehicles	April 2018	1,010	Online
J.D. Power/Miller Canfield	Automated Vehicles: Liability Crash Course	September 2017	1,512	Online
J.D. Power/NAMIC	Fall 2018 Automated Vehicle Pulse Survey Questionnaire	August 2018	500	Online
Pew	Automation in Everyday Life: American's Attitudes Toward Driverless Vehicles	May 2017	4,135	Online
Reuters/Ipsos	Most Americans Wary of Self-Driving Cars	January 2018	2,592	Online
UMTRI	Motorists' Preferences for Different Levels of Vehicle Automation	June 2015	505	Online
Bansal et al.	Assessing Public Opinions of and Interest in New Vehicle Technologies: An Austin Perspective	October 2014	347	Online

[4] This study includes 2,000 consumers in the United States and Germany. Some questions were reported by respondents' nationality.

Source	Report/Survey Title	Survey Month/Year	Sample Size	Survey Method/Format
Howard & Dai	Public Perceptions of Self-driving Cars: The Case of Berkeley, California	April 2013	107	In-person

The surveys differed in size and scope: a few included only a small set of automated vehicle questions fielded online using national omnibus surveys[5]; others included automated vehicle questions along with several other technology or mobility-related topics. Only a few surveys focused solely on automated vehicles, covering consumer perceptions along with other aspects of automated vehicles.

Fourteen of the surveys were conducted online, with six conducted by phone, one by mail, and one in person. With a few exceptions,[6] the surveys were sent to a nationally representative sample of U.S. adults. In several cases, the incoming data were weighted to better reflect a national audience. Most surveys have large sample sizes (i.e., ranging from 1000 to 4000 respondents) yielding small margins of error for aggregate results (and larger sub-groups).

2.3 Results

The following subsections summarize results from the surveys reviewed. The questions asked in the surveys fall into three general categories, representing a spectrum of interest parameters related to consumer perceptions of automated vehicles. The first set of surveys asked about respondents' willingness to try an automated vehicle; based on the phrasing of the questions and results, these questions are assumed to pertain to a willingness to experience an automated vehicle once, rather than to use one regularly. A separate set of questions appears to assess the extent to which respondents are interested in buying or regularly using an automated vehicle, representing a deeper level of interest. The final set of survey questions shed some light on these first two areas, assessing respondents' perceptions of safety in automated vehicles; questions in this area cover their perceptions generally—as passengers, and as drivers of vehicles that will share the road with automated vehicles.

2.3.1 Willingness to Try

The following figures summarize previous surveys focused on the willingness of respondents simply to try an automated vehicle. In most cases, a majority of respondents (X% to Y%) are disinclined to ride in

[5] An **omnibus survey** is a method of quantitative marketing research where data on a wide variety of subjects is collected during the same interview. It's also called a piggyback survey. It is a research in which multiple clients share the cost of conducting research.

[6] JD Power/NAMIC survey with current insurance customers. Typically, smaller samples have larger margins of error. Cox Automotive and UMTRI studies target specific groups of people, such as licensed drivers or people who have used one transportation method in the past six months. The two academic surveys focus on the residents living in a region in the United States rather than the whole population of the nation.

or try an automated vehicle. Two trends are worth noting. First, successive surveys by AAA revealed a slight decrease in resistance to trying automated vehicles over the course of 2017; however, resistance appeared to increase in April 2018 and remained about constant through a subsequent survey in January 2019. It is possible, though not conclusive, that this increase in concern about riding in an automated vehicle may have been a response to the March 2018 crash in which an Uber test vehicle struck and killed a pedestrian. Further repetitions of this survey could reveal the extent to which resistance to trying an automated vehicle remains high.

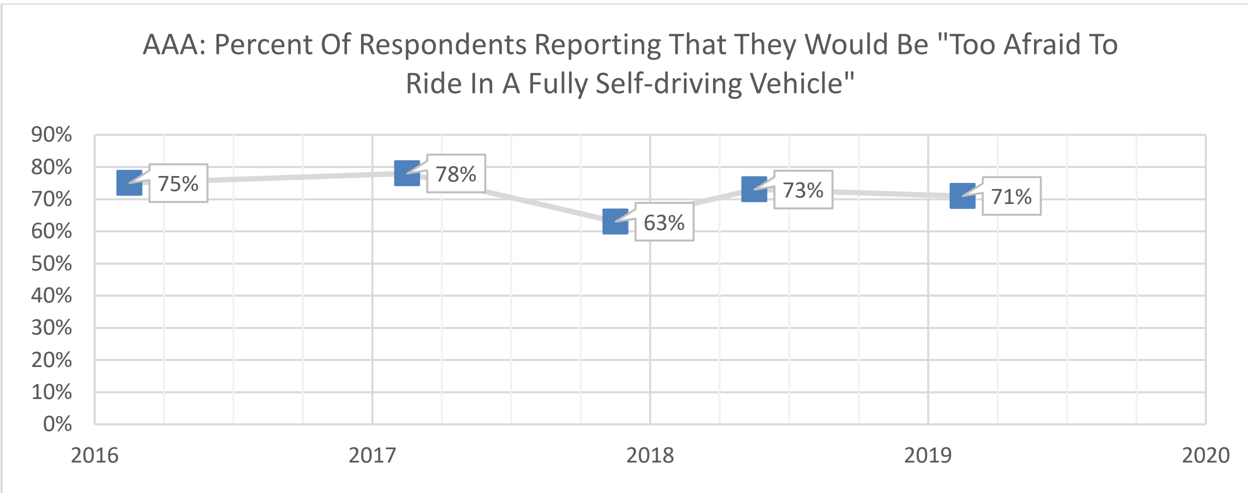

Figure 2: Responses to a poll fielded by AAA regarding the public's willingness to ride in a fully self-driving vehicle

Second, considering results from all surveys that have asked respondents about interest in or concern about trying or riding in an automated vehicle, it is not possible to draw definitive conclusions about trends in public opinion, particularly given the differences in survey instruments and sampling methodologies. Having said that, it appears that the level of negative responses in this area may have declined slightly over time.[7] Figure 3 summarizes survey results focused on unwillingness to try riding in an automated vehicle.

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[7] The surveys summarized in Figure 3 used the following question/response phrasing:

- AAA: Would be too afraid to ride in a fully self-driving vehicle
- Brookings: Very unlikely or somewhat unlikely to ride in a self-driving car
- Cox Automotive: Would feel uncomfortable in an AV fully driven by a computer
- Gallup/Northeastern: How likely or unlikely are you to use the following types of AI: Fully self-driving cars? (1-5 scale): % “Unlikely” (1 or 2)
- HNTB: Would not be willing to ride in an autonomous vehicle today
- J.D. Power/Miller Canfield: Definitely or probably would not ride in a fully self-driving vehicle
- Pew: Would not want to ride in a driverless vehicle if given the opportunity,
- Reuters/Ipsos: Some automakers are developing cars that can drive themselves and be used as taxis. Please indicate how comfortable you would be riding in an entirely self-driving car. % “Not Comfortable”

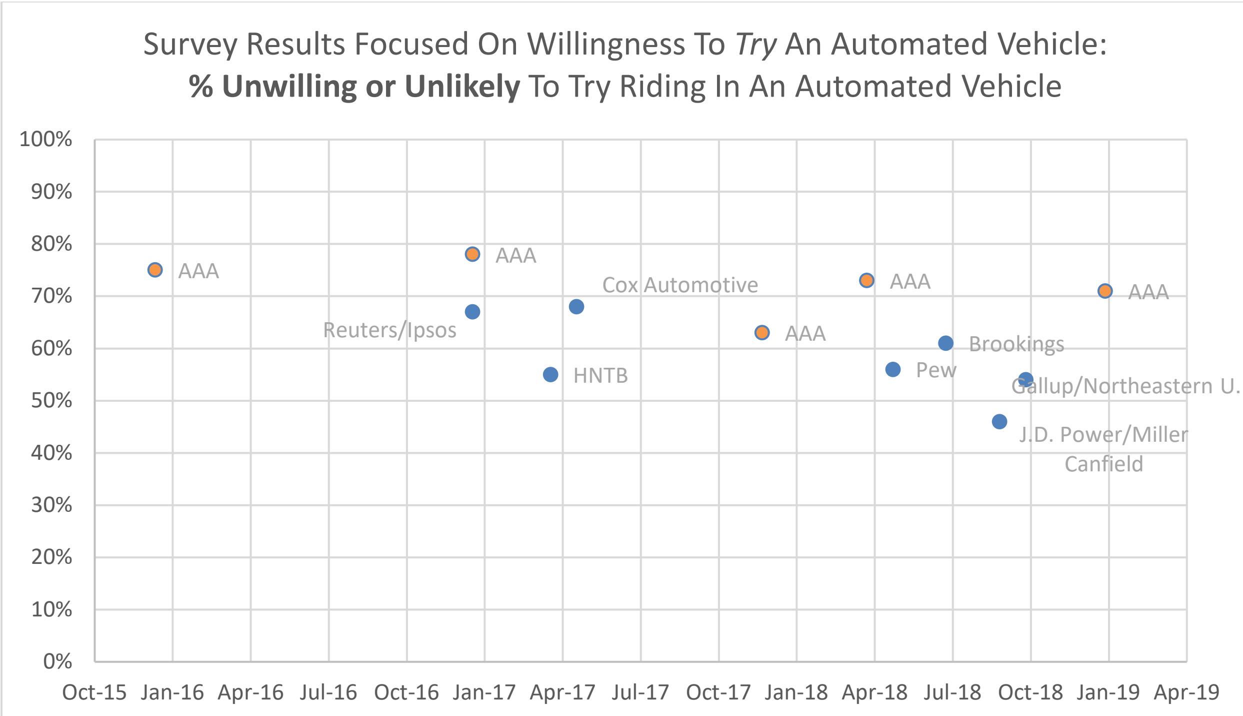

Figure 3: Summary of multiple survey results focused on the public's willingness to try or ride in an automated vehicle; results include the AAA survey responses mentioned above

Figure 4 summarizes the full results of the questions on willingness to ride in an automated vehicle.

