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## Article

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Review

# Individual Predictors of Autonomous Vehicle Public Acceptance and Intention to Use: A Systematic Review of the Literature

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**Abstract:** Fully autonomous vehicles (AV) would potentially be one of the most disruptive technologies of our time. The extent of the prospective benefits of AVs is strongly linked to how widely they will be accepted and adopted. Monitoring and tracking of individuals' reactions and intentions to use AVs are critical. The current study aims to explore and classify individual predictors (i.e., influential factors or determinants) of public acceptance of, and intention to use AVs, by conducting a systematic literature review and developing a conceptual framework to map out the individual influential factors that shape public attitudes towards AVs, which influence user acceptance and adoption preferences. This framework contains the key factors identified in the systematic review—i.e., demographic, psychological, and mobility behavior characteristics. The findings of the review disclose that public perceptions and adoption intentions vary significantly among different socio-demographic cohorts. Commuters value different aspects concerning AVs, which shape their intentions on acceptance and adoption. Thus, direct experience with AVs along with education and communication would be helpful to change people's attitudes towards AVs in a positive way. The study informs urban and transport policymakers, managers, and planners, and helps in planning for a healthy AV adoption process with minimal societal disruption.

**Keywords:** autonomous vehicles; autonomous driving; autonomous vehicle adoption decisions; public attitudes toward autonomous vehicles; intention to use autonomous vehicles; user acceptance of autonomous vehicles; mobility behavior; urban mobility; mobility innovation

## 1. Introduction

Transportation plays a central role in the society and economy [1–3], and at the same time, it is a major contributor to the greenhouse gas emissions [4,5]. In recent years, as part of the smart and sustainable transport agenda, autonomous driving solutions are introduced. There is a great promise that fully autonomous on-road vehicles (AVs) yield a variety of societal and environmental benefits, provided that AVs rely on the clean propulsion system. The prospective benefits would likely include facilitated mobility for transport disadvantaged (e.g., elderly, disabled), enhanced traffic efficiency, improved safety, and lower emissions [6–8].

Nevertheless, the anticipated benefits of AVs are unlikely to be realized without the broader uptake of AVs, which is linked to public acceptance and adoption intention [9]. In this regard, new business models, such as a sharing economy and a small organization with rapid growth, have appeared. In addition, a sharing economy, whose marginal costs are minimized [10], such as Shared-AVs (SAVs),

will become more easily implemented. SAVs could offer on-demand services on non-fixed routes, and they are capable of ridesharing in different ways—i.e., “car sharing with or without ownership, ride-sharing with or without ownership, taxi-service or public transit” ([11], p. 88).

Understanding the likelihood of acceptance and adoption intention of AVs is important as AVs may alter the mobility behavior and lifestyle of users [12]. Nonetheless, since AVs are not publicly available in the traffic system, except for a few trials, predicting the exact travel demand in this context is challenging—e.g., ownership trends, preferred mode choices, vehicle kilometers travelled (VKT). There might also be reactions to the introduction of this technology in the public domain [13]. For instance, Menon et al. [14] found that almost 61.5% of US drivers are unwilling to ride AVs. Thus, it can be anticipated that the major barrier to diffusion of AVs may not originate from the technology side, but rather stem from low public acceptance [15–18].

While some people are enthusiastic to use AVs, others are not willing to relinquish control of their vehicles, so they are not ready to purchase one [19,20]. To increase AVs' public acceptance, it is necessary to monitor risk and benefit perceptions closely to find out factors affecting AV acceptance and adoption intention [13,17], since “consumer perceptions will ultimately determine the success or failure of AVs, and potentially drive policy changes as AVs become more common” [21], p.218. To obtain a behaviorally realistic view of AV acceptance and adoption intention, it is critical to explore “unobservable (latent) subjective attitudes and preferences influencing decision-making, along with the observable factors” [22], p.457—e.g., demographic and surrounding built environment characteristics of trip-takers, along with their current mobility behavior characteristics eliciting the decision process [23].

While there have been some review studies revealing insights on AV public acceptance and intention to use [23–26], a knowledge gap remains. Particularly given the rapid growth in the publications on AVs in the recent years, there is a need for undertaking systematic investigations to generate a cohesive understanding on the factors affecting AV public acceptance and intention to use. A literature search on public perceptions on AVs has revealed that more than half of the literature ( $n = 42$ ; 52.2%) on the topic was published in 2019. To our knowledge, no systematic literature review work is published yet that includes these latest studies.

To address this knowledge gap, as part of the bigger picture study on autonomous vehicle adoption challenges of Australian senior citizens, this particular study aims to identify and classify individual determinants of AV public acceptance and intention to use. The study concerns passenger vehicles with level 4 and level 5 of automation according to Society of Automotive Engineers (SAE) [27], which represents automated performance on limited road sections (highly AVs) and automated performance on all roadway and environmental conditions (fully AVs), respectively. The methodologic approach of the study includes conducting a systematic literature review and developing a conceptual framework to map out the influential factors that form attitudes towards AVs, which affect user AV acceptance and adoption decisions.

The current paper is organized as follows. Section 2 synthesizes the existing theories and models of technology acceptance and user adoption behavior, then elaborates on the research design. Section 3 illustrates the results including the general findings and the categorized factors. Section 4 provides discussion, limitations of the reviewed studies and their practical implications for further research. Section 5 concludes the paper by describing the key findings and their contributions, and summarizes the potential limitations of the current study.

