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To Drive or not to Drive - A Critical Review regarding the Acceptance of Autonomous Vehicles

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To Drive or not to Drive - A Critical Review regarding the Acceptance of Autonomous Vehicles

Completed Research Paper

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Abstract

With the advent of autonomous vehicles (AVs), research has put much effort in investigating the factors relevant for the acceptance of this new technology. In order to identify, critically assess, and combine extant findings, we performed a structured literature review regarding the acceptance of self-driving vehicles. Results of this review spanning 58 articles include (1) a comprehensive AV acceptance framework outlining significant factors across three areas: individual characteristics, vehicle characteristics and policy/society. We also (2) analyze the operationalization of relevant constructs and items in the identified studies as they strongly diverge in extant literature. This new level of detail helps researchers and practitioners to pervade and compare the AV acceptance research in-depth. Additionally, we contribute to the AV research stream as we (3) identify possible future research avenues, which we examine regarding content, method, and focus.

Keywords: autonomous vehicles, acceptance framework, construct identity fallacy, literature review

Introduction

Traditional automotive manufacturers as well as technology companies make big bets by investing large amounts in the development of self-driving cars or autonomous vehicles (AV). For example, the US car manufacturer GM has set an annual budget of $4.35 billion (Welch and Behrmann 2018) and the German automotive supplier Bosch plans to spend $4.6 billion by 2021 (Buchenau 2019) to boost the development of connected and autonomous vehicles. These bets are influenced by market projections as those of Rahul et al. (2018) who estimate a global autonomous vehicle market of $557 billion by 2026.

On a broader level, society expects to drastically reduce traffic deaths as 94 percent of today's crashes are due to human error (NHTSA 2018). Furthermore, expansive AV adoption concerns politics: Emission and congestion reductions might help to achieve the goals defined in the Paris climate agreements (Greenblatt and Saxena 2015). However, wide-spread AV adoption also entails policies considering questions regarding liabilities, ethics, or licensing requirements which need to be put in place in the near future (Fagnant and Kockelman 2015). Experts predict that "once technological and regulatory issues have been resolved, up to 15% of new cars sold in 2030 could be fully autonomous" (Mohr et al. 2016, p. 11).

However, there is no market without demand. So, (when) are individuals actually willing to use self-driving cars and adopt autonomous vehicles? By knowing the factors that influence usage and buying intentions, both companies and politics could aim to create respective vehicles and guidelines. Against this backdrop, a rapidly growing body of literature has emerged in recent years, which explores the drivers and inhibitors of AV acceptance (Gkartzonikas and Gkritza 2019).

While scholars extensively discuss acceptance factors for autonomous vehicles, they continuously investigate new factors leading to a large pool of results difficult to pervade. Thereby, the related stream of literature does not consistently leverage relevant constructs or items – a well-known issue in behavioral sciences, coined by Larsen and Bong (2016) with the term "construct identity fallacy". Decades earlier, Bacharach (1989, p. 501) stated: "If [theorists] are working with inappropriate constructs and variables, how these constructs and variables are assembled into hypotheses and propositions is irrelevant". Accordingly, this paper will answer the following research questions:

RQ1: Which factors do significantly influence the acceptance of autonomous vehicles?
RQ2: How do various authors define and measure these relevant AV acceptance factors?
RQ3: How does this open up possible future research avenues?

In order to answer these questions, we conduct an extensive literature review adhering the steps proposed by Okoli and Schabram (2010). Following Rowe's (2014, p. 242) call to "to publish more literature reviews [...] for the [information systems] (IS) community", we create a comprehensive overview of acceptance factors derived from previously disconnected research streams.

This study specifically contributes to IS research by deriving an overview of the convergence and divergence of acceptance factors in current AV research. While scholars can utilize our findings to create enhanced theories, lawmakers and automotive companies can leverage our results for policy design and organizational decision-making. Additionally, we outline a roadmap for further research based on current research results, when they are either too scarce or ambiguous and thus require further attention of scholars.

The remainder of the paper is structured as follows: We introduce the related literature regarding AV acceptance research before describing the methodology applied during the literature search and analysis process. Based on thereby identified studies, we will present a comprehensive acceptance framework for autonomous vehicles. We complement our overview by a critical discussion of diverging constructs and items, which is fundamental for the holistic interpretation of our derived acceptance framework. During our analysis, we identify and outline avenues for further research. Afterwards, we discuss on the overall findings, their limitations as well as our theoretical and practical contributions.

Related Literature

We define autonomous vehicles according to the Society of Automotive Engineers (SAE) taxonomy stating that automated driving systems are "the hardware and software that are collectively capable of performing the entire dynamic driving task on a sustained basis" (SAE International 2018). Thereby, the term is specifically used for SAE automation levels 3, 4, or 5 of driving automation with levels of automation ranging from level 0 (no driving automation) to level 5 (full driving automation). While SAE levels 0, 1, and 2 provide advanced driving assistance systems (ADAS) still requiring the driver to drive and constantly monitor the environment, levels 3, 4, and 5 allow the driver to hand over control to the vehicle with a decreasing degree of required supervision up until level 5 where the car can fully drive on its own.