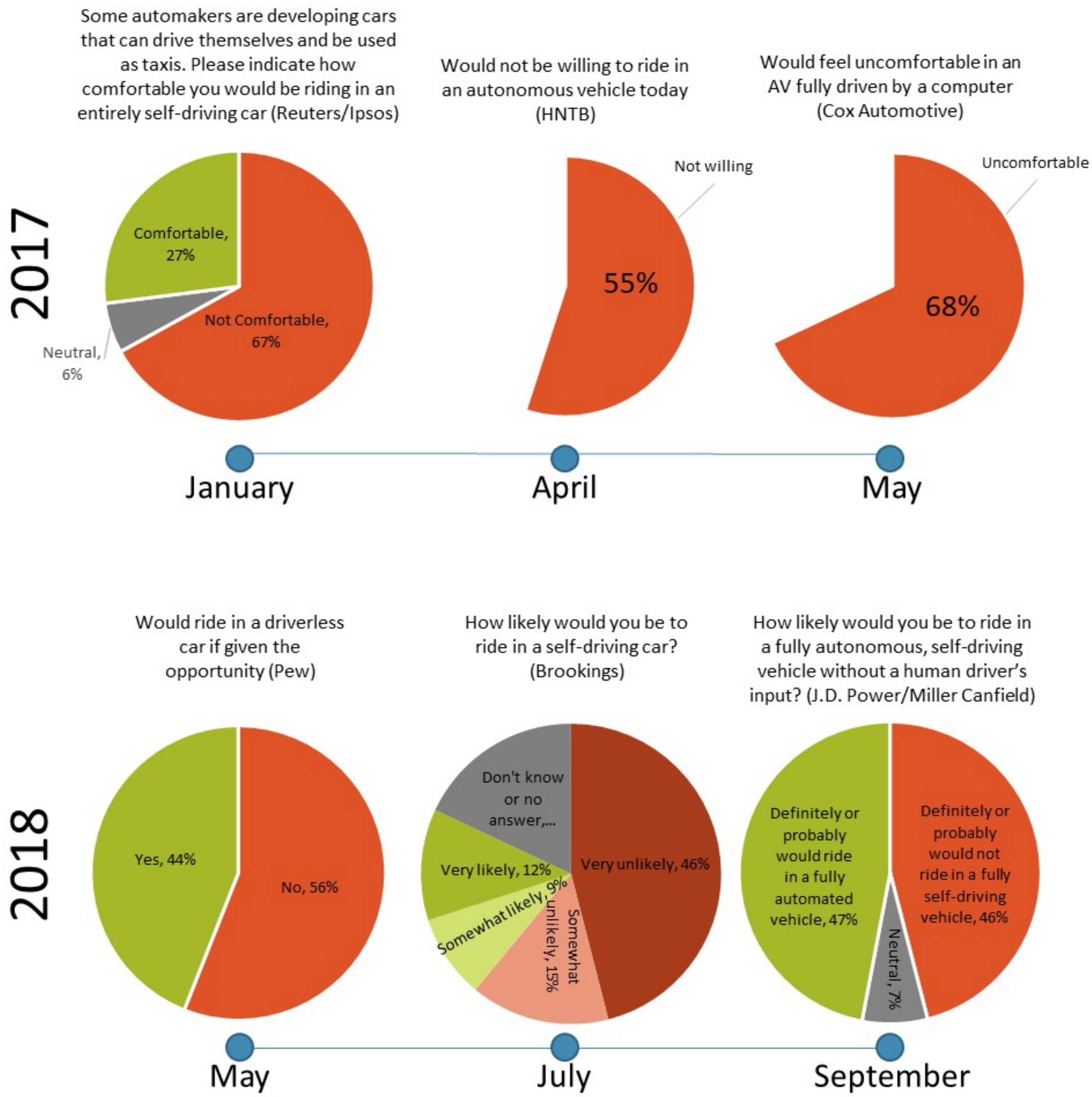

Figure 4: Summary of responses on willingness to try or ride in an automated vehicle; incomplete pie charts reflect survey results that did not provide percentages for every response category

2.3.2 Willingness to Buy or Use Regularly

A second set of the studies reviewed probed beyond respondents' willingness to try an automated vehicle, and explored the extent to which they would be willing to use an automated vehicle regularly, or to buy one. One study presented options for different levels of automation that might be available to consumers in the future, while others presented the option for a "Level 5 Autonomous Vehicle" or "driverless car" and asked whether respondents would be willing to buy or use them.

The single study that presented different levels of automation revealed that few respondents were interested in having a personal vehicle that is "completely self-driving," while roughly equal proportions of respondents were interested in "partially self-driving" and "no self-driving." Among recent studies that asked purely about Level 5, "driverless," or "fully self-driving" vehicles, about half of respondents indicated that they would never want to use or to buy such a vehicle.

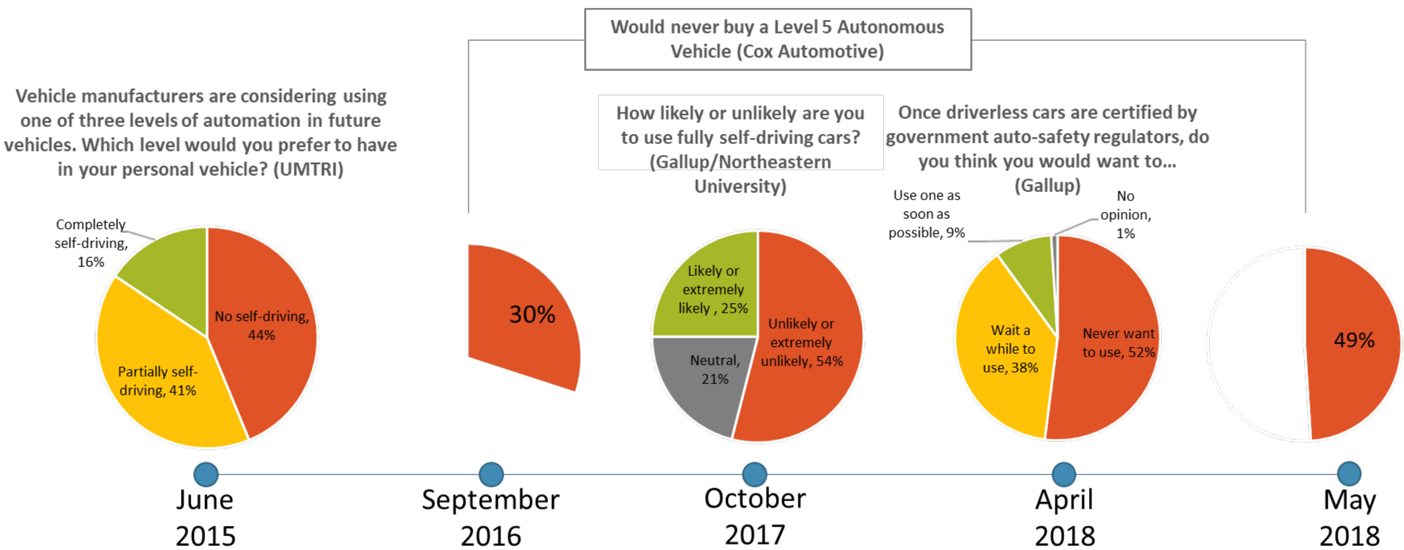

Figure 5: Summary of survey responses on willingness to buy or regularly use an automated vehicle

2.3.3 Safety Perceptions

A final set of studies reviewed reveal the extent to which respondents perceive automated vehicles as safe. These studies may provide some context for the extent of interest (or lack thereof) revealed in the surveys summarized above about consumer willingness to try, buy, or regularly use an automated vehicle.

Across most of the studies reviewed, at least half of respondents expressed at least some concerns or feelings of discomfort about the safety of automated vehicles, particularly those characterized as Level 5, "driverless," or "fully self-driving." Interestingly, the Cox Automotive surveys summarized in Figure 7 suggest that respondent perceptions of safety decreased with level of automation, with the highest perceptions of safety associated with Level 3 (the survey did not ask about safety perceptions of Levels 1 or 2). These perceptions run counter to prevailing industry and academic concerns about the risks of

Level 3 automation, particularly in the feasibility of safely transitioning between automated and human control in circumstances where the human driver's situational awareness has been compromised by being "out of the loop" for an extended period of time. The National Highway Traffic Safety Administration (NHTSA) has documented some challenges of Level 3 automation in its 2018 *Human Factors Design Guidance for Level 2 And Level 3 Automated Driving Concepts*—namely that "…emerging research suggests that drivers, when relieved of actively controlling the vehicle, may engage in a variety of non-driving tasks that can involve significant levels of distraction." However, the driver of a Level 3 vehicle may need to take over manual control of the vehicle. Due to the inherent risk, several vehicle manufacturers and technology developers have publicly acknowledged that they do not plan to develop Level 3 automated driving systems.[8]

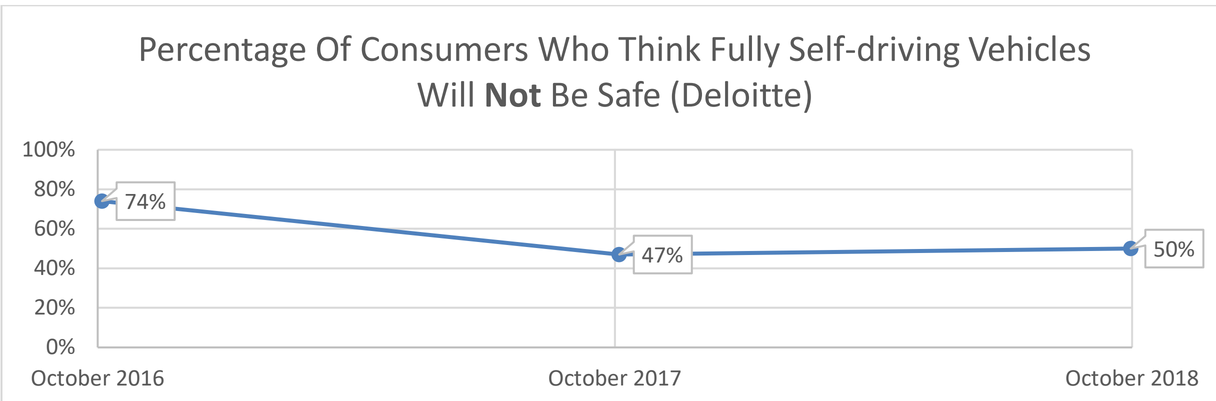

Figure 6: Results of multiple surveys by Deloitte on safety perceptions among consumers of fully self-driving vehicles