## 2. Materials and Methods

### 2.1. Theoretical Background

The world is evolving to a hyper-connected society. Transportation as one of the main society sectors is adopting innovative changes in the existing processes and services. Internet of Things (IoT) and location-based big data facilitated transactions that were not possible in the past. In the closed-innovation concept [28], “technology policy has emphasized the supply side of development,

but in the open innovation paradigm on the contrary, it must work on the demand side. The concept of ‘demand articulation’ was effective in formulating corporate policies for technology and market development, and also in government policies for accelerating the commercialization process of emerging technologies” ([10], p. 3). Attempts to create a dynamic economy are collectively called the Fourth Industrial Revolution [10].

The Fourth Industrial Revolution that has been progressing since the start of the 21st century, and features the creative connection between technology and the market in all industries based on IT, that is, the creative and open combination of technology and the market through open innovation, or growth based on the open business model [29]. Examples include smart cities based on an open innovation or open business model platform, and AV systems that spread throughout the nation from a specific region [30]. For a converted new market industry, such as the AV industry, a new business model itself leads to market growth, and technology development is required to implement the new business model in a sophisticated manner. In the current emerging period, the effect of the business model is even greater than the effect of technology [31].

Research policies in both the public and private sectors are important to guide technological developments under limited resources. Patent development, knowledge transfer, and the commercialization of technology applications are also critical aspects of the development of technology [30].

Former studies that concentrated on AVs exemplified how socioeconomic characteristics are correlated with AV acceptance [24,25,32]. Furthermore, scholars investigated the significance of public perceptions, personal characteristics, and attitudes in determining the intention to adopt AVs (e.g., [23,33–35]. Public perception is “simply the type of information obtained from a public opinion survey” ([36], p.40). Surveys have been done on the public perceptions of AVs, mostly considering people as potential users (e.g., [37–40]). Individual attitudes toward AVs are a key contributor of the technology demand, governing policies and future investments in infrastructure [41].

Some scientists stress the importance of making a distinction between “acceptability” and “acceptance”. According to Jamson [42], acceptability is “how much a system is liked”, while acceptance is “how much it would be used”. Despite the manifestation of different views toward acceptance and acceptability, they both are recognized to be based on the individuals’ judgement of the system [43]. Previous research efforts borrowed from the theories and models of user adoption that were developed to clarify the relationships between attitudes and human behavior [17,44].

These models are comprised of the “technology acceptance model” (TAM) [45,46], “theory of planned behavior” (TPB) [47], and the “unified theory of acceptance and use of technology” (UTAUT) [48,49]. In some cases, one of these models as a main theoretical frame of reference was extended with another theoretical model as the original theory was not able to signify the distinct properties of AVs [50,51]. According to Jing et al. [52], “the application of theory-based models can provide stronger predictors and explanations about the determinants of AV adoption intention” ([53], p. 2). Table 1 summarizes the paradigms, contributions, and representative constructs of these theories with their definitions, with reference to some relevant studies.

**Table 1.** Summary of the most common technology acceptance theoretical models (Source: Authors).

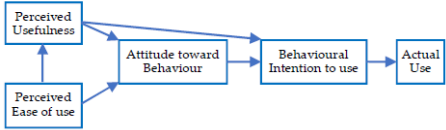
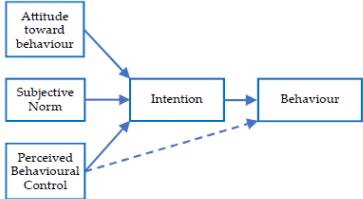
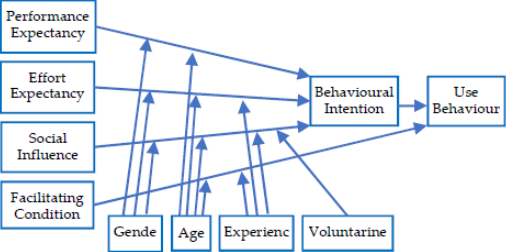
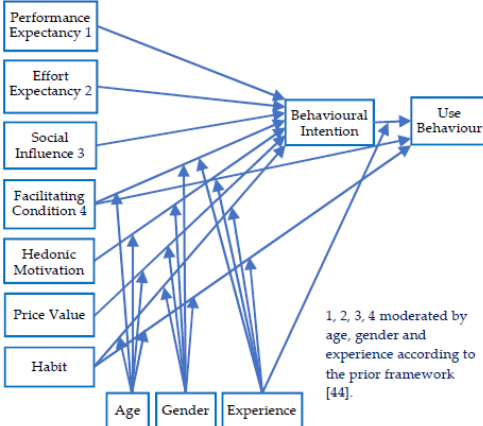
Theory Characteristics	Paradigm & Contribution	Representative Constructs	Definition	Relevant Studies
<p><b>Technology Acceptance Model (TAM)</b></p>  <p>(1)</p>	<p>Psychology This theory can explain how “users’ perception of the usefulness and ease of use of automated systems influence the AV adoption” ([49], p. 3).</p>	<p>Attitude Toward Behavior</p> <hr/> <p>Perceived Usefulness</p> <hr/> <p>Perceived Ease of Use</p>	<p>“An individual’s positive or negative feelings (evaluative affect) about performing the target behavior” ([54], p. 216)</p> <hr/> <p>“The degree to which a person believes that using a particular system would enhance his or her job performance” ([45], p. 320)</p> <hr/> <p>“The degree to which a person believes that using a particular system would be free of effort” ([45], p. 320)</p>	<p>[13,15,17,50,51,55–66]</p>
<p><b>Theory of Planned Behavior (TPB)</b></p>  <p>(2)</p>	<p>Psychology This theory can explain how attitudinal, normative and control belief components affect the adoption of AVs [49].</p>	<p>Attitude Toward Behavior</p> <hr/> <p>Subjective Norm</p> <hr/> <p>Perceived Behavioral Control</p>	<p>Same as in TAM</p> <hr/> <p>“The person’s perception that most people who are important to him think he should or should not perform the behavior in question” ([50], p. 302)</p> <hr/> <p>“The perceived ease or difficulty of performing the behavior” ([48], p. 188)</p>	<p>[50–53,55,67–70]</p>

Table 1. Cont.