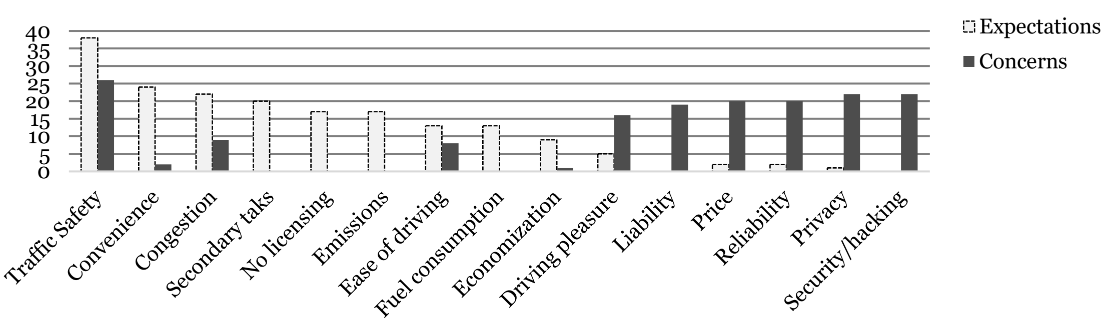

Figure 1. Perceptions of Autonomous Driving

With the advent of self-driving vehicles, research started investigating related user perceptions consisting of various expectations and concerns. Based on these, Figure 1 provides an overview of the most frequently discussed factors in descriptive AV acceptance literature. While *traffic safety* is the most relevant factor mentioned by potential users, it is also the most debated. On the one hand, survey participants expect higher traffic safety due to reduced human error, on the other hand, they worry that self-driving cars will not react properly in unforeseen situations (Hohenberger et al. 2017; Howard and Dai 2014). Factors which are perceived as predominantly positive are improved *convenience*, *reduced congestion* and travel times, *no licensing* requirements leading to increased mobility for the old and impaired, the ability to perform *secondary tasks*, reduced *emissions* and less *fuel consumption* (Buckley et al. 2018; König and Neumayr 2017). *Privacy, security* risks and *hacking, liability* issues, insufficient *reliability* and malfunctioning, higher purchase prices and reduced *driving pleasure*, however, are the concerns or risks most often identified in surveys (Abraham et al. 2018; Kyriakidis et al. 2015; Shabanpour et al. 2018; Ward et al. 2017).

Besides the vehicle-related aspects mentioned above, the willingness to use a self-driving car appears also to be affected by *individual demographics* like gender, age, or household size (Bansal et al. 2016; Dong et al. 2017; Hassan et al. 2019; Hulse et al. 2018; Nazari et al. 2018). Attitude and character traits also have been shown to affect decision-making regarding AV use (Charness et al. 2018; Haboucha et al. 2017; Lee et al. 2018a). Furthermore, incentives from politics like special AV-lanes, and social influence can affect the willingness to use a self-driving vehicle (Madigan et al. 2017; Shabanpour et al. 2017).

From a theoretical perspective, two prominent acceptance models provide the base for the majority of studies: Technology Acceptance Model (TAM) (Davis et al. 1989) and Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al. 2003). According to TAM, perceived usefulness, perceived ease of use, and attitude towards AVs influence the behavioral intention to drive in an autonomous vehicle. In contrast, performance expectancy, effort expectancy, and social influence are relevant according to UTAUT. But also other models like the Car Technology Acceptance Model (CTAM) (Osswald et al. 2012), or the Theory of Planned Behavior (TPB) (Ajzen 1991) are used in AV acceptance research.

Given the large number of research investigating user perceptions and acceptance, several literature reviews have shed light on different aspects of this research stream. However, they neither focus in-depth on vehicle characteristics – which are especially important for car manufacturers – nor on the diverging specification and operationalization of constructs. Nordhoff et al. (2016) and Seuwou et al. (2016) both create conceptual acceptance models purely based on UTAUT, but do not critically discuss the constructs included or their statistical significance. Nishihori et al. (2018) and Furukawa (2019) concentrate on general advantages and disadvantages of self-driving vehicles, but neglect their individual influence on AV acceptance. Others, however, put their focus solely on ethical issues or trust requirements (Adnan et al. 2018; Hakimi et al. 2018). In contrast, Becker and Axhausen (2017) and Gkartzonikas and Gkritza (2019) stay on a meta-level, outlining objectives, investigated factors, and demographic characteristics of available surveys – still leaving our stated research questions unanswered.

Methodology

We performed our literature review following the eight step approach proposed by Okoli and Schabram (2010) (shown in Figure 2) which leads to the following sub-sections. As such, we aim to be "systematic in following a methodological approach, explicit in explaining the procedures by which it was conducted, comprehensive in its scope of including all relevant material, and hence reproducible by others [in the IS community] who would follow the same approach" (Okoli and Schabram 2010, p. 1).

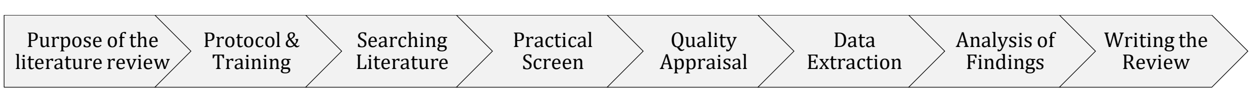

Figure 2. Literature Review Process by Okoli and Schabram (2010)

Purpose of the literature review

First, we would like to state the purpose and scope or our review by leveraging Cooper's (1988) taxonomy (see Figure 3). Our focus is mainly on *research outcomes*, i.e. the combination and comparison of identified AV acceptance factors. Several acceptance models are adapted and applied in various contexts ranging from privately owned cars to car sharing and to autonomous public transport while participants are asked to either fill in structured questionnaires or drive in (simulated) cars. This has led to very context-specific results (Langdon et al. 2018)

Our goal is thus to *integrate* consistent research outcomes in one comprehensive acceptance framework. Further, we emphasize *central research issues* like diverging results or under-researched aspects for further investigation. Thereby, we try to keep a *neutral position*. However, we also *criticize* the AV acceptance research using constructs and items, which are not comparable.