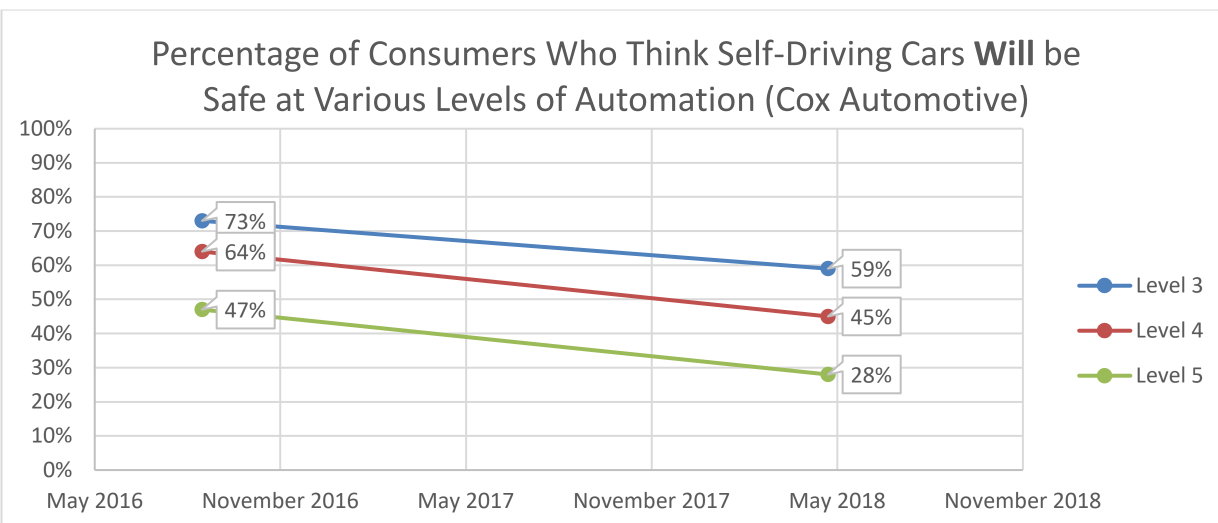

Figure 7: Results of multiple surveys by Cox Automotive of consumer perceptions of safety in Level 3, 4, and 5 automatedvehicles (results originally reported as "Safe - % Agree")

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[8] See John R. Quain, "Makers of Self-Driving Cars Ask What to Do With Human Nature," New York Times, July 7, 2016, (https://www.nytimes.com/2016/07/08/automobiles/wheels/makers-of-self-driving-cars-ask-what-to-do-with-human-nature.html).

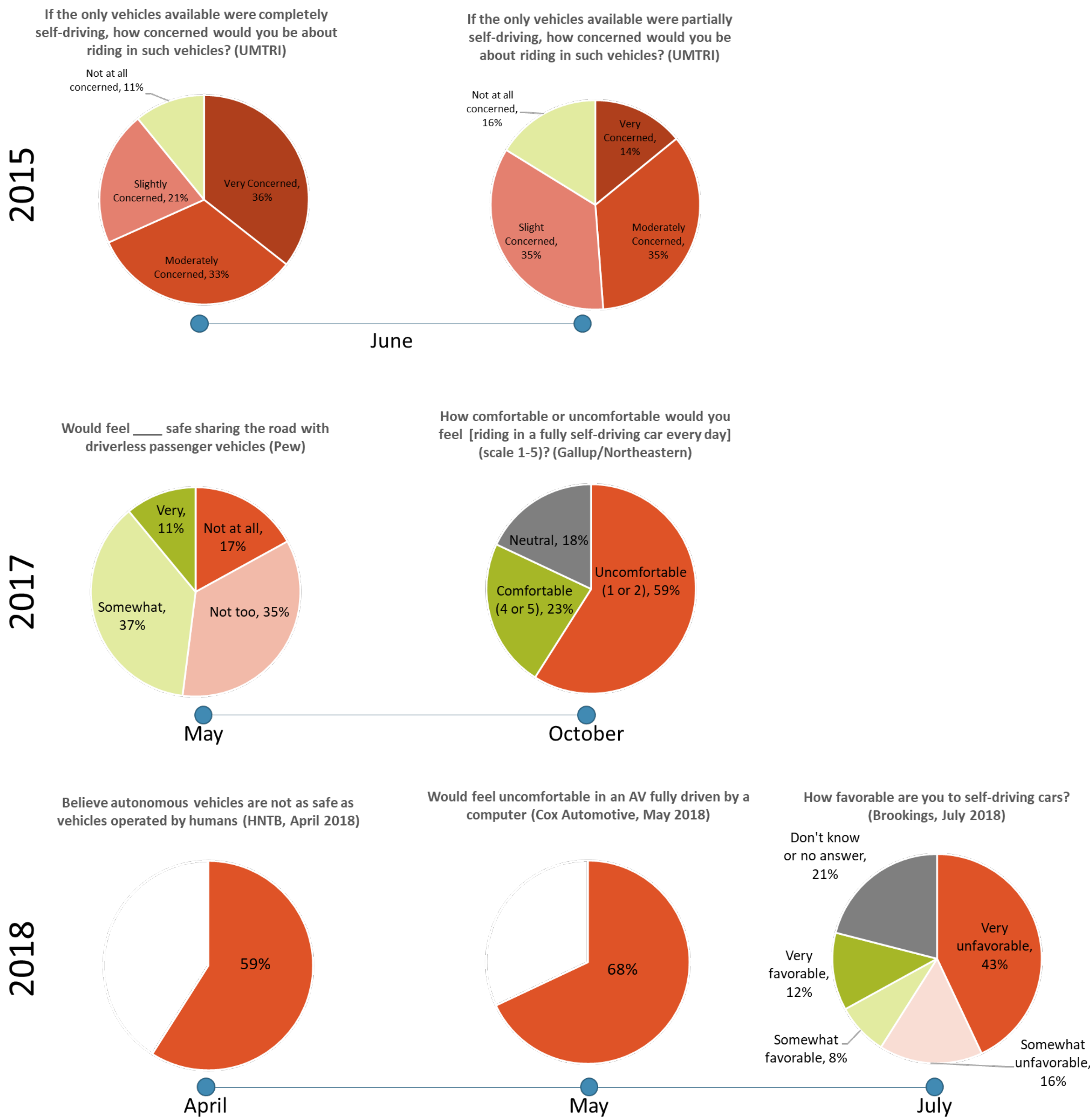

Figure 8: Summary of survey results focused on respondents' perceptions of safety and/or comfort riding in or driving among automated vehicles

3. Review of Survey Approaches

3.1 Automated Vehicle Descriptions

The review above of consumer perception surveys and studies revealed variation in the extent and manner with which survey instruments described automated vehicles to survey respondents. None of the surveys provided a detailed concept or presented pictures to describe the vehicles. One survey used simplified SAE automation levels to describe different levels of automation, and included brief descriptions of each level's functionality, although these descriptions were not entirely accurate. Three other surveys provided basic descriptions, while the remaining surveys reviewed presented respondents with only a few words to describe the vehicles. See Table 2 for a summary of terms used by the source.

Short descriptions of automated vehicles included the following:

- Simplified SAE Levels of Automation, and descriptions of automated vehicle functionality:[9]
    - Level 5: Vehicles don't contain steering wheel or pedals, and can't be driven by humans.
    - Level 4: Vehicle can operate all aspects of driving. Humans can still drive if they want to.
    - Level 3: Vehicle can take over driving in the city or on highways, but requires a human driver for unmarked roadways or highly congested areas.
    - Level 2: Corrects lane drift and avoids forward/rear collisions.
    - Level 1: Cruise control, anti-lock brakes, lane-keeping assist.
    - Level 0: No cruise control, anti-lock brakes, or lane-keeping assist.
- Fully-automated: Driverless cars that use technology to drive and do not need a human driver.[10]
- Driverless vehicle: Cars and trucks that can operate on their own without a human driver.[11]
- Fully automated vehicle: A car in which the occupants have no control.[12]

With such limited descriptions, it is likely that many respondents answer the survey questions based on what they have learned about automated vehicles from the media. Additionally, the wording used in a description can affect a respondent's view of the technology. Descriptions that focus on what has been taken away from the vehicles—i.e., no steering wheel, no pedals, and occupants have no control—without balancing information about potential benefits may create negative bias towards the technology.

Surveys that used shorter (two- to three-word) terms to describe automated vehicles presented the

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[9] Definitions provided to survey respondents in Cox Automotive (2018). It is worth noting that these descriptions are not wholly accurate; for example, manual controls and the capability to be driven by a human are not precluded in a Level 5 vehicle and conversely, a Level 4 vehicle could conceivably be deployed without manual controls or the ability for a human driver to operate it (albeit in a limited ODD).

[10] Gallup, 2018.

[11] Pew, 2017.

[12] JD Power/NAMIC, 2018.

following (frequency of use noted in parentheses):

- Automated vehicle (1)
- Autonomous vehicle (1)
- Completely self-driving car (1)
- Driverless vehicle (1)
- Fully-automated, driverless car (1)
- Fully automated, self-driving car (1)
- Fully automated vehicle (1)
- Fully self-driving car (2)
- Self-driving car (2)

These even shorter and varying terms present great potential for speculation among respondents, as well as variation in how each respondent actually interprets the nature of the technology or system in question, particularly in the case of surveys that presented no definitions of these terms. Previous research pointed out the issue that there is no agreed name for the referent to which respondents hold an attitude.[13] These different terms—autonomous, automated, connected and autonomous, driverless or self-driving—could mean different things to the public.[14] In addition, some surveys, especially among those commercially sponsored surveys, are less fastidious about clarifying what level of automation is being asked about. Future studies need to determine whether the respondents understand the concepts presented in the survey and whether the various definitions affect survey results.[15]

[13] Chris Tennant, Sally Stares, and Susan Howard, "Public discomfort at the prospect of autonomous vehicles: Building on previous surveys to measure attitudes in 11 countries," *Transportation Research Part F: Traffic Psychology and Behaviour* 64 (2019): 98-118.
[14] Steven E. Shladover, "Connected and automated vehicle systems: Introduction and overview," *Journal of Intelligent Transportation Systems* 22:3 (2018), 190-200, DOI: 10.1080/15472450.2017.1336053.
[15] Reginald Boersma, P. Marijn Poortvliet, and Bart Gremmen, "The elephant in the room: How a technology's name affects its interpretation," *Public Understanding of Science*, 28 no. 2 (2019): 218–233, https://doi.org/10.1177/0963662518812295.

