Certification as a Means of Increasing the Adoption Intention of Autonomous Vehicles

[Working Paper]

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Abstract

Autonomous vehicles (AVs) are about to revolutionize the transportation industry. However, consumers' low trust in this technology seriously impedes adoption. Based on qualitative interviews with German participants, this article explores the idea that the certification of AVs increases consumers' trust in and willingness to adopt AVs. The results show that consumers are skeptical of and lack knowledge about this new mode of transportation. Nevertheless, study participants are generally inclined to use AVs in the future and are even more willing to do so if such cars have been certified by a trustworthy authority. While hardware and software certification are seen as mandatory, respondents lacked knowledge about data certification and AV data privacy issues.

Keywords: autonomous vehicles, signaling, certification, trust, adoption intention

Introduction

In the next few years, the automotive industry will change fundamentally, largely due to the introduction of autonomous vehicles (AVs) [1]. In general, autonomy describes "the ability of a system to make its own decisions and to act on its own, and to do both without direct human intervention" [2, p. 277]. This definition implies that cars will increasingly develop from a mechanical to a highly technological product [3]. Yet, not only will cars change, but the AV market introduction will also hugely impact society [4]. This development will create numerous opportunities, but also involves several obstacles. One major problem is that consumers do not sufficiently trust AV technology [5]. They are skeptical about AVs as they have to rely on a for them potentially harmful technology they cannot control [6]. Other concerns with regard to AVs include data privacy [6] or accident-related physical harm [7]. Moreover, as research shows, consumers are hesitant to adopt AVs [8]. Thus, one open question is how best to enhance consumers' trust in AVs and their intention to adopt this technology. Various measures have been suggested to achieve this objective, including the promotion of AVs by opinion leaders [9] and providing the public with detailed information about those cars [10], [11]. Moreover, some researchers have recommended giving consumers the opportunity to interact with AVs to accustom them to this technology and thereby to develop more positive attitudes toward it [12].

A rather new approach—and the one suggested and evaluated here—is to certify AV hardware, software, and data. What follows focuses on Germany, where the testing, inspection, and certification market has a long history, ever since the foundation of the TÜV (Technischer Überwachungsverein [Technical Inspection Association]) in 1866 [13]. At approximately the same time, the first certification initiatives also emerged in the United States, for example, the Underwriters Electrical Bureau, which has been responsible for testing the safety of products since 1894 [14]. However, while several studies have examined

the certification of autonomous technology in information systems research [e.g., 15], the influence of AV certification on consumers' decision-making is largely underresearched. This article seeks to close this gap by exploring whether AV certification might feasibly increase trust in this technology and promote its adoption. It also analyzes under which conditions consumers might consider certification successful and discusses their general attitude toward AVs. To answer these questions, extensive qualitative interviews with German consumers were conducted. After an introduction of the theoretical background, the results of the interviews are presented and discussed, and implications for theory and practice are provided.

Theoretical background

Certification of digital technologies

The effectiveness of certification and its influence on consumers have been studied for decades [e.g., 16]. By definition, "certification is the (voluntary) assessment and approval by a (accredited) party on a (accredited) standard" [17, p. 172]. Research has found that certification as a quality signaling method works because the "quality of a product is fully revealed to consumers by a certifying expert, whose verdict is assumed to be beyond doubt" [18, p. 187]. In recent years, various factors have been found to influence the success of certification seals. Examples include trust in the certification authority [19], in the certification scheme [17] and in the seal itself [20]. Further important aspects are the reputation [21], credibility, independence [22], and dependability [23] of the certifying entity, as well as assessment quality [21], strictness [24] and objectivity [25]. In general, various parties may act as the certification authority, such as governments, companies [26], or third-party authorities [27].