While the literature search process should lead to an *exhaustive* set of literature, the final analyzed and cited publications represent a *selective* subset. We organize our analysis around *concepts*, i.e. around constructs and items as they are of special interest for *scholars* and *practitioners* when leveraging them for theory advancement, policy design, or AV development.

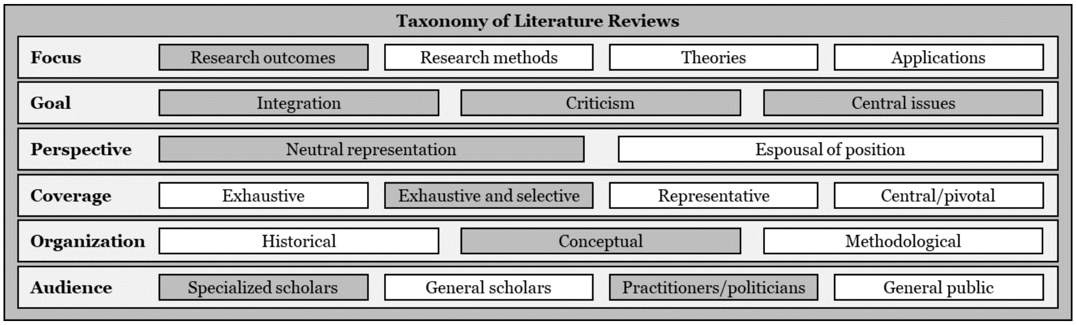

Figure 3. Applied Taxonomy of Literature Reviews (Cooper 1988)

Protocol and Training

Before actually searching the literature, we agreed on two researchers performing the review simultaneously. In order to allow both of them to include the same set of relevant literature, we agreed on a common research protocol. The reviewers regularly discussed difficulties and inconsistencies during their selection process and adjusted the inclusion and exclusion criteria accordingly. We will describe the contents of the protocol as we outline the performed review steps in the next sections.

Searching the Literature

We defined the search terms by conceptualizing the topic based on studies concerning acceptance of autonomous cars published in either behavioral science, transportation, or IS journals and proceedings (Vom Brocke et al. 2009). We also added *willingness to buy/pay* as synonyms for *acceptance* as we think that AVs are only fully accepted, if the consumers are willing to spend money for their usage. This resulted in the following search query: [automated OR autonomous OR self-driving OR driverless OR connected OR smart] AND [vehicle(s) OR car(s) OR driving] AND [accept* OR adopt* OR "willingness to buy" OR "willingness to pay"].

In order to identify appropriate studies, we chose suitable academic databases, which contain relevant behavioral science and IS publications as well as research from related fields like transportation and computer science (Levy and Ellis 2006): ACM Digital Library, AIS Electronic Library, EBSCOhost Business Source Premier, IEEE Xplore Digital Library, ScienceDirect, and WebOfScience. Within these databases, we conducted a keyword search focusing on the years 2014-2019 in January 2019. The initial search including all databases and journals resulted in 4557 articles excluding any duplicates.

Practical Screen

In order to objectively decide which articles are relevant and appropriate for our final analysis, we determined inclusion and exclusion criteria (Webster and Watson 2002). We thus retained the following publications: (1) Studies investigating factors that affect the acceptance of autonomous driving (SAE level 3-5), (2) studies researching autonomous vehicle acceptance in the private context and (3) completed or full scientific research papers written in English. These studies were not limited to only highly rated journals or conference proceedings to ensure a retrieval of an exhaustive result list of this young research field. On the other hand, we excluded: (1) Studies focusing on autonomous vehicle acceptance of other road users (e.g. pedestrians), (2) studies investigating how a specific acceptance factor, e.g. trust or convenience, can be influenced, and (3) studies focusing on smart applications within autonomous cars.

Scanning the document titles and abstracts for relevance by applying the above criteria, we already excluded most of the search results leaving 117 articles for a more thorough inspection with at total of 66 full texts remaining. Following Levy and Ellis (2006) we conducted a reference backward and forward search. Using Google Scholar, we increased the set of unique relevant papers to a total of 124.

Quality Appraisal and Data Extraction

We sorted the final set of publications by type of research and agreed on a "hierarchy of evidence which ranks certain kinds of studies as intrinsically providing more valid and reliable results than others" (Okoli and Schabram 2010, p. 26). Following this approach, we only selected studies that apply structural equation models, regression analysis, or utility models since they simultaneously examine multiple acceptance factors.

As most of the 58 remaining publications use slightly different terms for similar constructs and items, we first performed an initial coding process as proposed by Okoli and Schabram (2010). We extracted the exact terms for constructs and items used in the literature and combined the terms into sets using pattern coding (Saldana 2009). Both researchers performed the coding individually and combined their results afterwards.