Table 2: Summary of terminology and definitions used in surveys reviewed

Source	Terminology Used
AAA	Fully self-driving car
Brookings	Self-driving car
Cox Automotive	SAE Automation Levels: • Level 5: Vehicles don't contain a steering wheel or pedals, and can't be driven by humans. • Level 4: Vehicle can operate all aspects of driving. Humans can still drive if they want to. • Level 3: Vehicle can take over driving in the city or on highways, but requires a human driver for unmarked roadways or highly congested areas. • Level 2: Corrects land drift and avoids forward/rear collisions. • Level 1: Cruise control, anti-lock brakes, lane-keeping assist. • Level 0: No cruise control, anti-lock brakes, or lane-keeping assist.
Deloitte	Fully self-driving
Gallup	Fully automated, driverless cars: Cars that use technology to drive and do not need a human driver.
Gallup/ Northeastern University	Fully self-driving car
HERE Technologies	Autonomous Car-as-a-Product (CaaP), Autonomous Car-as-a-Service (CaaS)
HNTB	Autonomous vehicle
J.D. Power/Miller Canfield	Your current vehicle: Vehicle you own today (Level 0, though some respondents may have Level 1 or 2 technologies). Automated, self-driving vehicle with LIMITED automation: This means the vehicle can drive itself, but a human driver must still pay attention and take over at any time. The vehicle is supposed to notify its driver if intervention is needed, for example, when weather or road conditions don’t permit automated driving (e.g., construction zone and blizzard) (Level 3). FULLY automated, self-driving: There is not a human driver inside the vehicle, there is no steering wheel, and the vehicle remains in control for the entire trip without any human intervention (Level 4).
J.D. Power/NAMIC	Fully automated vehicle: A car in which the occupants have no control.
Pew	Driverless vehicles: Cars and trucks that can operate on their own without a human driver.
Reuters/Ipsos	Self-driving car

Source	Terminology Used
UMTRI	Completely self-driving: The vehicle will control all safety-critical functions, even allowing the vehicle to travel without a passenger if required. Partially self-driving: The driver will be able to hand over control of all safety critical functions to the vehicle; only occasional control by the driver will be required. No self-driving: The driver will always be in complete control of all safety functions, but the driver will be assisted with various advanced technologies.
Bansal et al.	Level 3 and Level 4 technology autonomous vehicles
Howard & Dai	Self-driving Technology

3.1.1 Automated Vehicle Acceptance – Measures of Prospective Use

Automated vehicle acceptance is often represented by questions measuring intent to use. Table 3 shows the results of the seven surveys that included an intent-to-use measure.

Table 3: Expected Use of Automated Vehicles

Year	Source article or report	Expected Automated Vehicle Use
2017	Americans Hit the Brakes on Self-Driving Cars (Gallup)	Likelihood to use: **Likely use (4 or 5 on scale 1-5): 25%** **Unlikely use (1 or 2 on scale 1-5): 54%**
2018	Public Opinion Survey on AI and Emerging Technologies (Brookings)	Likelihood to ride in: **Likely (somewhat, very likely): 21%** **Unlikely (somewhat, very unlikely): 61%**
2018	Fall 2018 Automated Vehicle Pulse Survey Questionnaire (JD Power)	Use AV as rideshare (more limited purpose) **Definitely/Probably use: 26%** **Definitely/Probably not use: 73%**
2018	HNTB's America THINKS Survey, The Road to Autonomous Vehicles (HNTB)	Willingness to ride in: **Willing: 44%** **Not willing: 55%**
2017	Automation in Everyday Life: Subsection- American's Attitudes Toward Driverless Vehicles (Pew)	Ride in (if opportunity): **Yes: 44%** **No: 56%**
2018	Americans Expect Driverless Cars to Be Common in the Next Decade; Driverless Cars Are a Tough Sell to Americans (Gallup)	Likelihood to use (if certified by regulators) **Use now/Wait a while: 47%** **Never want to use: 52%**
2018	2018 Cox Automotive Evolution of Mobility Study (Cox Automotive)	Would never buy an automated vehicle: **49% (response choices unknown)**

Acceptance levels vary based on whether a scaled[16] or limited multiple choice question was used. Scaled questions with multiple points resulted in lower prospective usage levels. This is because scaled questions offer more response options for respondents who are unsure, neutral or undecided about their future use of automated vehicles. When reporting on likely automated vehicle use, neutral or undecided respondents are typically not included, potentially providing a more precise estimate.[17] On the other hand, for new technologies about which respondents have little or knowledge, a "Don't Know" response category may be valid and useful. Limited choice questions that do not include a neutral or "Don't Know" option force respondents into a positive or negative response, which may not be appropriate in certain cases.

Among the surveys reviewed, results varied based on the question format employed:

- Likelihood or probability scales (5-point) showed top-2 box (likely or probable) automated vehicle usage results ranging from 21 percent to 26 percent.[18]
- Limited choice usage questions (Yes/No, Willing/Unwilling, or Now/Wait/Never) showed (positive) usage ranging from 44 percent to 47 percent.
- The bottom-2 box (unlikely), and negative choices (unlikely, not willing, never) ranged from 52 percent to 61 percent, with one exception.[19]

Regardless of question type, the surveys reviewed revealed less variation among those who are negative towards automated vehicles than among those who are positive or neutral. The results suggest that at this moment there is a stable set of consumers who are not interested in automated vehicles (~55 percent) whereas consumers who may be open to automated vehicles include those who are more likely to use (~25 percent) and those who are still on the fence (~20 percent).

3.1.2 Discussion on Survey Limitations

Partially related to the methodology issues discussed above is the efficacy of surveying consumers on their prospective use of a new technology that they have never experienced. Several studies—many focused on the dynamics of resistance to innovation—have highlighted considerations related to how consumers perceive genuinely new technologies and limitations in how they evaluate their potential adoption. For example, Ram and Sheth (1989) identify five barriers that may foster resistance to innovation, including:[20]

- The innovation may not be compatible with existing work flows and practices.

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[16] e.g., a 5-point response scale ranging from "strongly agree" to "strongly disagree."
[17] Scales measuring likelihood of use or probability of use are reporting using Top-2 Box scores (positive) and Bottom 2-box (negative). Neutral mid-points or Don't Know responses are not included.
[18] Acceptance or rejection on a 5-point scales use top-2 box and bottom-2 box to measure acceptance, excluding the neutral midpoint.
[19] The question from the JD Power survey uses a 4-point scale that does not include a neutral point. It measures a more limited use (rideshare). These factors may have led to a higher negative score (73 percent).
[20] S. Ram and Jagdish N. Sheth, "Consumer Resistance to Innovations: The Marketing Problem and its solutions," *Journal of Consumer Marketing* 6, no. 2 (1989): 5-14. https://doi.org/10.1108/EUM0000000002542.

- Consumers do not understand the value of the innovation.
- Consumers view the innovation as being too risky and postpone adoption until the risk is mitigated.
- The innovation requires a customer to deviate from established norms and traditions.
- A product's image, whether deserved or underserved, can produce a barrier to adoption.

Many, if not all, of these barriers hold some relevance to automated vehicles, as do factors affecting consumer preferences for so-called "really new products" or RNPs (as opposed to incrementally new products, or INPs). Hoeffler (2003) cites longstanding research suggesting that when consumers are asked to construct their preferences for a product at the time of measurement, rather than retrieving a preference from prior experience, their views may be unstable and easily changed by small adjustments in the measurement procedure.[21] Hoeffler generally concludes that RNPs tend to be associated with higher levels of uncertainty than INPs, which may compromise the predictive accuracy of methods for assessing consumer preferences. He suggests that mentally simulating how a product fits into existing usage patterns can improve the accuracy and stability of measuring consumer preference for RNPs. However, Hoeffler presents a caution about the use of mental simulation in measuring consumer preference:

> *Across all the studies, consumers were asked to think about new products (concept statements of the actual products themselves).* ***Whenever there is forced exposure in this manner, the question whether true preferences or preferences that were built into the measurement exercise are being captured must be asked****. It is always a concern when people have been guided to think about products in ways they would not during the product adoption decision. Careful evaluation of a product concept can change consumers' preferences and perceptions of newness for the product.*

Zhao et al. (2012) builds on Hoeffler's earlier research and points to factors that may influence how consumers perceive RNPs.[22] They suggest that encouraging consumers to imagine multiple uses of an RNP without providing specific examples may lead to lower evaluations. This suggests that surveys providing only basic descriptions of automated vehicles, without expounding on how they might operate or how they might be used, could dampen consumer responses to their prospective adoption. In contrast, Zhao et al. point out that providing multiple examples of an RNP's new benefits—thereby limiting the extent to which a consumer has to imagine their prospective use of the product—may lead to higher evaluations and faster adoption in the marketplace. More broadly, Mukherjee and Hoyer (2001) found that, while novel attributes and features tend to increase the favorability of products, this

[21] Steve Hoeffler, "Measuring Preferences for Really New Products," *Journal of Marketing Research* 40 no. 4 (2003): 406–420, https://doi.org/10.1509/jmkr.40.4.406.19394.
[22] M. Zhao, S. Hoeffler, and D. W. Dahl, "Imagination Difficulty and New Product Evaluation," *Journal of Product Innovation Management* 29 (2012): 76-90, doi:10.1111/j.1540-5885.2012.00951.

generally only holds true for low-complexity products.[23] Adding novel attributes to complex products, on the other hand, can actually lower consumer evaluations of these products, even in the face of information provided to consumers about explicit benefits of the product or novel feature(s).