Theory Characteristics	Paradigm & Contribution	Representative Constructs	Definition	Relevant Studies
<p><b>Unified Theory of Acceptance and Use of Technology (UTAUT)</b></p>  <p>(3)</p>	<p>Psychology and Behavioral Economics This theory can explain how “the representative constructs facilitate the formation of positive attitudes towards AV adoption” ([49], p. 3).</p>	<p>Performance Expectancy</p> <hr/> <p>Effort Expectancy</p> <hr/> <p>Social Influence</p> <hr/> <p>Facilitating Conditions</p> <hr/> <p>Hedonic Motivation</p> <hr/> <p>Price Value</p> <hr/> <p>Habit</p>	<p>“The degree to which an individual believes that using the system will help him or her to attain gains in job performance” ([48], p. 447)</p> <hr/> <p>“The degree of ease associated with the use of the system” ([48], p. 450)</p> <hr/> <p>“The degree to which an individual perceives that important others believe he or she should use the new system” ([48], p. 451)</p> <hr/> <p>“The degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system” ([48], p. 453)</p> <hr/> <p>“The fun or pleasure derived from using technology” ([49], p. 162)</p> <hr/> <p>“Consumers’ cognitive trade-off between the perceived benefits of the applications and the monetary cost for using them” ([49], p. 162)</p> <hr/> <p>“The extent to which people tend to perform behaviors automatically because of learning” ([49], p. 162)</p>	<p>[33,53,55,70–78]</p>
 <p>(4)</p>				

Additionally, for the sake of examining the adoption likelihood of a novelty by the public, the “diffusion of innovation theory” (DOI) [79] envisages individuals’ perceptions of the novelty—such as AV [23]. In this domain, “attitudes” are regarded as psychological tendencies that signify the degree to which individuals like or dislike a particular entity [80]. Attitude, considered as a moderator of beliefs and intentions, exists in both the theories of TPB and TAM [81]. Furthermore, Rogers [79] pointed out that potential users’ overall attitude towards an innovation determines their adoption decisions, and significantly impacts their acceptance of the AVs, which has been acknowledged by the AV acceptance studies as well [82–84].

In this context, “intention to use” is a significant notion as fully AVs are not yet publicly available. Intention to use is formed according to acceptance levels unless the technology becomes tangible and riders gain a chance to experience it, in reality, and are able to make decisions and give consistent and reliable answers to questions concerning actual use [54]. This method was deliberated upon the interpretation was made that the general public are mostly unfamiliar with AVs, thus potential misconceptions and uncertainties regarding such innovations could affect the accuracy and consistency of reported findings [50,62,85]. This issue points to an inconsistency in the literature regarding predictors of public acceptance and adoption preferences of AVs.

## 2.2. Research Design

The study undertakes a systematic review of the AV literature to address the main research question of: What are the individual predictors of public acceptance and intention to adopt AVs? The rationale is that although there are some review studies published on this topic [23–26], there is not any comprehensive review of the most recent studies in the field. Considering the fact that more than 50% of publications (n = 42; 52.2%) on this topic were published during 2019, covering this gap via providing a comprehensive review of key findings of the latest investigations on AV adoption intention, and developing a conceptual framework, is necessary. This—including the large amount of recently published work in the analysis—differentiates our research from the prior studies. The adopted methodologic approach is a three-phase procedure that is used by many studies [86,87].

In an initial planning phase, we developed the research aim, question, and keywords, and we set the inclusion and exclusion criteria. The research aim was framed to identify and classify individual determinants of AV public acceptance and intention to use and the most common measurement items had been used for each factor. The inclusion criteria target English language peer-reviewed journal articles, available online in full-text and related to the research aim. Studies focusing only on highly and fully automated passenger vehicles with SAE [27] automation levels of 4 and 5 were included in the review. The exclusion criteria were intended to be publications except for those pointed out in the inclusion criteria. An online search was done through a university’s search engine, enabling access to 393 different databases, comprising Scopus, Science Direct, Web of Science, Wiley Online Library, Transport Research International Documentation (TRID).

The second phase involves reviewing relevant articles. The initial publication date in the search was not determined, as the earliest surveys on AVs were from 2012 [24], whereas the end date (when the search was carried out) is December 2019. The query string applied for database searches was: (automated OR autonomous OR driverless OR self-driving) AND (car OR vehicle) AND (perception OR acceptance OR adoption OR intention OR preference OR choice experiment). The keywords focused on the title and abstract of the articles explored. The search firstly resulted in overall 1966 records.

The filtering or screening process for selecting relevant literature pieces (via exclusion and inclusion approaches) forms an integral part of a systematic review. This is done in two stages: (a) Screening, and; (b) Eligibility (Figure 1).