We structured the research results following Webster and Watson (2002) by creating a concept matrix (a shortened version can be found in the Appendix) and analyzed which acceptance factors influence users' intention to use a driverless car – either positively, negatively, or non-significantly. Through the inclusion of not only constructs but also items, we create the thus far missing transparency of what these studies actually assessed and what effectively influences user acceptance.

Synthesis of Studies and Writing the Review

We compared and aggregated the results per coded acceptance factor to answer the first research question. In cases where most studies have converging significant results, we included this factor in our comprehensive framework. Factors with diverging results, or those only examined in less than five studies have been excluded.

In order to assess the second research question, we investigated whether all constructs only have items assigned, that have the same code. We performed this analysis by creating a pivot table including all construct and item codes. The overview makes cases apparent, in which authors use different abstraction levels for constructs and items.

From an epistemological perspective, we make tacit knowledge explicit when writing our review. Following Schryen et al. (2015) our synthesis is based on already explicit domain knowledge. However, when we adopt a new perspective by including items in our analysis, we externalize previously tacit knowledge. The framework development combines explicit domain meta-knowledge into codified knowledge available for other researchers. Lastly, the identification of research gaps and inconsistent research results makes tacit domain meta-knowledge also explicit.

Analysis and Results

Factors Influencing the Acceptance of Autonomous Vehicles

We developed a comprehensive acceptance framework including congruent significant acceptance factors (constructs and items) from the analyzed publications to inform future research endeavors and practitioners. In order to build a solid framework, we only used constructs and items analyzed in at least five publications and with a clear tendency of a positive or negative significance. Factors excluded from the framework are listed in Table 1.

While several individual characteristics have not been assessed by many studies, the level of automation has not been extensively investigated using the included methodologies (regression, SEM, and utility models), either. Other forms of research, however, have shown a significant decrease in behavioral intention for higher levels of automation, which might be due to decreased perceived usefulness, ease of use and safety (Rödel et al. 2014, Hewitt et al. 2019). Contrary to these findings, our analysis could not categorize perceived security as significant although the passenger's life can be at risk in case of a hacking attack. Thus, further research could analyze the relationship of perceived safety and perceived security.

	NOT analyzed in at least five publications	NOT showing a clear tendency of significance
Individual characteristics	Medical conditions, marital status, household Type, regular working times/flexible travel times, car ownership, parking constraints, technology experience, ADAS experience, emotional stability, desire for control, political attitude, agreeableness, extraversion, conscientiousness, carelessness, self-enhancement	Distances from home to X
Vehicle characteristics	Motion sickness, accessibility, level of automation, ethics, experiencing the AV, provided information	Perceived security, enjoyment, management of unforeseen situations
Policy/Society	Exclusive AV lanes, more urban space, facilitating conditions, image	-

Table 1. Acceptance factors excluded from the AV acceptance framework

The derived AV acceptance framework, shown in Figure 4, is broadly categorized into three areas: *Individual characteristics*, *vehicle characteristics*, and *policy/society*. The algebraic signs (+) or (-) added in parenthesis after each factor indicate if the majority of available studies identified the factor's influence as either positively significant or negatively significant. In order to underpin these results with more quantitative analysis, we also included the number of publications and the percentage split of positive significant, non-significant and negative significant results for each acceptance factor.