Merat et al. (2017) address some of these issues specifically in the context of automated vehicles, reviewing the challenges and limitations of surveying individuals about such a novel technology to which they have not been exposed directly.[24]

They note:

> *…a major shortcoming of most such large-scale surveys is that, due to the lack of wide-scale deployment and use of AVs by the general public, they cannot provide survey respondents with an accurate overview of the capabilities and limitations of the new technologies in question. It is also difficult for the surveys to capture an accurate understanding of users' actual use and impression of these vehicles. Results are therefore likely to be influenced by the interviewer's descriptions, or rely on respondents' impressions, which are, for example, shaped by promotional videos.*

In light of these limitations, the authors review how interaction and hands-on experience with automated vehicles shape user trust and acceptance. Among individuals who used an automated shuttle as part of the CityMobil2 demonstration project in Europe, the authors note that user enjoyment of the experience—in part

BUILDING ACCEPTANCE FOR "REALLY NEW PRODUCTS"
THE CASE OF SCREW-TOP WINE BOTTLES

Garcia et al. (2007) apply much of the theoretical literature on adoption of RNPs in a case study on the introduction of screw-top wine bottles. Their case study contrasts the technical superiority of screw-top closures compared to traditional cork, but also highlights the resistance that they faced as an RNP, among both consumers and distributers, particularly in the United States. Garcia notes substantially higher adoption rates in Australia and New Zealand and attributes the difference to a "coopetition" marketing approach.

Instead of the vertical marketing approach taken in the United States, whereby individual wineries undertook campaigns to market the advantages of screw-top closures throughout their supply chain and to end consumers, wineries in Australia and New Zealand joined forces collaboratively to educate the market.

The results of these differing approaches are quite dramatic; in 2005, screw-top closures represented less than five percent of wine sales in the United States, whereas in New Zealand and Australia they were included on 80 percent and 40 percent of domestically sold bottles, respectively.

[23] Ashesh Mukherjee and Wayne D. Hoyer, "The Effect of Novel Attributes on Product Evaluation," *Journal of Consumer Research* 28, no.3 (December 2001): 462–472, https://doi.org/10.1086/323733.
[24] Natasha Merat, Ruth Madigan, and Sina Nordhoff, "Human factors, user requirements, and user acceptance of ride-sharing in automated vehicles," *International Transport Forum* (2017), https://www.itf-oecd.org/human-factors-user-requirements-and-user-acceptance-ride-sharing-automated-vehicles.

attributed to its novelty—was a significant factor in attitudes toward wanting to continue using the vehicles, as were the vehicle's performance, resources provided to support automated vehicle use, and the social norms surrounding automated vehicle use.[25]

This suggests that, in addition to the aforementioned survey issues, a framing effect arising from the naming of the attitude objects and the sequencing of questions could also potentially influence the survey outcome. For instance, the terms to designate the automated vehicle in the survey may have a priming effect if they suggest that automated vehicles are a natural progression of increasing levels of automation. Some studies take steps to brief the respondents regarding the attitude object (Zmud et al., 2016; Howard & Dai, 2014).[26][27] For example, Zmud et al. (2016) presented a video that shows how people who are not able to drive may benefit from having automated vehicles (though Tennant et al. (2019) point out that the video used in Zmud et al.'s study promotes the technology rather than presenting it neutrally). Given that the descriptions of RNPs could provide a particular framing to the topic and thereby prime responses, it is suggested that the attitude object needs to be clearly defined and in a neutral tone for respondents.

In the area of performance, Merat et al. (2017) present several cautions. First, they point to previous research that has highlighted the detrimental effects of unrealistic performance expectations on long-term consumer acceptance, suggesting that automated vehicle developers may need to moderate the public's expectations about automated vehicle performance through small-scale, managed demonstrations that provide early and iterative exposure.[28] Second, Merat et al. point to the importance of communication and feedback to users to build trust in the performance of the vehicle.

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[25] Ruth Madigan et al., "What influences the decision to use automated public transport? Using UTAUT to understand public acceptance of automated road transport systems," *Transportation Research Part F: Traffic Psychology and Behaviour* 50 (2017): 55-64, ISSN 1369-8478, https://doi.org/10.1016/j.trf.2017.07.007.

[26] Johanna Zmud, Ipek N. Sener, and Jason Wagner, "Consumer Acceptance and Travel Behavior Impacts of Automated Vehicles," Texas A&M Transportation Institute PRC 15-49 F, Accessed July 2019, https://static.tti.tamu.edu/tti.tamu.edu/documents/PRC-15-49-F.pdf.

[27] Daniel Howard and Danielle Dai, "Public Perception of Self-driving Cars: The Case of Berkeley, California," In Paper presented at the Transportation Research Board 93rd Annual Meeting, Washington, DC.

[28] Matthias Beggiato and Josef F. Krems, "The evolution of mental model, trust and acceptance of adaptive cruise control in relation to initial information," *Transportation Research Part F: Traffic Psychology and Behaviour* 18 (2013): 47–57, doi:10.1016/j.trf.2012.12.006.

4. Review of Technology Adoption Models

When considering consumer perceptions of automated vehicles, an understanding of the factors influencing user acceptance of new technologies is useful in several respects. First, technology adoption theories provide a broad framework for empirical research on consumer acceptance of automated vehicles by distinguishing between determinants of acceptance that derive from:

- The technologies themselves;
- The users of the technologies;
- The commercial, personal, and societal contexts in which those technologies are used.

Second, technology adoption theories specifically about user acceptance of automated vehicles can be instructive in the development of survey instruments and other research methods. For example, technology adoption theories can indicate specific factors to focus on, and/or indicate how factors typically included in studies of acceptance of new automotive technology may need to be modified to address the unique characteristics of automated vehicles with regard to user psychology and societal context (among other factors).

Finally, a holistic understanding of technology adoption paradigms generally, and their application to automated vehicles specifically, can inform the development of responsive, effective, and equitable public policy.

4.1 Innovation Diffusion and Market Uptake

There is an extensive literature addressing technology adoption. At a macro level are theories describing the rate of market uptake of new technologies. The best-known of these is the *innovation diffusion* theory, popularized by Everett Rogers in 1962.[29] Rogers originally used this model to explain how new ideas and trends spread and are adopted; it has proven equally useful at describing the market uptake of new technologies. The diffusion theory divides the population (or the market) for a new technology into five categories:

- Innovators: People who are venturesome and interested in new ideas. Very willing to take risks, they want to be the first to try a new technology.
- Early Adopters: These people typically are opinion leaders. They are comfortable adopting new ideas, and embrace change.
- Early Majority: These people typically need to see evidence that an innovation works before they are willing to adopt it.
- Late Majority: Skeptical of change, these people will adopt an innovation only after it is in widespread use.

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[29] Everett Rogers, *Diffusion of Innovations*, 5th Edition, (Simon and Schuster, 2003).

- Laggards: These people tend to be very conservative and bound by tradition. They typically resist adopting new innovations

Rogers posited that the distribution of the population into these five categories followed a normal distribution, as shown in Figure 9.

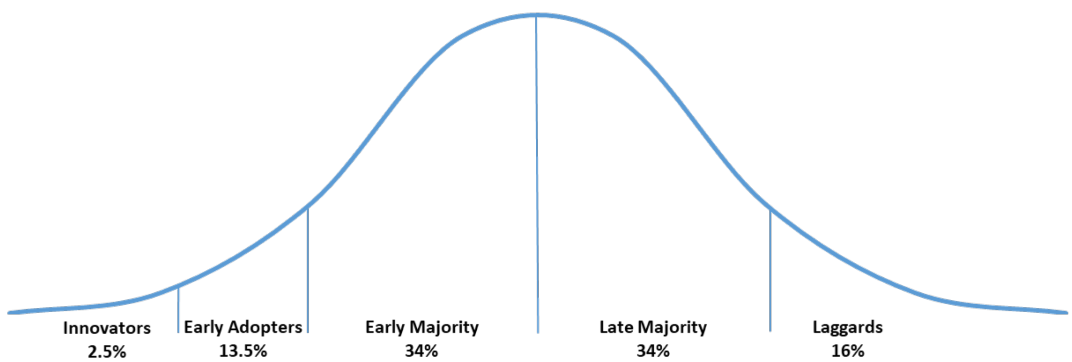

Figure 9. Innovation Diffusion Curve

With this idealized population distribution, the adoption/market penetration of a new technology over time produces the now-familiar "S-curve" cumulative distribution, a theoretical example of which is shown in Figure 10.

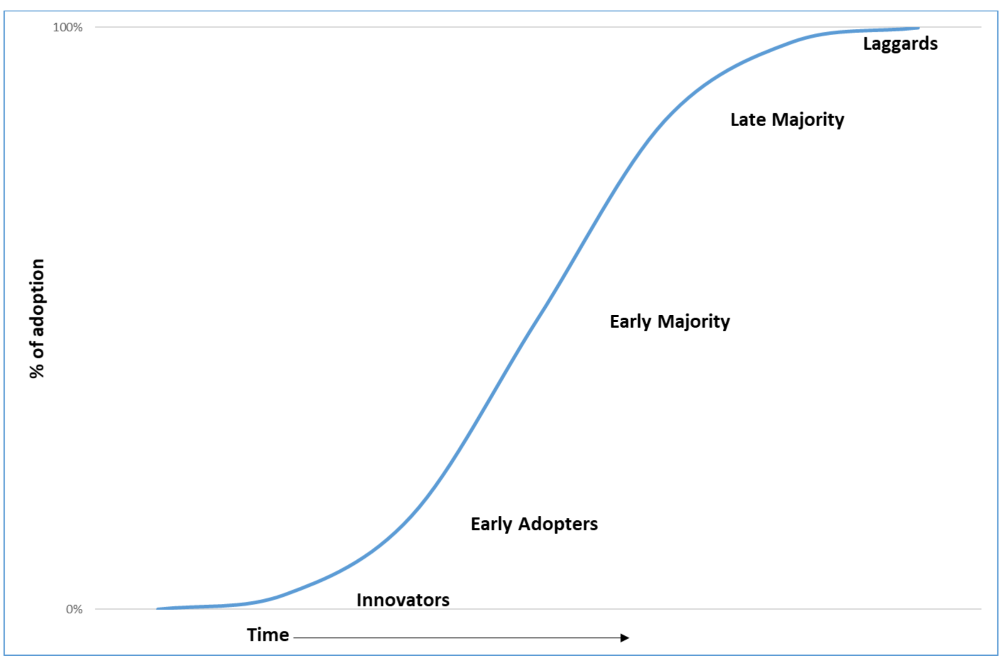

Figure 10. Innovation Diffusion S-Curve

Most new consumer technologies have followed s-shaped market adoption curves, although the inflection points and slopes of these curves have varied with the technologies. Recent innovations such as smartphones and high-definition television (HDTV) have had nearly vertical s-curves, due to their extremely rapid mass adoption (see Figure 11).