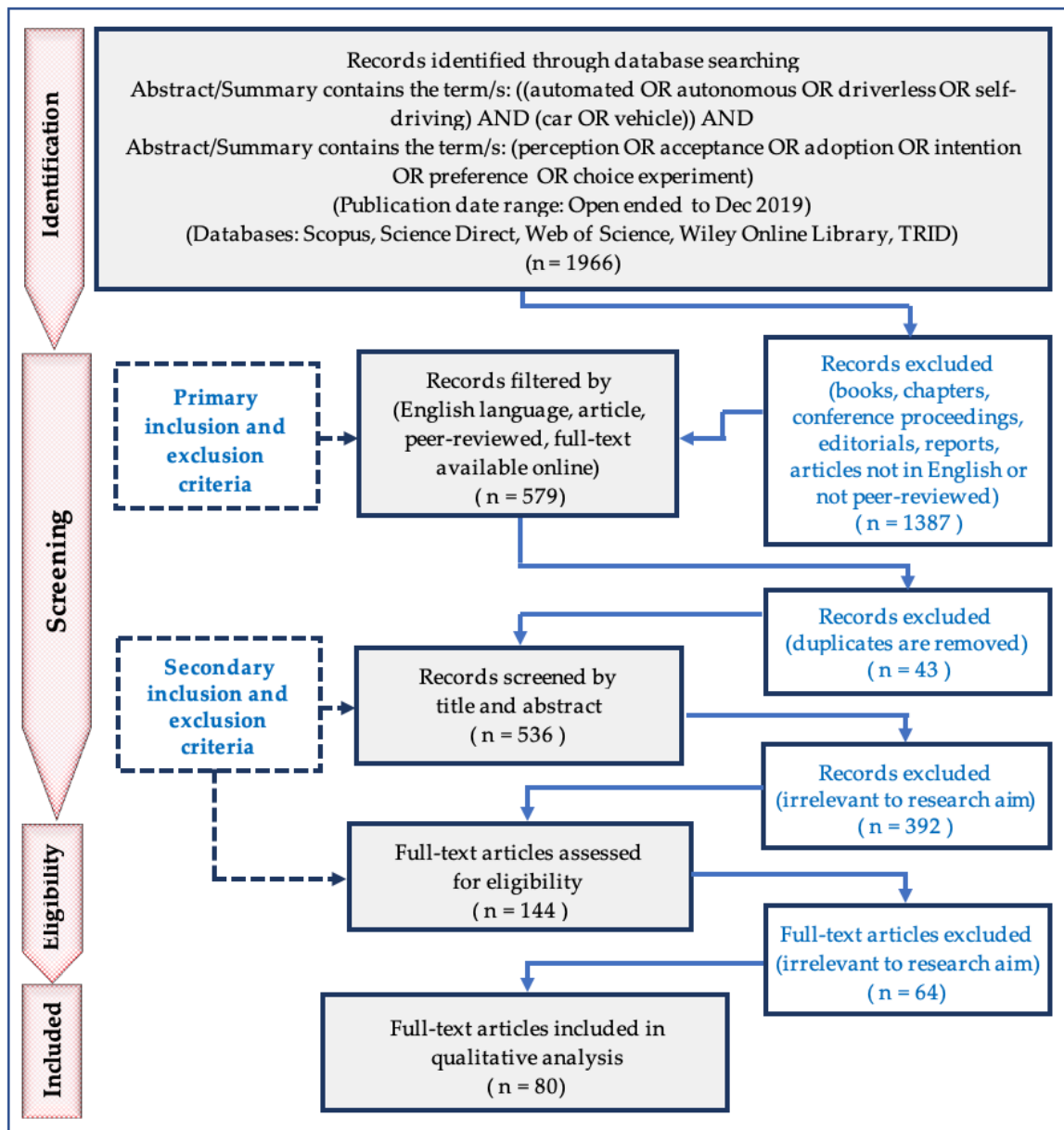


Figure 1. Literature selection procedure (Source: Authors).

In the screening stage, the identified articles were screened and lessened to 579 by applying the primary inclusion and exclusion criteria. This amount was “eye-balled for consistency and accuracy of the keyword search” [88], and the duplicates were also removed. Next, the abstracts of the remaining 536 articles were evaluated by applying the secondary inclusion and exclusion criteria and the records against the research aim were excluded. Then, in the eligibility stage, the full-texts of 144 articles were retrieved and screened to definitely decide whether the study fits the eligibility criteria of our review. Finally, after exclusion of the irrelevant papers regarding the aim of the study, the number of articles was narrowed down to 80 for the review, categorization, and analysis round.

The current study is founded on a descriptive rather than statistical analysis of literature. As for Yigitcanlar et al. ([87], p.353), “qualitative techniques of pattern matching and explanation building have been adopted to descriptively categories the journal articles under specific categories” [84]. In this regard, according to Yin, [84], pattern matching refers to scanning for commonalities and disparities in which an eye-balling technique is sufficiently convincing to draw a conclusion or categorization. The selection criteria to formulate the categories is itemized in Table 2. The categorization was adjusted



and allocated into three different clusters that may potentially impact the public acceptance and adoption intention of AVs—i.e., demographic, psychological, and mobility behavior characteristics. These individual determinant categories are described in detail in the following section and also their relevant studies were illustrated in Table 3.

**Table 2.** Category formulation selection criteria (Source: Authors).

Selection Criteria
1. Identify the similarities and common patterns among the research outcomes through eye-balling the literature.
2. Highlight the major characteristics and factors that influenced the public perceptions and adoption of AVs.
3. Assign the best applicable themes to categorize the reviewed literature, based on the research aim.
4. Validate the assigned themes with the other literature and review studies.
5. Reassess the selection and organizing the categories, then confirm the design of them.
6. Adjust and allocate the categorization into different clusters that impact the AV public adoption intention.

In the third phase, which involves reporting and dissemination, the findings were critically documented and presented in the form of a review paper. Additional publications on the subject, which were retrieved through conducting forward and backward citation chasing, were simultaneously included as supporting literature to comprehensively elaborate the theoretical background and overall findings of the research. Even if these publications do not meet the selection criteria, this strategy is an invaluable method to identify relevant sources as we are tapping into the expertise and prior research of the authors. Hence, we are essentially browsing a curated list of sources.