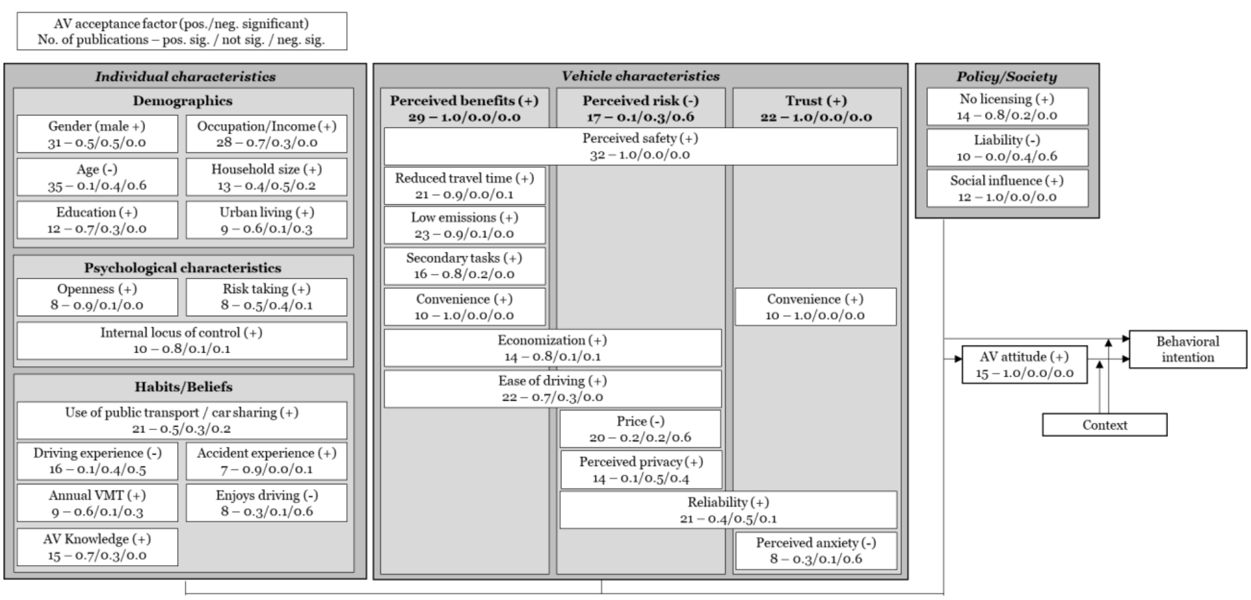

Figure 4. Significant Autonomous Vehicles Acceptance Factors

Individual characteristics can be split into demographics, psychological characteristics and habits/beliefs. Young men, who have a high education and income living in a large household, are especially prone to be early AV adopters (Abraham et al. 2017; Hohenberger et al. 2016; Hudson et al. 2019; Wang and Akar 2019). Openness towards new experiences and an internal locus of control are further significant psychological predictors of AV adoption (Chen and Yan 2018; Motak et al. 2017; Spurlock et al. 2019; Woisetschläger 2016). While driving experience reduces the behavioral intention to use a self-driving car, accident experience increases the probability (Bansal and Kockelman 2018; Nazari et al. 2018; Raue et al. 2019; Shabanpour et al. 2018). Furthermore, technology savviness and AV knowledge increase the probability to choose an AV (Bennett et al. 2019; Hardman et al. 2018; Sener et al. 2019).

Vehicle characteristics are subdivided into perceived benefits, perceived risks, and trust since they emerge as the biggest clusters during our literature analysis. The framework in Figure 4 shows which items are related to which category with some factors like safety spanning across all subcategories since extant research classifies them as benefit, risk, and even trust-building factor. Other factors like economization or ease of driving, however, are not regarded as trust-building factor, but either as benefit when properly available or as risk when missing.

Perceived safety was assessed by 41 percent of the analyzed studies and thus the most discussed factor influencing AV acceptance and willingness to pay (Berliner et al. 2019; Lee et al. 2018b; Niranjan and Haan 2018). Related acceptance factors include perceived privacy, which, however, is mostly assessed on item level in the identified studies (Liu et al. 2018a; Panagiotopoulos and Dimitrakopoulos 2018). Convenience and ease of driving combined with the ability to perform secondary tasks influence consumer decisions positively (Koul and Eydgahi 2018; Lee et al. 2018b; Leicht et al. 2018; Wadud and Huda 2019). While less congestion and lower emissions might especially attract environmental friendly users (Wu et al. 2019; Yap et al. 2016), improved economy and higher prices will influence financial conscious users (Jiang et al. 2018; Liu et al. 2018b; Webb et al. 2019). Further vehicle characteristics that positively influence the behavioral intention are reduced travel time, high reliability and driving ranges (Daziano et al. 2017; Hegner et al. 2019; Kaur and Rampersad 2018; Stoiber et al. 2019).

From a *policy/society* perspective, incentives from politics like no licensing requirements enable young or impaired people to use a self-driving car and demonstrably improve wide-spread AV adoption (Dong et al. 2017; Zhang et al. 2019). Exclusive AV-lanes and clear liabilities (e.g. with the car manufacturer) can affect the willingness to use a self-driving vehicle even further (Liu et al. 2019; Shabanpour et al. 2017). Last, social influence is a significant influencing factor (Madigan et al. 2016).

Studies comparing the attitudes towards AVs before and after experiencing a ride in a simulator observed a positive effect of the system experience (Hartwich et al. 2018). A higher attitude in turn, positively influences the behavioral intention to use a self-driving car (Jing et al. 2019; Zhang et al. 2019). The context, however, also needs to be taken into consideration when assessing the acceptability of self-driving cars (Kaur and Rampersad 2018; Krueger et al. 2016; Lee et al. 2017). Payre et al. (2014) even identify contextual acceptability as the second most important factor following attitude to estimate the intention to use a self-driving car.

Critical Comparison of Constructs and Items

During the analysis of common acceptance factors, divergent constructs and items regarding policy and vehicle characteristics emerged. While we found variables regarding individual characteristics to be mostly consistent, we took a closer look into those papers explicitly outlining the items used to measure vehicle characteristics and policy elements. Despite this being only a limited set, we are able to highlight some crucial differences that are important to consider when evaluating the overall findings of extant AV acceptance research, and our contributions to this research stream.

			Ease of driving	**Perceived safety**	**Reliability**	**Driving pleasure**	**Price**	**No licensing**	**Economization**	**Low emissions**	**Perceived privacy**	**Perceived security**	**Situation management**	**Reduced travel time**	**Secondary tasks**	**Convenience**	**Liability**	**Construct**
Used as…	**Item for**	Perceived benefits	2	10	-	1	-	4	3	3	-	-	-	8	7	3	-	**19**
		Trust	-	4	9	-	-	1	-	-	-	2	1	-	-	1	-	**10**
		Perceived risks	1	3	6	3	4	-	1	-	4	4	4	-	-	-	4	**8**
	Construct		**15**	**5**	**5**	**4**	**3**	**2**	**2**	**2**	**2**	**2**	**2**	**1**	**1**	**1**	**1**	

Table 2. Construct and Item Usage Counted by Publication (N=30)

The overview in Table 2 demonstrates clearly, that almost all car-related characteristics are used both as items in some publications and as constructs in others. Furthermore, as already shown in Figure 4, some items are used for perceived benefits, perceived risks or trust depending on the author. This makes current results difficult to compare and led us to include the item level in our above framework of AV acceptance factors.