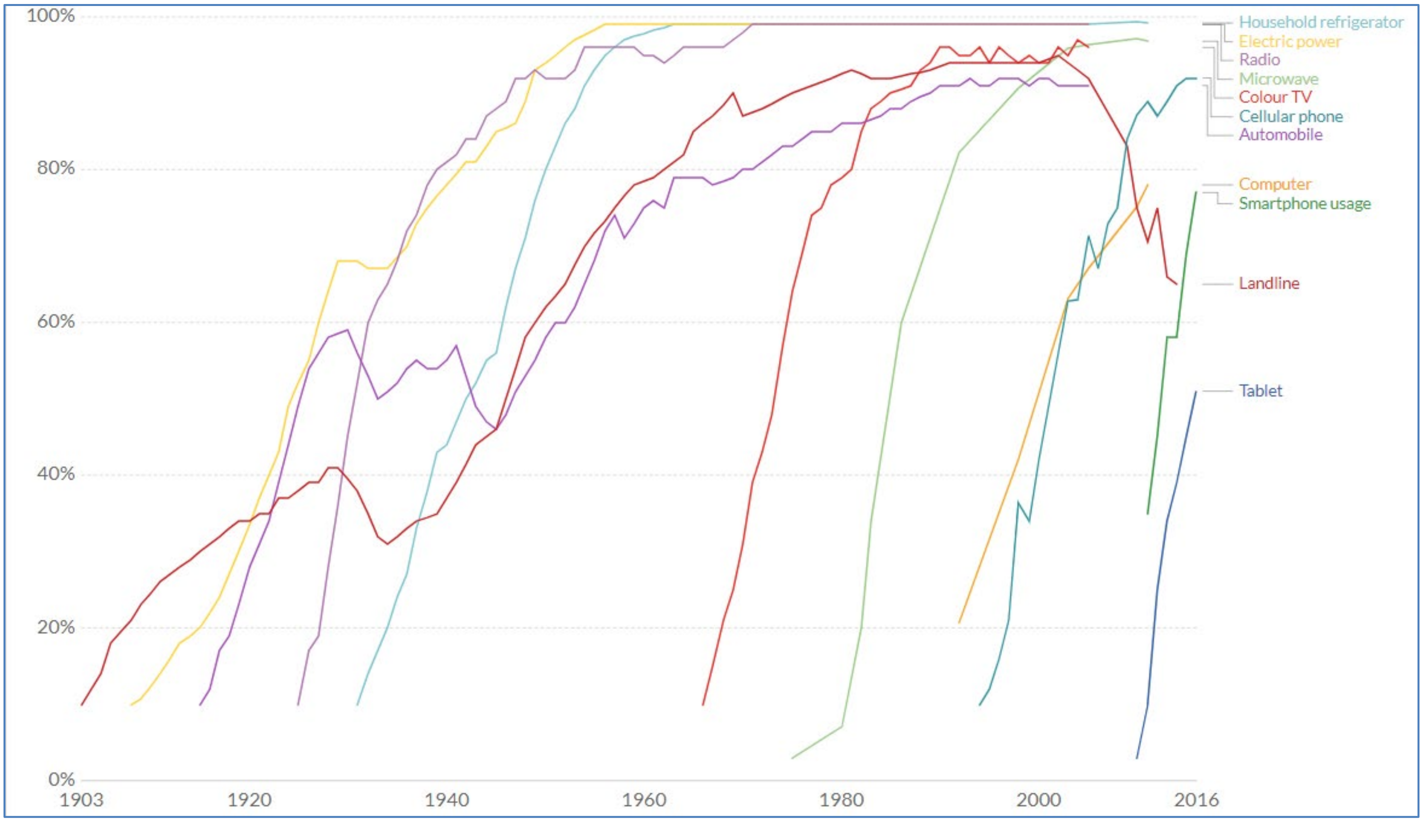

Figure 11. Percentage of US Households Using Particular Technologies[30]

New automotive technologies have undergone s-shaped adoption curves. For example, data from the U.S. Environmental Protection Agency track adoption of a variety of fuel-conserving vehicle powertrain technologies, as shown in Figure 12.

[30] Chart created using: https://ourworldindata.org/technology-adoption.

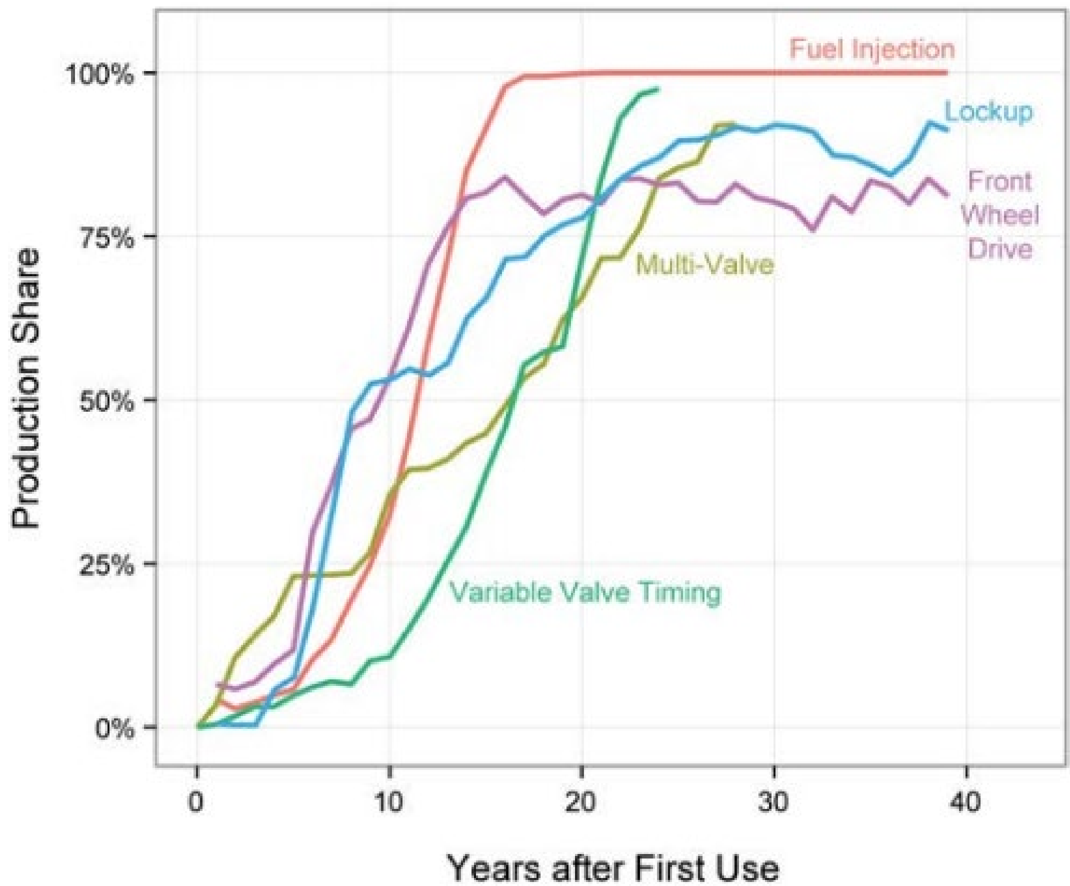

Figure 12. Industry-Wide Automotive Technology Adoption[31]

4.2 Factors Influencing Technology Adoption

Theories explaining specific factors that influence adoption of new technologies have been the focus of research and debate for several decades. From among the eight major models and theories of technology acceptance, this paper summarizes four paradigms that have particular relevance for consumer adoption of automated vehicles.

4.2.1 Innovation Diffusion Theory

In addition to characterizing individuals in terms of their general willingness to adopt new technologies, as described above, innovation diffusion theory also suggests that seven characteristics of a new technology influence the degree to which users will adopt it (albeit at varying rates). All of these factors

[31] Figure 12 source: https://www.epa.gov/sites/production/files/2016-10/documents/2014-01-0781_0.pdf.

have potential applicability to understanding acceptance and adoption of automated vehicles:[32]

- Relative Advantage: The degree to which potential adopters perceive a new or modified technology as being better than its precursor.
- Ease of Use: The degree to which potential adopters perceive a new or modified technology as being difficult to use.
- Image: The degree to which potential adopters perceive a new or modified technology as enhancing their image or social status.
- Visibility: The degree to which potential adopters of a new or modified technology see others using the technology.
- Compatibility: The degree to which potential adopters perceive a new or modified technology as being consistent with their existing values, needs, and past experiences.
- Results Demonstrability: The degree to which the results of using a new or modified technology are tangible, and can be communicated.
- Voluntariness of Use: The degree to which potential adopters perceive a new or modified technology as being voluntary, or of free will.

4.2.2 Technology Acceptance Model (TAM)

Fred Davis introduced the Technology Acceptance Model in 1985.[33] The TAM theorizes that attributes of a given technology (denoted in Figure 12 as X1, X2, etc.) combine to create users' perceptions of the technology's usefulness and ease of use. In turn, perceived usefulness and ease of use together determine the attitude of a potential user toward that technology and, thus, whether the person will actually adopt the technology. The model also argues that perceived ease of use has a causal effect on perceived usefulness. The TAM is illustrated in Figure 13.

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[32] Descriptions of innovation diffusion theory factors are paraphrased from: G. C. Moore and I. Benbasat, "Integrating Diffusion of Innovations and Theory of Reasoned Action Models to Predict Utilization of Information Technology by End-Users," in *Diffusion and Adoption of Information Technology*, ed. K. Kautz and J. Pries-Hege, (London: Chapman and Hall, 1996), 132-146.

[33] F. D. Davis, "A Technology Acceptance Model for Empirically Testing New End-User Information Systems: Theory and Results," (Ph.D. diss., Massachusetts Institute of Technology, Cambridge, 1985).