### 3. Results

#### 3.1. General Observations

The descriptive analysis of the 80 carefully and robustly selected articles regarding their year of publication revealed a rising interest in this domain due to increased availability and technical innovations (Table 2). Almost half of the publications ( $n = 42$ ; 52.2%) were in 2019, close to one quarter of them ( $n = 22$ ; 27.5%) were in 2018, and the rest ( $n = 16$ ; 20%) were in 2017 or earlier (the earliest dated back to 2014). These figures prove similar trends to the former review studies confirming the growing interest in understanding acceptance and adoption intention determinants of autonomous mobility during the last few years via stated/revealed preference and choice experiments [23,24,26,89].

Most of the literature that was targeted to investigate the determinant factors on AVs' public acceptance and adoption intention, and attempted to uncover the nature of the relationship between psychological characteristics and preferences of several user clusters (as latent variables, which are not directly observable) using the demographic as well as trip and mobility behavior characteristics (as the observed variables, which could be directly measured). Even with the reporting of different viewpoints, most of them commonly used three theoretical frameworks i.e., TAM, TPB and UTAUT with data extracted from stated preference experiments mostly distributed online. Most of the reviewed studies targeted a random sample of the general population of a region [13,40], a country, or multiple countries [19,39,90] as their audience. Additionally, prior surveys mostly used structural equation modelling (SEM) [15,58,63,65,66,91], regression modelling and factor analysis [82,84,92] as their methodological approaches.







The categorization of the individual predictors is presented in detail in the following sections.

### 3.2. Demographic Factors

Common demographic factors that affect public perceptions on and adoption intention of AVs are listed in Table 3 and elaborated below:

- *Gender*: In terms of gender, most studies found that males are likely to be more interested in AVs [69,84,89], have greater intention to use or own them than females [13,132,142], be more willing to pay for AVs, less worried about them [39], and feel confident to let fully AVs to perform all functions [139]. Findings of a survey by Hohenberger et al. [108] also support this—i.e., mothers perceived more concerns towards letting their children be transferred by AVs with/without their parents, although some surveys reported a contradicting trend [143,144]. However, this experiment was conducted by only 32 participants and the gender difference was very low.
- *Age*: The impact of age on acceptance is varied. Most scholars investigated the age effects, reporting that young people are more open to AV technologies [117,132], whereas older people show a more negative attitude towards AVs [84], perceive AVs as less helpful and more challenging, and hence, they are less interested in riding in AVs [37,38], so they are less willing to pay for them [95,145]. In contrast, Kyriakidis et al. [39] and Nordhoff et al. [90] reported insignificant age impacts on perceptions and adoption intention of AVs. However, some research observed a positive relation between age and AV acceptance caused by perceptions of receiving more flexible and safer mobility, through gaining the experience of riding in a trial automated shuttle [33].
- *Education level*: Generally, the perceptions towards innovations are positively correlated with their potential users' educational level [92,121]. In the case of AV adoption, highly educated people tend to show more willingness to use AVs as they perceive them to be safer [128]. It seems that more educated people might have higher expectations, more positive attitudes and greater intention to use to AVs due to potentially having a better understanding of new technologies and trusting them more [37,38]. Likewise, Kyriakidis et al. [39] and Liu et al. [116] stated that well-educated people are willing to pay more for the AVs. In contrast, Zmud and Sener [60] argued that education level is irrelevant to the intention to use AVs.
- *Employment status*: Hudson et al. [109] reported that individuals' degree of comfort with self-driving vehicles decreased if they were manual workers, unemployed, retired and farmers. Additionally, they found that individuals whose work involves driving, like truck and taxi drivers, as well as travelling salesmen, were more positive than most.
- *Household income*: It has been demonstrated that willingness to pay for AVs is positively correlated with level of income [95]. Kyriakidis et al. [39] and Bansal et al. [40] observed that higher-income individuals are more willing to purchase AVs. Similarly, Howard and Dai [146] found a correlation between income level and AV adoption preference. Conversely, some other research findings revealed no relevance between income level and AVs' general acceptance [90] or intention to use AVs [24,60]. Hardman et al. [105] pointed out that "pioneers" or "pro-automated" users are likely to have the highest income, while AV "sceptics" or "laggards" may have the lowest income. However, there is not any clear trend regarding the willingness of individuals with different incomes to adopt different SAV commute modes, as their prices are not established yet [125].
- *Household structure*: Some studies identified a higher interest in AVs among households with children [13,22]. Accordingly, parents rated improving mobility to be the main advantage of AV adoption intention [19,112]. Parents also rated carpool arrangements to be more useful while parents cannot accompany their children in an AV—e.g., sending an AV to pick up children from school [112]. Such an outcome is in line with the findings of Haboucha et al. [92], who identified having children as a determinant motivator of SAV adoption.

- *Residential condition (type, size, and location)*: According to Regan et al. [143] and Hudson et al. [109] individuals residing in urban regions have greater interest in AVs and show more willingness to pay for them. Urban dwellers perceived AVs to be more beneficial than suburban residents [40,112].