Previous certification research has examined highly diverse topics, for example, e-commerce [e.g., 28], food and nutrition [e.g., 29], cloud solutions [e.g., 30], and autonomous systems [e.g., 31]. Certification has been found to positively influence various factors, such as brand image [32], [33], perceived product quality [34], [35], and customer satisfaction [28]. Other studies have shown the influence of certification on purchasing willingness. Although largely considered positive [36]–[39], there are also contradictory results [40]. Regarding trust, a key factor in AV adoption [see below, e.g., 41, 42], numerous scholars have reported a positive influence of certification on trust [43]–[47], on trusting intentions [48], and on perceived trustworthiness [49], [50]. Other researchers, in contrast, have found no evidence for a positive effect of certification on trust [40], [51]–[53] or on trusting beliefs [54].

Current research on the certification of autonomous products comes mainly from the area of information systems, such as automated transport systems [e.g., 55], advanced driver assistance systems [e.g., 15], or platoons [e.g., 56]. This focus, however, means that the consumer perspective on the need to certify autonomous products and, more specifically, AVs is largely missing. The research presented here marks a first step toward addressing this gap. In general, the aim of AV certification is to reassure car manufacturers and to keep consumers safe [15]. Koopman and Wagner [57] describe ensuring the safety of AVs as a multi-faceted challenge, because a certification strategy for AVs must address various issues at once, such as hardware reliability, human-machine interaction, software verification, and legal concerns.

Trust in autonomous vehicles

Prior research has shown that trust is central to deciding whether or not to adopt new technological products [57], [58]. For instance, Tay et al. [59, p. 77] concluded that “trust is pivotal in helping users overcome the perception of risk and uncertainty before the use of a

new technology." Several factors influencing trust in AVs have been studied to date. These variables include AV experience [60], [61], automation failures [62], take-over requests [63], anthropomorphization [64], [65], cultural aspects [66], as well as system transparency and technical competence [42]. Along these lines, trust has been found to influence AV adoption decisions [6], [9], [41], [42], [61], [67], [68]. Apart from trust, other factors affecting AV adoption decisions are perceived usefulness [41], perceived ease of use [9], [67], perceived safety [61], social influence [9], psychological ownership, and self-efficacy [69]. Yet others include the locus of control [42], ethical dilemmas [70], feelings of anxiety [71], conscientiousness, emotional stability, openness to experience [10], and socio-demographic variables [8], [72].

Another factor that is linked to trust in AVs is data privacy [73]. This is because AVs are able to collect and analyze a huge amount of data and to work together in real-time with several entities [74]. Thus, with the introduction of AVs, consumers will most likely no longer be able to move anonymously, as AV data enable manufacturers and other entities to track drivers and to see at which locations they have been [75]. Nevertheless, while potentially disadvantageous to consumers, this information might prove very useful and economically beneficial for companies as it provides valuable insights, e.g., for demand planning or advertising [75].

Methodology

Even though research on AVs has significantly increased in recent years, many questions still remain underexplored. Additionally, while its need has been established on a general level, AV certification is yet to be investigated in-depth, especially its effect on consumer behavior. Hence, this study uses exploratory qualitative interviews to provide insight into how AV

certification impacts consumer trust and adoption intention. It also seeks to better understand consumers' attitudes toward AVs and toward certification in general as well as certification success factors.

Thirteen semi-structured qualitative interviews with German consumers were conducted in autumn 2018. Although the number of interviewees is not very high, previous research has shown that while overarching themes can be defined as early as after six interviews, "saturation occurred within the first twelve interviews" [76, p. 59]. Arsel [77], highlighting the importance of interviews in consumer research, observed that "the interactive, flexible but focused nature of interviews still makes them one of the most trustworthy and effective sources of data about consumers" [77, p. 939]. Semi-structured interviews were selected as a means of data collection as they enable pursuing a line of thought through predefined topics and questions, but at the same time allow for the flexibility of delving deeper into areas of interest [77].

Participants were randomly selected from the panel of a market research agency with the goal of being representative of the German population in terms of age and gender. Interviewees had to fulfill various participation criteria: They had to have a valid driver's license, be over 18 years old, and have undergone a technical vehicle inspection in the past. Regular car inspections are mandatory under German law [78]. The gender split of participants was fairly equal, with six (of thirteen) interviewees being female and ages ranging between 25 and 63 years. Interviews were conducted by telephone and lasted between 20 and 45 minutes. All conversations were tape-recorded with the consent of participants and selectively transcribed and categorized. Participants were told to assume that the car in question was a fully AV. For the purpose of the study, fully autonomous driving was defined as "the full time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*" [79, p. 2].