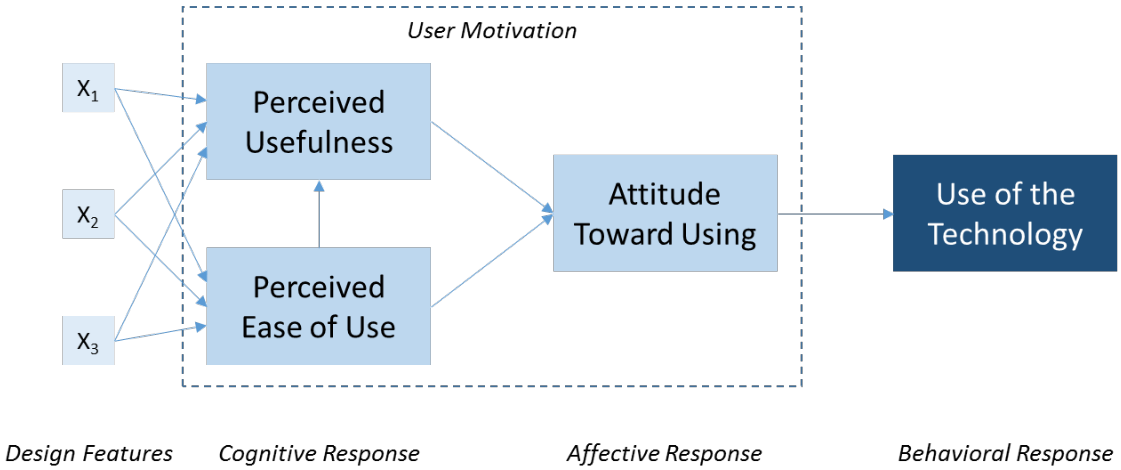

Figure 13. Technology Adoption Model (adapted from Davis, 1985)

Davis originally developed the TAM to explain user acceptance of IT systems; the model has since been modified, extended, and adapted to help understand user acceptance of a wide range of technologies. The TAM has obvious relevance to consumer adoption of automated vehicles, since usefulness and ease of use will be key features of automated vehicles. However, the TAM doesn't include several factors that are likely to influence consumer's adoption of automated vehicles. Other technology acceptance paradigms address these gaps.

4.2.3 Technology Acceptance Framework

While the TAM comprises three core factors, the Technology Acceptance Framework incorporates a range of factors to explain perceptions of new technology, and how those perceptions influence technology acceptance.[34] These factors include the **perceived risks, benefits, and costs** of new technology, all of which are broadly applicable to understanding acceptance and adoption of new technologies generally. In addition, the Framework, and its authors' discussion of it, contain two attributes that are potentially significant for the understanding of automated vehicle acceptance.

- ***Trust.*** The Framework contends that trust in the actors responsible for new technologies influences potential users' perceptions of the technologies' costs, risks, effects, and benefits. This relationship is straightforward in the case of traditional vehicles: consumers' purchase decisions are influenced by their level of trust in the major automotive brands. In the case of automated vehicle purchases, the situation may become more complex, because there may ultimately be a much wider range of consumer-facing entities, including not just the well-known automotive brands, but also newer automotive manufacturers like Tesla, transportation network companies like Uber, and automated driving technology development companies like Waymo (and many others).[35] Furthermore, if automated vehicles enable driverless ride-hailing services (as most industry analysts predict they will, and as Uber is already working to develop),

[34] N. M. A. Huijts, E. J. E. Molin, and L. Steg, "Psychological factors influencing sustainable energy technology acceptance: A review-based comprehensive framework," *Renewable and Sustainable Energy Reviews* 16, no. 1(2012): 525-531.

[35] Brand names are used as illustrative examples, and do not constitute endorsement by the USDOT.

consumers' level of trust of the companies behind such services (in addition to consumers' level of trust of the vehicles themselves) may influence their use of such services.

- ***Citizen vs. Consumer Acceptance.*** The Framework's authors distinguish between two forms of technology acceptance: *citizen acceptance*, which refers to the public's reaction to the placement of a new technology in their environment, and *consumer acceptance*, which refers to the public's purchase and use of the technology. This distinction is relevant to automated vehicles: even travelers who never use such vehicles could have strong feelings about sharing the roads with them, and it seems reasonable to assume that for automated vehicles *citizen acceptance* will be highly correlated with *consumer acceptance.*

4.2.4 Unified Theory of Acceptance and Use of Technology (UTAUT)

Developed in 2003, the Unified Theory of Acceptance and Use of Technology (UTAUT) unifies the eight major technology acceptance models by creating composite factors that combine elements of the other models.[36] Like the other technology adoption models, the UTAUT was originally developed to explain IT technology adoption, and this is reflected in some of the factor definitions. Nevertheless, the factors appear to be applicable to other technologies, including automated vehicles.

The UTAUT's authors posit that four composite factors are key determinants of user intention and, ultimately, adoption/use of technology, as described below:[37]

- Performance Expectancy. The degree to which an individual believes that using a system will help him or her obtain gains in job performance. For automated vehicle adoption, performance expectancy might be defined as the user's ability to accomplish various tasks—some work related, others not—and meet various needs, including while traveling.
- Effort Expectancy. The ease of use of a new or modified technology. Effort Expectancy has clear applicability for automated vehicle adoption, since one of the key benefits of automated vehicles will be ease of use, particularly for people who are not able to drive conventional vehicles.
- Social Influence. The degree to which an individual perceives that other people believe he or she should use the technology. Social Influence could have applicability to automated vehicle adoption from a number of perspectives, including the status associated with using automated vehicles (especially during the early years of market introduction), and the degree to which both private-sector and public-sector entities advocate for automated vehicle use.
- Facilitating Conditions. The degree to which an individual believes that an organizational and technical infrastructure exists to support use of the technology. Public perceptions of the adequacy of automated vehicle testing and safety certification (whether conducted by the government or vehicle manufacturers) could be among the facilitating conditions influencing acceptance of automated vehicles.

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[36] V. Venkatesh, M. G. Morris, G. B. Davis, and F. D. Davis, "User acceptance of information technology: toward a unified view," *MIS Quarterly* 27, no. 3 (2003): 425-478.
[37] Descriptions of factors and moderators are paraphrased from ibid.

The UTAUT model also includes four moderator variables that the UTAUT's authors theorize influence the effects of the main factors in certain circumstances. The moderators are beyond the scope of this paper, and are therefore not included. Nevertheless, some of the moderators—notably, gender and age—are factors for which studies of automated vehicle adoption need to control. Figure 14 illustrates the main components of the UTAUT.

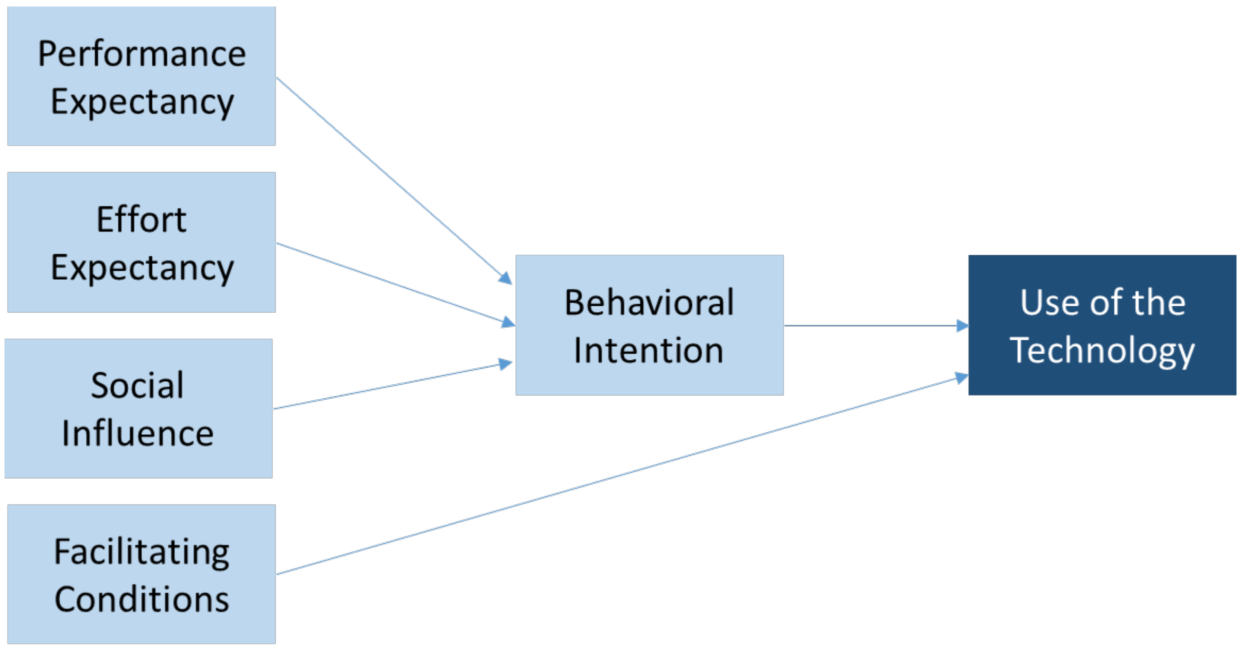

Figure 14. Unified Theory of Acceptance and Technology Use (adapted from Venkatesh, et al, 2003)

4.3 Application of Technology Adoption Models to Automated Vehicles

As discussed previously, most early technology adoption models addressed IT systems. Within the last four years, researchers have begun applying technology adoption models to automated vehicles. These studies have generally adapted existing models and have used empirical research (e.g., consumer surveys, interviews, and focus groups) to validate the efficacy of the factors in the models. Not surprisingly, these studies have identified additional factors that appear to influence consumer acceptance of automated vehicles. Despite this moderate success, there is essentially unanimous agreement among researchers that they have not yet identified all relevant variables. This is an emerging field: ongoing research will undoubtedly reveal additional factors that are important determinants of consumer acceptance of automated vehicles.