### 3.3. Psychological Factors

Common psychological factors that affect public attitude towards AVs and intention to adopt AVs are listed in Table 3, and elaborated below:

- *Personal innovativeness (Tech savviness)*: AVs project an image of technological innovation, which can positively affect tech-savvy individuals' adoption trend [40,90,97]. This means that enthusiasts who are willing to try new technologies before others may perceive greater comfort and safety via AVs [60,121], and are likely to be early AV adopters [13,62,82,92].
- *Awareness of AVs*: Current knowledge about AVs seems to differ considerably across different socio-demographic clusters and might influence adoption likelihoods and concerns [11,97,99,134]. Interest in adopting AVs appears to be more generally among individuals who are familiar with technology and especially those who are more informed about various modes of AV services and their several benefits [19,39,126,136]. Nevertheless, negative information can decrease the intention to use, while positive information may increase AV acceptance [20,90,147].
- *Environmental concerns*: Concerns about pollutant emission impacts on global warming positively influence on the decision to use SAVs [83,148] as well as electric AVs [63,89]. In a survey by Brown et al. [149], consumers were concerned about environmental sustainability, highlighting the necessity of fuel efficiency improvement, and the expectation for governments and organizations to establish environmental targets.
- *Facilitating conditions*: The influence of facilitating conditions (in the same concept with "perceived behavioral control, self-efficacy, locus of control, compatibility and lifestyle fit" [26]) on the intention to adopt AVs was investigated in several studies [50,52,73,100,150]. Bennett et al., [97] stated that people, who think they can control events and outcomes by effort and ability, have an internal locus of control that might impact their intention to ride in AVs. According to Payre et al. [82], individuals with an internal locus of control seem to be less willing to use AVs than others.
- As the level of automation increases, perceived behavioral control and intention to use will decrease [56]. Thus far, many scholars indicated that people generally prefer, to some extent, to retain control over the AVs rather than completely handing over the control to the AVs. For instance, Hassan et al. [91] disclosed that 81% of the participants desired to partially control their vehicles as AVs are unlikely to be guaranteed. In Schoettle and Sivak [37,38] and Nordhoff et al. [90], most of the participants commonly wanted a control button to be in an AV. Conversely, Zmud et al. [13] found no correlation between the desire for control and intention to use, contrary to what many have hypothesized.
- Moreover, individuals' perceptions of AV and mode choice decisions are relatively associated with its consistency with their lifestyles, existing values and past experiences [79,104,125], whereas potential concerns could be correlated to AV complexity [67,146]. Besides, compatibility has been recognized to positively influence the perceived usefulness of AVs [56], whereas it indirectly affects attitude and intention [92,123]. Compatibility is expected to be a critical predictor of the uptake of AVs that may raise resistance towards innovation in the case of not being conformable with people's lifestyle [151].
- *Subjective norms (social influence)*: Social trust (reliance on people of the social circle) or peer pressure (social influence) have a positive impact on AV acceptance and may promote the willingness to pay as well [66,114]. Acheampong and Cugurullo [69] observed that social influence is positively correlated with AVs' perceived benefits and perceived ease of use. Brown et al. [149] pointed out that many customers consult with their friends or families when purchasing a vehicle.



- Moreover, Bansal et al. [40] pointed out that most individuals prefer to ride in AVs, specifically the shared ones, after their friends, families, and neighbors have adopted them. This stems from a public belief that cars are commonly considered as a status symbol (prestige), which emphasizes the correlation of intention to use with the social environment [13,123]. Nonetheless, according to Panagiotopoulos and Dimitrakopoulos ([66], p.782), the "more trust someone gets on his/her intention to use AVs, the less will be influenced by social norms (family, friends, etc.)".
- *Hedonic motivation (driving-related sensation seeking and pleasure)*: The tendency to seek novel, complex, and intense sensations and experiences (including taking driving risks) affects the intentions to use AVs [23]. Individuals who enjoy driving their vehicles and usually drive alone in most of their trips prefer to control their vehicle and are less likely to use AVs [92]. Nevertheless, a passionate driver might even enjoy getting a ride from an AV for the daily commutes with congestion, so the joy of driving may be limited to non-commuting trips [24].
- *Perceived usefulness and perceived ease of use of AVs*: These two factors of TAM theory (in the same concept with performance expectancy and effort expectancy in UTAUT theory) are positively correlated with the intention to use AVs [17,60]. In Nordhoff et al. [33], perceived usefulness and perceived ease of use were used as "shuttle effectiveness" measurement factors, which were related to comparing the performance of autonomous shuttles with participants' current commute modes, mainly determining the component of "intention to use". Depending on to what extent users perceive that AVs are easy to use, or the potential for an accident to occur [84], they determine whether or not they will use AVs.
- *Perceived benefits of AVs*: Some relative advantages of AVs are expected to be independent mobility for non-drivers (i.e., transport disadvantaged groups, disabled people, elderly people), increased productivity while travelling caused by multitasking, shorter travel time, less parking problems due to using on-demand services, lower insurance premiums, improved safety, greater environmental friendliness, relief from the stress of driving tasks, reduced vehicle ownership, enhanced fuel economy, the ability to drive after the use of alcohol or medication, congestion reduction, and the capability to send untenanted AVs to perform errands [8,19,40,69,84,93,98,104,112,118,141,152–157].
- *Perceived risks of AVs*: Expected disadvantages were more pronounced among the public regarding cybersecurity issues, safety issues, the learning curve to use AVs, ethical issues on personal privacy and data sharing (location or destination tracking), equipment or system failure, interactions with conventional vehicles and the other modes of transport, affordability of AVs, lack of control in a crash situation, and potential health issues due to modified lifestyle needs [8,35,80,91,92,109,110,123–125,129,133,139,144,150,151,154–166]. As for Sener and Zmud [85], most of the ride-hailing service users who were reluctant to use AVs, could not perceive them to be safer vehicles in all circumstances, so only preferred to adopt the ride-hailing service option of AVs. This is because they perceived there to be greater comfort in a "human override" mode due to the idea of better performance of humans in impulsive situations. Conversely, individuals who preferred private ownership of AVs believed that they could be safer than conventional vehicles [167–170].
- In other words, riders' level of confidence with not being behind a wheel, feeling comfort with surrounding vehicles, and privacy concerns, are likely to be related to their perceptions—e.g., higher perceived usefulness of AVs and lower perceived risks [39], intention to use and adoption of AVs [15,82]. This supports the findings of Nazari et al. [22], who stated that safety concerns may decrease interest in SAVs. While some consumers believe that AVs are likely to be liable for higher accident occurrence, some others agree that AVs could potentially reduce the prospective accident rates [40]. Individuals' general fears and concerns are found to increase hesitation to share data with intelligent transport systems (ITS), especially their personal information [100]. People will undoubtedly use AVs if they could be convinced that they can trust such innovative technologies regarding safety, data privacy or security protection aspects [66,126].
- Trusting other passengers, feeling comfortable while using SAV services (autonomous shuttles as public transport feeders, autonomous taxis, carsharing or ridesharing vehicles), and sharing