Prior to the interview, participants were briefly introduced to the interviewer and to the procedure and aim of the study. Then, if existent, the respondents' open questions were answered. Both steps are in line with Arsel's [77] recommendations on conducting qualitative research. The interviews approached the research questions from a general angle, starting with trust in technology. The focus was subsequently narrowed to trust in AVs, participants' attitude toward certification, the issue of consumers' opinion of and attitude toward AVs, and their need for AV certification. Questions, for example, included "What would help you to gain trust in AVs?" and "What would you think if AVs were certified?" (see Figure 1 for the key topics of the interview guideline).

[Insert Figure 1 about here]

Results

With a few exceptions, the majority of interviewees stated that technology plays an important role in their lives. Even though some feared that the use of technology might get out of hand in the future, they were mostly open to innovative technical products. However, some products were described as unnecessary, for instance, if their benefit was not directly visible. When asked what was important about technical products, participants listed the following aspects: usefulness and reduced physical and/or cognitive workload, easy handling, time-saving, and reliability. However, participants also voiced several concerns about innovative technological products: data privacy, feeling controlled, over-reliance, and dependency.

Regarding AVs, this study found that while participants' knowledge about autonomous driving varies considerably, it is generally rather low. This is mainly due to the fact that

interviewees perceived AVs as a too distant reality—they estimated that fully AVs would not be on the streets for the next 10 to 15 years. Participants were of the opinion that AVs will lead to more efficient driving, combined with time-saving, fewer accidents, and less congestion. They described AVs as especially useful for elderly and mobility-impaired persons. However, respondents struggled with the idea of completely handing over control to an AV and no longer being able to make their own decisions, a finding in line with Hegner et al. [41]. Participants stated that they would rather trust human drivers than AVs as this technology is potentially harmful. Thus, current trust levels in AVs are rather low. Further concerns included ethical issues, AV decision-making in safety-critical situations, and AV accountability in the event of an accident. Other major points of criticism concerned cybersecurity, the threat of hacking and data privacy.

Even though most respondents were generally open to autonomous driving, they were at the same time also skeptical. They feared that the technology was not yet fully developed and will not function properly when introduced to the market, being a severe danger to health and life. Participants were not eager to try fully AVs as early adopters but rather planned to use such cars once reassured that they functioned properly and safely. When asked to indicate which measures would increase their trust in AVs, respondents mentioned test drives, media campaigns and advertising, the publication of statistical data and information from car testing series, as well as AV inspections by independent organizations. They also stated that they would be more inclined to adopt AVs after some car-sharing experience and using other autonomous means of transport (e.g., autonomous public buses).

Concerning certification in general, participants had diverging opinions: While some observed that certification influenced their product evaluation and purchasing decisions, others were more skeptical. These doubts stemmed mainly from past scandals, especially in the food and nutrition sector, leading respondents to doubt the quality of certification seals. This result is

linked to the finding that participants use certification seals to evaluate more expensive products (e.g., technological devices) rather than fast-moving consumer goods. Although respondents regarded certification as a quality indicator, they also stated that this does not provide one hundred percent certainty about the quality of a product, but at least indicates that a product has been checked by an additional entity. Analyzing the interview data also revealed factors considered important for the trustworthiness of a certification seal: It ought to be reputed and approved by the government (but does not need to be issued by it). Moreover, participants identified crucial factors for the success of certification companies: independence, not being driven by financial interests, and adherence to strict certification criteria. These results are in line with findings in the literature [22], [24]. Furthermore, participants mostly did not trust unknown seals—and if they did, then to a considerably lower degree than well-known ones.