Some factors like perceived security or the performance of secondary tasks (e.g. reading, sleeping or watching a movie) are assessed more often as items of other constructs than as constructs themselves. As a result, the specific influence of these factors, for instance, secondary tasks, is diluted when measured as part of the construct of perceived benefits. This might lead to wrong interpretations in two ways: First, publications measuring perceived benefits with a diverging set of items are likely to report different effect sizes and significance levels. Second, influence factors just measured as items for other constructs might be crucial in understanding AV acceptance. However, this might not become explicit as other constructs would be strengthened.

These inconsistencies might stem from the context of TAM and UTAUT as underlying theoretical models. Many authors define perceived usefulness, for example, as “the extent to which consumers believe that using a particular technology system will enhance his or her job performance” in accordance with TAM (Davis et al. 1989). Performance expectancy is mostly defined as “the degree to which an individual believes that using a (new) system will help him or her to attain gains in job performance” in accordance with UTAUT (Venkatesh et al. 2003). Both definitions stem from an organizational context, where job performance is rather clearly defined. In the AV context however, there is no common definition of performance or usefulness. This could explain why the items used for the measurement of this and other constructs like risks and trust diverge.

Identification of Possible Research Avenues

Autonomous vehicles present multiple opportunities to explore phenomena at the intersection of vehicle manufacturers, politics, and society. Especially the assessment of factors driving the acceptance of self-driving cars has been shown to be a challenging question explored by a large number of studies. In this paper, we present a number of common findings, but also want to shed light on issues that we came across during our analysis that future AV researchers can tackle as they investigate these remaining challenges.

Although the society has many positive expectations towards autonomous vehicles, potential users also raised several concerns during qualitative interviews (compare Figure 1). Thus, it is important to specify the factors causing these negative perceptions and to define strategies how to improve it. Especially regarding the most discussed and significant factor perceived safety, this could yield important insights for car manufacturers’ research and development priorities.

During our analysis of AV acceptance factors, we realized that there are still potentially important aspects researched by only few researchers. For example, medical conditions could inform the willingness to use of impaired drivers. Furthermore, factors without a clear tendency of significance like perceived security could be a major influence factor not yet identified due to sampling variances. While the previous factors have been investigated in few studies, though, the political and social impact has been largely neglected so far. Further research should address potential levers shaping politics and public opinion and their impact.

This literature review aims at initiating a scholarly discussion about AV constructs and items, and represents a starting point for the research community to continue and advance the definition of context sensitive constructs and items to measure the acceptance of AVs. In order arrive at a concrete definition of relevant AV acceptance factors including the related constructs and items, we invite the IS community to work on this challenge since suggesting solid construct definitions in the paper at hand would have diluted the focus of this review. This will allow further research to leverage explicit constructs with clearly associated items to measure the same latent variable.

Our review demonstrates that methodology and context matter considerably when exploring AV user acceptance (Langdon et al. 2018): Users deliberating the purchase of an AV will exemplify differing requirements than AV users in a public transport context. Furthermore, participants from survey-based studies purely state their intentions towards using an AV, which do not necessarily match actual behavior. Simultaneously, participants of “paper-based” studies might have very different perceptions of AVs leading to more variance in results compared to a more realistic laboratory setting. Accordingly, simulator studies try to provide an actual experience, which as of now however often fails to be very realistic for instance, when LCD displays are used to simulate a real ride (Cho et al. 2016). Lastly, studies utilizing actual cars cannot realistically assess level 5 automation, simply since this type of vehicle does not exist yet. In addition to that, the AVs used in some studies did not move faster than 8 km/h (Nordhoff et al. 2018a) leading to a reduced perceived usefulness. Hence, further research should combine and advance currently available methods to achieve a more realistic perspective.

As soon as the transportation and IS community understands which factors influence AV user acceptance, we do not need yet another acceptance model including an additional acceptance factor. It is more important to shift the focus towards elements influencing user satisfaction e.g., by using a KANO analysis, which allows for a categorization into basic needs, performance needs, delighters as well as indifferent and reverse factors (Kano and Noriaki 1995). Starting there, research could examine which vehicle characteristics define the willingness to pay.

In summary, we present a succinct overview of our proposed research avenues in Table 3 covering the themes: Negative AV perceptions, limited research attention, diverging research results, construct identity fallacy, methodologies, and evolution of research focus.