a vehicle while travelling with family members, regular friends, social media friends, or a stranger, can directly affect perceived usefulness, and behavioral intention to use AVs [92]. Cunningham et al. [102] reported that “riding in a self-driving public transit” vehicle and “sharing a self-driving car” were the least favorable options amongst respondents. According to Bansal et al. [40], 50% of participants were comfortable sharing rides with strangers only for short drives.

- Additionally, the extent to which an AV carries out a trip as anticipated or scheduled is found to make users concerned [125]. In other words, the uncertainty of users as to whether they can arrive at the destination on time or not negatively affects intention to use AVs [122]. Zmud and Sener [60] found that deficient trust in AVs was the reason for nearly 41% of the participants not intending to use AVs as their everyday commute mode. Abraham et al. [146] revealed that more trust in driverless vehicles’ design and further comfort with full automation is correlated to the willingness to pay more for AVs. Acceptance and trust in AVs considerably increased after initial exposure to fully AVs but it did not change that much after several ride experiences [106].
- Perceived benefits and perceived risks are the key determinants of public acceptance of, intention to use, and willingness to pay for, AVs [15,16,111,114], despite some existing contradictory reports regarding no contribution between perceived risks and intention to use AVs [114]. As for Payre et al., [82], such inconsistency stems from dissimilar AV deployment contexts—e.g., “different road types, driving environments, and/or physical/mental status” ([56], p.414). Risk perception of potential AV customers might make them think twice before choosing a transit mode that substantively decreases their control of prospective situations, and, consequently, this could affect their perceived benefits as well as those of decision-makers of the daily commute mode. Thus, the potential involvement of users in AV technology is likely to be greater if their prospective benefits have properly converged, and decision-makers introduce suitable and effective solutions for a safer commute of potential users, to increase acceptance of such novelties [33,90,121].

#### 3.4. Mobility Behavior Factors

Common mobility behavior factors that affect public perceptions on and adoption intention of AVs are listed in Table 3, and elaborated below:

- *Vehicle ownership*: Some previous studies suggested that car owners who use their automobile regularly are more likely to purchase private AVs [39,104]. Similarly, AVs make private ownership more favorable for individuals, who currently do not own cars since they will not need to drive the vehicle themselves [125]. *Driving license*: Bansal et al. [40] observed that individuals who have a driving license are less willing to adopt SAVs as a frequent model.
- *Exposure to in-vehicle technologies*: Studies that explored existing vehicles’ levels of autonomy found a positive relation to their owners’ insights towards AVs [157]. These respondents seem to be more open to emerging technologies, as they already tried using and trusting systems (e.g., cruise control), which relieved them from the full responsibility of driving [24,39].
- *In-vehicle time*: Travelers expressed a more negative attitude towards in-vehicle time in AVs than in conventional vehicles as they did not perceive the hypothetical advantage of being able to do more productive activities during riding in AVs, maybe due to an uncomfortableness they were feeling when imagining riding in AVs, which is attributable to having no real experience of travelling in AVs [6,141].
- *Commute mode choice*: Current automobile users [83] seem to be in favor of both shared as well as private AVs, however, Zmud and Sener [60] reported a converse attitude and found them more hesitant to adopt AVs than users of other transit modes, while there is a great likelihood that multi-modalists adopt shared ones [83], indicating “differences in travel behavior implications between SAV and PAV ownership models” ([136], p.7). Accordingly, the intention to use AVs is higher amongst commuters who use ride-hailing services for the long-term [62].

- *Driving frequency:* According to Nordhoff et al. [90] and Shabanpour et al. [133], people who drive greater VKT are more positive toward AV technology, and are more willing to pay for fully AVs [39,40]. This is because individuals who drive frequently may have to tolerate more fatigue, stress and another consequent factors correlated with long driving tasks, and consequently they are highly intended to use AVs for their transportation [121].
- *Crash history:* Respondents that had more driving experience and former contributions to conventional car-based traffic accidents perceived AVs as safer alternatives for daily transport [40].
- *Trip purpose:* People may intend to use autonomous shuttles in bad weather conditions, in closed areas (e.g., exhibitions, large factories, airports, university campuses, retirement homes, hospitals), in suburban districts which are generally unserved by public transit, in urban touristic/unfamiliar regions, for the transport of goods, or for one-way travel [26].
- *Daily travel time:* Individuals who have longer daily travel times are anticipated to have higher intention to use AVs [125], as travel time is likely to be decreased since connected AVs could potentially predict and escape from bottlenecks and drive in platoons [6].
- *Mobility impairments:* Studies observed more intention to use AVs amongst the disabled group [13]. Disability or physical conditions prohibiting people from driving are assumed to be significant motivators of AV acceptance [123]. Such findings add to prior literature, which indicated that the mobility of the transport-disadvantaged population could be potentially facilitated by AVs [67,91,114].