Regarding AVs, interviewees highlighted that certification is crucial and ought to be mandatory. The majority of participants agreed that certification would increase their trust in AVs or at least indicate its trustworthiness. As with the general certification quality criteria, respondents stressed the importance of AVs being certified by a trustworthy, well-known institution. An unknown company would have no consumer trust, at least initially. Additionally, participants reported that they would always prefer using a certified AV compared to an uncertified one. More specifically, the need for certification was discussed for several elements of AVs: hardware and software, as well as the data generated, exchanged, and used when driving an AV. Regarding vehicle hardware (e.g., brakes, lights), respondents stated that AVs should be certified analogously to the certification standards and cycles currently being used in Germany (i.e., every two years on average). The software used in AVs, in contrast, should be checked and certified more regularly than the hardware, at least prior to installation or updating. While participants unanimously agreed that AV hardware

could be certified by the same companies as today, they expressed concerns about whether such entities could also execute software certifications due to a lack of skills and possible staff shortages. Interviewees deemed existing certification companies suitable to perform software certification only if they significantly extended their IT knowledge and increased the number of skilled employees in this area of certification. However, new software certification companies were also viewed skeptically because of a lack of consumer trust in their expertise. This finding ties in with study participants repeatedly highlighting the importance of certification providers needing to be trusted actors in the certification market from the outset.

Regarding the certification of AV data, it became clear that most respondents were not aware of the practice of and the need for data collection and exchange when using AVs. Only after the interviewer explained this aspect did participants realize the critical nature of this topic in terms of data privacy and security, among others. Regarding data privacy, respondents' opinions oscillated between two extremes. While some pointed out the high standards and importance of data protection in Germany, others stated that they did not mind AVs collecting personal data, as they already felt monitored by data-driven devices (e.g., by their smartphones). In general, all participants considered data certification necessary, at least for reasons of data security.

Optimally, according to respondents, no personal data should be collected. If, however, data collection was necessary, data should be anonymized when used. Moreover, the information collected should be regularly deleted. Furthermore, data usage should be restricted to certain entities and certain purposes. These include, for example, technical improvements or emergencies, yet not advertising or similar activities. Some participants also doubted whether it is technically possible to conduct data certification due to the enormous amounts of data generated and exchanged by AVs and the limited storage capacity of servers. Another point raised by respondents concerned the fact that manufacturers might be reluctant to share AV

data with certification companies, especially when problems with an AV occurred. Moreover, participants wished that if data certification was necessary, then the data of German AV consumers should be stored on servers located in Germany rather than elsewhere.

Regarding the frequency of data certification, interviewees stated that data certification should take place in regular intervals. Nevertheless, responses about suitable time periods varied, as they did about who should certify AV data. Various possible entities for data certification were proposed, including a government agency, the respective car manufacturer, a new third-party institution, or a collaboration between the government and another entity (e.g., the manufacturer or a company specializing in and experienced with data handling, storage, and collection). Regarding AV data certification, interviewees also expressed concerns about data being distributed to further entities and the lacking knowledge of certification authorities for properly performing this task. Finally, participants feared that certification companies might follow self-serving motives, ones benefitting only their business interests, yet not protecting consumers and their data privacy.

Discussion

The results show that participants are aware of the emerging AV technology, but do not entirely grasp its future societal and economics implications. Although the interviewees in this study were generally open to new technologies and innovation, their little knowledge about and trust in AV technology indicate that further education and trust creation measures are needed for AVs to be introduced successfully in the future. However, what exactly is the best approach needs to be thoroughly evaluated. In this regard, certification seems to be a viable measure to increase trust in AVs. Importantly, the certification seal, certification process, and certifying authority must meet certain quality requirements. These include, for example, a

reputable and trusted certification authority with a proven track record of performing certification in certain industries and conducting a trustworthy and secure certification process.