Theme	We must overcome…	We need to…
Negative AV perception	• Providing a purely descriptive list of positive and negative AV perceptions	• Understand in depth what causes negative sentiments towards significant acceptance factors (e.g. regarding driving pleasure, security and safety) (Ernst and Reinelt 2017; Salonen 2018) and how to improve respective car characteristics and associated user perceptions (Abraham et al. 2018)
Limited research attention	• Focusing acceptance research mostly on individual and vehicle characteristics • Preforming the majority of studies in the context of privately owned vehicles	• Assess potential impacts of policies and regulations (e.g. purchasing subsidies, guidelines permitting or prohibiting vehicles driving without passengers, licensing requirements, ethical guidelines for AV algorithms) (Brell et al. 2018; Hein et al. 2018; Karnouskos 2018) • Determine acceptance factors for other ownership models like public transport and shared vehicles with and without ride sharing
Diverging research results	• Contrary, ambiguous study results (Fraedrich and Lenz 2014) • Building future models only by adding additional constructs to TAM or UTAUT	• Focus future studies on factors not yet clearly identified as positive-, negative- or non-significant (e.g. urban living, annual vehicle miles travelled, usage of other means of transport, risk taking preferences) (Földes et al. 2018; Woldeamanuel and Nguyen 2018) • Determine the explanatory power and parsimoniousness of research models by performing a meta-analysis (Chen and Yan 2018; Lee et al. 2018b)
Construct identity fallacy	• Missing comparability of research results (Larsen and Bong 2016) • Applying models from other contexts without adaption (Davison and Martinsons 2016)	• Clearly define what the AV research stream understands by benefits, risks and trust-building constructs (Whetten 1989) • Be more explicit by using unambiguous constructs and items
Methodologies	• Pure survey based assessments (König and Neumayr 2017) • Self-reported intentions' measuring (Nordhoff et al. 2018)	• Use real cars or simulators when assessing users' perception (Brell et al. 2018; Hartwich et al. 2018) • Put emphasis on the measurement of actual usage (Haboucha et al. 2017; Xu et al. 2018)
Evolution of research focus	• Focusing solely on user acceptance (Abraham et al. 2018) • Develop yet another acceptance model not significantly improving explanatory power	• Investigate, which AV characteristics do not only affect user acceptance but also user satisfaction (Pettersson and Karlsson 2015; Ro and Ha 2019) • Assess, for which features customers are willing to pay a premium (Hein et al. 2018)

Table 3. Proposed Future AV Acceptance Research Avenues

Discussion, Limitations, and Contributions

A fast growing number of studies assessing the AV acceptance of different user groups in different countries for different levels of automation in either private or public transport accumulates to a large body of knowledge. We organized this knowledge in an AV acceptance framework by performing a structured literature analysis.

Thereby, our work confirms the results of Becker and Axhausen (2017) who found young men living in urban environments and having technology experience as being positive about AVs. In addition to that, we identified traffic safety, even in unforeseen situations, and increased convenience, e.g. via smooth driving styles as relevant acceptance factors. Early adopters are interested in performing secondary tasks while driving, for example watching a movie, performing some work, or just talking to others. Furthermore, the car should warrant the passengers' privacy. In contrast to Nordhoff et al. (2016), we included policy incentives like exclusive lanes or no licensing requirements in our analysis. They, on the contrary, focused just on individual and vehicle factors. Policies like updated licensing requirements could especially increase the usage intentions of impaired individuals, whereas clearly defined liabilities concern all users of autonomous vehicles.

However, extant research mostly neglects political and societal aspects when discussing user acceptance. Further under-researched fields and diverging research results have been outlined in Table 1. These diverging results are often based on different constructs and items used to assess potential acceptance factors. In order to advance AV research, we hope that our proposed research avenues will inspire some scholars to investigate the suggested areas and add transparency to AV studies by applying more concrete and context specific acceptance factors.

As with any extensive literature review performed by multiple researchers over a certain period of time, our review might not have spanned across all relevant pieces of knowledge or potentially lacked consistency between the two involved researchers. Preventive measures like a search protocol and regular sessions to discuss difficult decisions were pursued throughout the process, but the possibility of differing selections remains.

We decided to include both acceptance literature and willingness-to-pay literature in our review since they are closely related. On account of this, we do not consistently exclude factors affecting the willingness to pay but not necessarily the acceptance when creating our framework. Researchers interested in a distinction of studies assessing intention to use or willingness to pay can refer to Table 4 in the Appendix.

Our work has a number of unique contributions, compared to other systematic literature reviews. By developing a very comprehensive acceptance framework, we converted available meta-knowledge into domain knowledge which can readily be used for further research (Schryen et al. 2015). Our approach can be distinguished from extant work as our analysis demonstrates a higher granularity through the inclusion of assessed items. Thus, researchers and practitioners can easily extract what actually influences the acceptance of self-driving vehicles and develop improved AV acceptance theories based on our research. From a practitioners' perspective, car manufacturers can push their efforts towards areas that are most important for user acceptance as well as towards areas where today's user perceptions are foremost negative. Policymakers can recognize the urgency with which they should define regulations regarding AV usage on public streets, including exclusive lanes, licensing requirements, and liabilities, which all have been proven to influence AV acceptance significantly.

Moreover, current AV acceptance studies are difficult to compare. As long as researchers do not use the same constructs' abstraction levels when investigating AV acceptance, practitioners cannot use the outcomes, for example for strategical project prioritization, and researchers cannot build on each other's results (Cooper 1998). Consequently, our literature review provides transparency concerning the operationalization and measurement of acceptance factors and gives new impulses to a more thorough debate about construct definitions and items used to explain and quantify AV acceptance. We hope that our call for more accuracy encourages researchers to not simply apply well-known constructs from other contexts, but adapt them to the specific opportunities and constraints that the AV context provides when proposing new acceptance models. In this regard, future meta-analyses could provide further valuable insight into the effect strength of constructs and the appropriateness of extant research models.

Furthermore, we are the first proposing a cross-sectional research agenda for AV acceptance research. In Table 3, we outline specific potential research areas from a content-, method-, and focus-wise perspective. We make implicit research gaps explicit by highlighting areas in the body of knowledge where consistent views are missing or that have only received limited attention (Cooper 1998). By presenting these areas, which need more research attention, we took an important step in guiding future research within this scattered young research stream.