For the most part, Table 4 summarizes studies to date that have identified "new" factors not included in earlier technology-acceptance models, and includes the authors' recommendations for future research.[38] With one notable exception, Table 4 does not present all the factors included in studies of automated vehicle acceptance; it focuses on those factors that are significantly different from the factors already included in older, IT-related consumer acceptance models. The exception to this is the inclusion of “trust” as a factor in most of the newer models. Trust is a component of the Technology Acceptance Framework (discussed in Section 4.2.3), but because consumers’ level of trust in automated driving systems appears to be such an important determinant of their overall attitudes toward the technologies, Table 4 includes “trust.” Some new studies have productively applied other factors besides trust previously included in technology-adoption models to understand adoption of automated vehicles; those studies are not included in Table 4, but are cited in this paper’s bibliography.

The study results summarized in Table 4 illustrate an inherent tension between the perceived safety benefits of automated vehicles, and consumers’ trust in automated technologies. Six of the seven studies identified factors related to perceptions of “trust” in automated vehicle technologies, and four identified factors related to perceived enhanced safety; three of the studies identified both “trust” and “enhanced safety” as factors. Because automated vehicles are not yet commonplace, study participants’ are basing their responses largely on speculative considerations, rather than on actual experience using automated vehicles. Furthermore, automated vehicle technology is complex, and study participants almost certainly do not fully understand it. In this context, it is not surprising that survey respondents do not universally trust automated vehicle technologies.

One study identified participants’ prior experiences with motor vehicle crashes as a factor influencing acceptance of automated vehicles. This indicates that the concept of a “safer” car may have meaning for consumers only in comparison with their experiences of conventional cars (i.e., safer than what?). Drivers who have been in crashes may be receptive to new technologies that offer enhanced safety, whereas drivers who have never been in crashes may have a different “baseline” for comparison. This concept of consumers evaluating the potential benefits of automated vehicles in comparison with conventional cars may apply to benefits other than safety, such as the ability to engage in activities other than driving while traveling. Although prior experiences with crashes are, thankfully, relatively rare, the vast majority of drivers have had the experience of being stuck in traffic, or having been on a long, tedious trip. Therefore, consumers may be more cognizant of and receptive to the potential “convenience” benefits of automated vehicles than the potential safety benefits.

Three of the five studies identified enjoyment of driving (or driving-related sensation seeking) as a factor that influences consumers’ acceptance of automated vehicles. This could prove to be significant, since for many people driving is an enjoyable experience that they may not want to relinquish in order to use an automated vehicle. On the other hand, as automated vehicles become more common, for many consumers the pleasure of not having to drive may eventually outweigh the pleasure of driving.

[38] Research on consumer acceptance of automated vehicles is a rapidly evolving field. The studies summarized herein represent the authors’ best attempt to provide an up-to-date literature review, but it is likely that there are studies we have missed.

Table 4. Overview of Automated Vehicle Acceptance Research (adapted from Kaan, 2017)[39]

Author	Key Factors	Future Research Recommendations
Nees (2016)	• Perceived utility (including enhanced safety) • Cost • Enjoyment of driving • Exposure to articles about automated vehicles • Perceived appropriateness of automation • Trust in/perceived reliability of automated vehicle technology	Additional research to understand the roles of age and driving experience, and the impact of idealized portrayals of automated vehicles.
Choi and Ji (2015)	• System transparency (ease of understanding) • Potential automated vehicle user's technical competence • Driving-related sensation seeking • Perceived ability to take control of automated vehicle if needed • Perceived risk of automated vehicle technology • Trust in automated vehicle technologies • Perceived external causes of accidents (i.e., accidents are largely due to unexpected events, and avoiding them is mostly a matter of luck)	Include personality characteristics of potential automated vehicle users.
Bjørner (2015)	• Driving pleasure • Culture • Personal traits • Setting/task • Trust in automated vehicle technologies • Perceived ability to take control of automated vehicle if needed	With regard to driving pleasure, the "flow" model (Mihaly Csikszentmihalyi, 1991) may be useful to consider. "Flow" describes the happiness people derive from being in a highly-focused mental state. Various cultural and situational variables influence "trust"—these may be fruitful areas to study.

[39] J. Kaan, "User Acceptance of Autonomous Vehicles: Factors and Implications" (Master of Science Thesis, Faculty of Technology, Policy and Management, Delft University of Technology, 2017).

Author	Key Factors	Future Research Recommendations
Payre et al. (2014)	• Perceived enhanced safety • Intention to buy vs. intention to use • Willingness-to-pay • Interest in impaired driving • Driving-related sensation seeking • Trust in automated vehicle technologies	Potential automated vehicle users' interest in technology should be taken into account.
Noblet et al. (2018)	• Familiarity with self-driving technology • Perceived safety of automated vehicle technology • Demographics	Include information on the structural constraints potential automated vehicle users face when making travel choices.
Nordhoff et al. (2016)	• Past crash experiences (perceived enhanced safety of automated vehicle) • Socio-demographic characteristics • Desired activities while travelling • Vehicle characteristics (includes level of automation) • Context (including country, mixed vs. segregated traffic, freeway vs. urban vs. rural use, use while impaired) • User mood and emotions • Equity (distribution of costs and benefits) • Willingness-to-pay • Trust in automated vehicle technologies	Include the expectations and views of stakeholders other than the drivers, who are involved in using, operating, or deciding on the implementation of driverless vehicles.
Panagiotopoulos and Dimitrakopoulos (2018)	• Trust in automated vehicle technologies	Target larger, more diverse samples of respondents.
Hewitt et al. (2019)	• Attitude • Self-efficiency • Anxiety • Perceived safety of automated vehicle technology	Highlight users' expected utility and clarify public expectations about the technology.

5. Conclusions and Implications for Future Research

The surveys, methodological critiques, and theoretical literature reviewed suggest several implications for future research and action related to measuring consumer perceptions of automated vehicles and, if desirable, building trust and positive sentiment toward them.

5.1 Automated Vehicle Descriptions

As automated vehicle technology advances, there is an opportunity for consumer acceptance research to move from testing reactions based on limited automated vehicle descriptions, to assessing more detailed automated vehicle concepts and usage scenarios. While it is not currently feasible to measure a large national sample of consumers who have taken a test ride or experienced an automated vehicle simulator, detailed automated vehicle concepts can be developed. Concepts that include technical details, user experience elements (e.g., seating, visibility), automated vehicle benefits, usage scenarios, and environmental elements (e.g., regulation) can improve the accuracy of consumer acceptance measures.

Moreover, any descriptions of automated vehicles in survey instruments should be presented as neutrally as possible and realistically relative to likely deployment characteristics. For example, descriptions that point to an absence of manual vehicle controls may unintentionally elicit biased responses and may also be misleading; even automated vehicles capable of automated driving on all roads and in all conditions could conceivably still be offered with manual controls, particularly if sold to individuals (as opposed to operating as part of a shared fleet). Future studies can consider reporting their quality control steps, which are used to ensure that the attitude object is clearly and neutrally defined for respondents.

5.2 Question Structure and Content

Future research should use scaled intent-to-use questions to provide a more detailed understanding of consumer consideration of automated vehicles. This will give researchers the ability to profile high-potential (and low potential) consumers to understand demographic or behavioral factors that may influence automated vehicle acceptance. Scales also provide more opportunity to see changes in intent-to-use as automated vehicle technology and legislation/regulation advance.

Future studies should also consider expanding potential explanatory variables by including more questions on demographics, attitudes (e.g. attitude to risk, attitudes to new technologies, social influences, etc.), and driving related behaviors. Previous studies on models of user acceptance of automated vehicles suggest that factors, such as performance expectancy, effort expectancy, and social influence, all play an important role in influencing users' intention to use automated road transport systems.[40] However, few surveys reviewed in this study have questions that cover all these key attributes of users. Having additional information on factors such as income, family composition, driving/commuting behaviors, driving enjoyment, and tech savviness could provide additional information to help researchers understand what drives consumer perceptions of automated vehicles and consider consumer education strategies accordingly. There are existing studies summarizing the survey results of consumers' attitudes towards automated vehicles in other countries. Tennant et al. (2019) reviewed 58 surveys reported in English language journals and newspapers covering the period from 2014 to January 2018. The 58 reported surveys were conducted in different regions/countries around the world (e.g. France, United States, Germany, United Kingdom, etc.).[41] Becker and Axhausen (2017) reported 16 studies on the acceptance of automated vehicles conducted in various locations between 2013 and 2015.[42] These studies provide a good start for researchers and policy makers to consider cross-regional comparison.

5.3 Linking Surveys to Actual Deployments

Even careful survey design may not be able to overcome the limitations of surveying individuals about a novel technology that they have yet to try. Results of the few published surveys of participants in automated vehicle demonstration projects have revealed a seemingly higher level of enthusiasm for the technology than have national surveys of a sample population that likely has limited direct exposure. Therefore, future deployments of automated vehicles should continue surveying users. Surveys that can establish a baseline measurement of participant perceptions of automated vehicles could be even more valuable, particularly if that baseline can include a control group that does not participate in the demonstration. Such a survey could help understand the extent to which direct experience with automated vehicles influences consumers' views. An important caveat is that the participants in automated vehicle demonstrations have self-selected: they are interested in automated vehicles and can reasonably be expected to be early adopters of technology.

5.4 Learning from Technology Adoption Models

Assessments of consumer perceptions of automated vehicles can draw numerous insights from existing literature on consumer technology adoption models. In particular, there may be value in focusing surveys on factors that are likely to influence consumers' general perceptions of automated vehicles,

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[40] Ruth Madigan, Tyron Louw, Marc Wilbrink, Anna Schieben, and Natasha Merat, "What influences the decision to use automated public transport? Using UTAUT to understand public acceptance of automated road transport systems," *Transportation Research Part F: Traffic Psychology and Behaviour* 50 (2017): 55-64, https://doi.org/10.1016/j.trf.2017.07.007.

[41] Tennant et al. (2019).

[42] F. Becker and Kay W. Axhausen, "Literature Review on Surveys Investigating the Acceptance of Automated Vehicles," *Transportation* 44, no. 6 (2017): 1293-1306.

including perceptions of utility, ease of use, safety, risk, trust, as well as enjoyment of driving conventional vehicles.

Moreover, because automated vehicles are still such a new technology, existing frameworks and theories about technology adoption (most of which were developed to understand IT technologies in work environments) almost certainly do not adequately address all important factors. Recent attempts to modify existing technology adoption frameworks to automated vehicles have yielded some important insights about factors that influence consumer acceptance of automated vehicles specifically, but more research is needed to develop robust paradigms and models.

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