Measures also need to be tailored to purpose, that is, whether it is a matter of certifying software, hardware, or data. Especially regarding data certification, respondents' opinions varied widely. Further, the low level of knowledge about data certification among respondents suggests that introducing educational measures would certainly benefit consumers. Moreover, study participants were partially ignorant about possible data privacy issues and the traceability of their lives via AV data collection. However, this might also be due to respondents being, at least to some degree, weary of these subjects and already feeling "see-through" and monitored. This is because, in their opinion, smartphones and other smart products are already gathering personal information and thus, AV data collection does not greatly impact their lives or bring about much change.

This study concludes that AV certification might be a feasible way of increasing trust in AVs as well as adoption intentions. And yet, the analysis also shows that this might not be a feasible way by all means. For although participants stated that they would rather use certified than uncertified vehicles, this does not mean that they strongly trust this technology, but that they merely consider certification as the better of two alternatives. Thus, apart from certification, other ways of increasing consumers' trust in AVs as well as their adoption intentions should be explored. In this regard, this study has probed consumer opinions about what would be possible measures for increasing respondents' trust and willingness to adopt AVs. Mostly, these suggestions were practical (e.g., displaying information about staff AV certification training in car repair workshops) and did not concern laws or other official regulations. Yet, these are central to AV safety, as AVs need be certified against government standards [15].

Conclusion

This paper has examined a new way of increasing consumers' trust in AVs as well as their intention to adopt this type of car: AV hardware, software, and data certification. To this end, qualitative semi-structured interviews with German participants were conducted. Overall, respondents were found to have a rather low knowledge of autonomous cars and were somewhat skeptical about this new form of mobility. In general, interviewees felt that certification would likely improve their trust in AVs. They also stated that they would be more inclined to use a certified AV compared to an uncertified one, as they had a higher trust in it. Importantly, moreover, software, hardware, and data all need to be certified by a suitable entity. However, who this certification authority should be is highly controversial: While hardware can be continued to be certified by entities already performing this task, study participants did not concur on who should conduct software and data certification. They did, however, agree that the certification authority should be trustworthy and have substantial knowledge in the respective area of work. Overall, despite several questions still needing to be resolved, AV certification seems a viable measure for increasing consumer trust in and adoption intention of this technology.

This research contributes to the literature on certification, trust in AVs, and the adoption mechanisms of autonomous products. While research on the certification of autonomous systems and AVs has increased significantly in recent years, such studies have mainly been conducted in the field of information systems. Insights into consumer behavior are largely missing. As such, this research marks as a first step toward evaluating consumer perceptions of the certification of autonomous products. Besides extending theoretical knowledge, this study has several implications for various industry sectors. First and foremost, AV manufacturers might take into account the use of AV certification to foster AV adoption, possibly in combination with other measures aimed at increasing consumer trust in such cars.

Companies in the certification, testing, and inspection industry will have to remain alert and flexible to changes in the market to stay successful. While established market participants will need to carefully examine their positioning and consider extending or repositioning their business activities, new certification companies (e.g., car manufacturers) might consider entering the certification, testing, and inspection industry. New market entrants, however, will only succeed if they can create enough consumer trust in their skills, processes, and certification seals. Companies seeking to have their AVs certified will need to carefully choose a certification firm that is perceived as suitable and trustworthy by consumers. On the regulatory side, governments, along with the responsible institutions, will need to define rules and standards for AV certification, or at least adapt existing ones to this new technology, in order to foster the market introduction and commercial success of this innovative means of transport.

Despite providing initial evidence on AV certification, the results of this study are restricted in some respects and more research in this direction is needed. Limitations include the regional focus (on Germany) and lacking participant segmentation based on socio-demographic variables such as age and gender. Furthermore, while the purpose of the study was to explore the feasibility of AV certification on a general level, some topics (e.g., the need for data certification and data privacy) should be analyzed in more depth to gain more detailed insights. As consumers will likely acquire more AV-related knowledge in the future, the topics discussed here could become central as regards consumers' attitudes towards and adoption of AVs. If, for example, concerns about data privacy and related issues are not handled appropriately in the future, this might develop into an additional barrier toward AV adoption and might even create stronger trust issues than currently existing ones.

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Figure 1: Summarized interview guideline based on subject areas

Figures

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