Appendix

Author	Context							Independent Variables											Dependent Variable			Item
	LOA	Ownership Model			Interaction			Individual Factors			Vehicle Characteristics			Policy/ Society		Other						
	SAE Level of Automation Considered	Public Transport	Shared Vehicle with / without Ride Hailing	Privately Owned Vehicle Not Defined	Driving in a Real Car	Driving Simulation	No Interaction	Demographics	Habits / Beliefs	Psychological Characteristics	Perceived Benefits	Perceived Risks	Trust	Policies	Social Influence	Experiencing AV	Attitude	Context	Intention to / Willingness to / Interest in Using/Adoption	Intention to / Willingness to / Interest in Buying/Paying	Other (e.g., Choice, Approval, Attitude)	Items Provided?
(Abraham et al. 2017)	0-5			X			X	X		X			X							X		
(Bansal and Kockelman 2018)	3-4			X			X	X	X											X		
(Bansal et al. 2016)	3-4			X			X	X	X											X		
(Bennett et al. 2019)	5			X			X	X	X	X									X			
(Berliner et al. 2019)	4-5			X			X	X	X		X	X	X							X		
(Buckley et al. 2018)	3			X		X				X	X		X		X		X		X			
(Charness et al. 2018)	5			X			X	X	X	X			X						X			
(Chen and Yan 2018)	3-5			X			X			X	X	X	X		X		X		X			X
(Choi and Ji 2015)	4			X			X			X	X	X	X						X			X
(Daziano et al. 2017)	3-5			X			X	X	X											X		
(Dong et al. 2017)	5	X					X	X	X		X	X	X	X					X			
(Ernst and Reinelt 2017)	5			X			X				X	X	X						X			X
(Haboucha et al. 2017)	5		X	X			X	X			X	X					X				X	X
(Hardman et al. 2018)	5			X			X	X	X		X	X	X								X	
(Hassan et al. 2019)	4-5			X			X	X	X		X	X	X						X			X
(Hegner et al. 2019)	5			X			X	X		X	X	X	X						X			X
(Hein et al. 2018)	5			X			X				X	X	X		X				X			X
(Hohenberger et al. 2016)	3-5			X			X	X				X							X			
(Hohenberger et al. 2017)	3-5			X			X	X		X	X	X	X						X			X
(Hudson et al. 2019)	5			X			X	X	X												X	
(Hulse et al. 2018)	5			X			X	X	X	X		X									X	
(Jiang et al 2018)	3-5			X			X			X											X	
(Jing et al. 2019)	5		X	X			X		X		X	X	X		X		X		X			X
(Karnouskos 2018)	5			X			X							X								X
(Kaur and Rampersad 2018)	5	X					X				X	X	X					X	X			X
(Koul and Eydgahi 2018)	5			X			X	X	X		X	X	X	X					X			X
(Krueger et al. 2016)	5		X				X	X	X												X	
(Lee et al. 2017)	5			X			X	X	X		X	X	X	X	X			X	X			X
(Lee at al. 2018a)	3-5			X			X			X									X			
(Lee et al. 2018b)	3-5			X			X		X	X	X	X	X	X							X	
(Leicht et al. 2018)	5			X			X			X	X	X	X		X					X		X
(Liu et al. 2018a)	4-5			X			X				X	X	X	X					X	X		X
(Liu et al. 2018b)	5			X			X				X	X	X	X					X	X		X
(Liu et al. 2019)	5			X			X	X	X		X	X	X	X						X		X
(Madigan et al. 2016)	4	X			X						X				X				X			X
(Madigan et al. 2017)	4	X			X			X			X	X		X	X	X			X			X
(Motak et al. 2017)	5	X			X			X	X	X	X				X	X	X		X			X
(Nazari et al. 2018)	5		X	X			X	X	X		X	X	X								X	X
(Niranjan and Haan 2018)	4			X			X				X	X	X				X				X	
(Panagiotopoulos and Dimitrakopoulos 2018)	3-5			X			X				X	X	X		X				X			X
(Payre et al. 2014)	4			X			X	X		X	X	X	X	X			X	X	X			X
(Raue et al. 2019)	4-5			X			X	X	X		X	X	X				X		X			X
(Ro and Ha 2019)	5			X			X				X	X	X	X			X		X			X
(Sener et al. 2019)	4			X			X	X	X		X	X	X		X		X		X			X
(Shabanpour et al. 2017)	5			X			X	X	X	X	X	X	X	X					X			
(Shabanpour et al. 2018)	5			X			X	X	X			X		X					X			
(Souders and Charness 2016)	3-5			X			X	X			X		X						X			
(Spurlock et al. 2019)	3-5			X			X	X		X	X								X			
(Stoiber et al. 2019)	4-5	X	X				X				X	X								X		
(Wadud and Huda 2019)	5			X			X	X	X		X								X			
(Wang and Akar 2019)	5		X	X			X	X	X								X				X	
(Ward et al. 2017)	5			X			X	X	X		X	X	X						X			
(Webb et al. 2019)	5		X				X	X	X		X	X							X			
(Woisetschläger 2016)	4			X			X			X	X	X	X							X		
(Wu et al. 2019)	5			X			X				X								X			X
(Xu et al. 2018)	3-5			X	X		X				X	X	X						X			X
(Yap et al. 2016)	5		X				X	X			X	X	X								X	X
(Zhang et al. 2019)	3			X			X				X	X	X	X			X		X			X

Table 4. AV Acceptance Concept Matrix

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