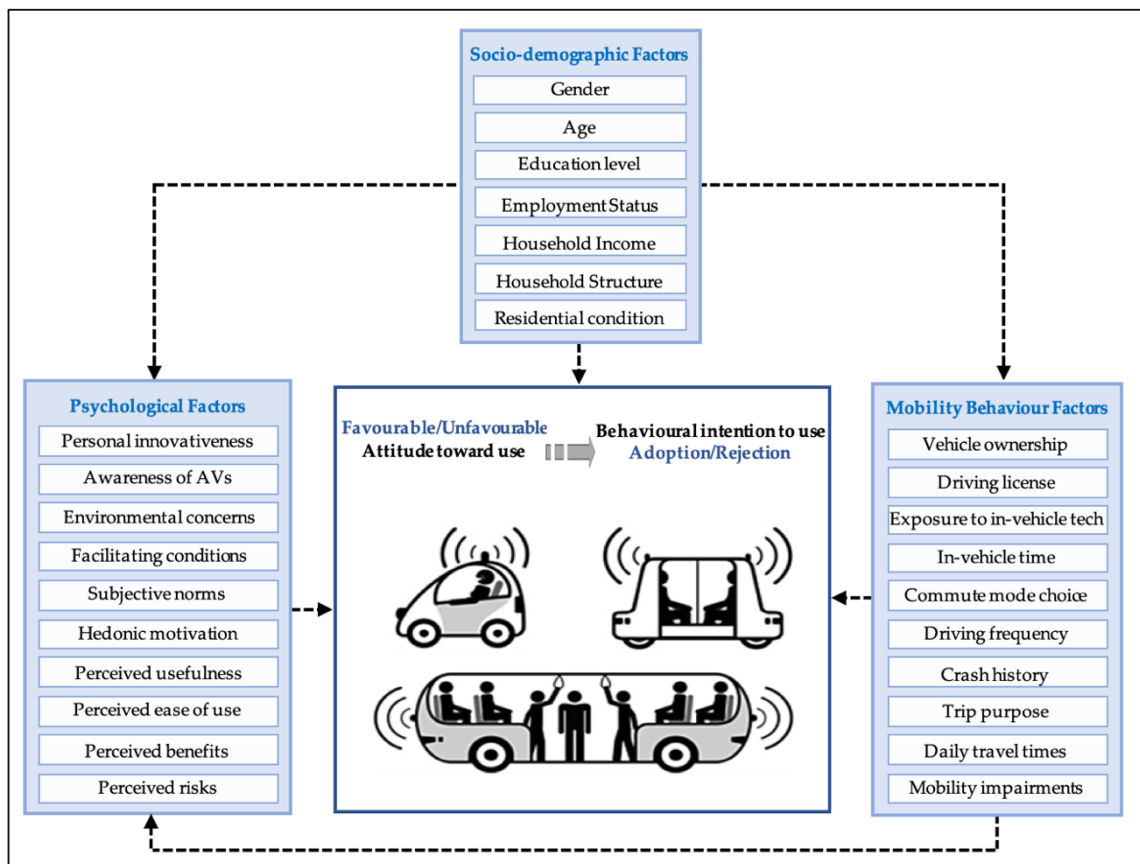
#### 4. Discussion

The prospective impacts of AVs are subject to how likely it is that such technologies will be accepted and used. Henceforth, as underlined by Pettigrew et al. [128] and Sener et al. [62], continuous monitoring and tracking intention to use the emerging AVs as a smart mobility solution is critical. Despite the application of various methodological approaches, data sources, and components, all of the reviewed research studies follow a common objective: “building an evidence-based consensus through continuous measurement of acceptance and potential adoption of AVs” ([62], p.66).

In order to complement the systematic literature review findings, this study developed a conceptual framework of individual determinant factors of behavioral intention to use AVs (Figure 2) based on the main technology acceptance theories presented in Section 2 (i.e., TAM, TPB, and UTAUT) that have good explanatory power for predicting the behavioral intentions and adoption decisions of the potential users. According to this conceptual framework, three main categories of individual determinant factors are comprised of demographic characteristics (i.e., gender, age, education level, employment status, ethnicity, household income, household structure, residential condition), psychological characteristics (i.e., personal innovativeness, awareness of AVs, environmental concerns, facilitating conditions, subjective norms, hedonic motivation, perceived usefulness, perceived ease of use, perceived risks/benefits) as well as mobility behavior characteristics (i.e., vehicle ownership, driving license, exposure to in-vehicle technologies, in-vehicle time, commute mode choice, driving frequency and annual VKT, crash history, trip purpose, daily travel times, mobility impairments).

These interrelated factors consequently form either positive (favorable) attitudes or negative (unfavorable) attitudes towards AVs, which influence individuals’ behavioral intention to ride in AVs and adoption/rejection decisions. Moreover, people are likely to decide to adopt different types of AV use—e.g., private ownership, shared ownership or shared use—based on their perceptions and preferences [89] that can be directly affected by individual factors as well. This conceptual framework can be applied to gain a better understanding of the determinants of individuals’ behavioral intention to use AVs to inform urban and transport policymakers, managers, and planners on the influential factors of public acceptance and adoption intention of AVs, which is critical to plan for a healthy AV adoption with minimized societal disruption. Nevertheless, it is expected that AV adoption trends and intention to use will probably change since such innovative services become more commercially

available [136], so doing alternate studies and running further stated preference experiments are critical to test prospective market interest.



**Figure 2.** Conceptual framework of individual determinants of AV public acceptance and intention to use (Source: Authors).

It is also helpful to increase the predictive power of “technology assessment models” in the context of vehicle automation through finding additional factors affecting AV adoption [66] and their interrelations [23], as well as proficiently capturing the weight of the influential components [26] for more accurate predictions.

## 5. Conclusions

Developments in artificial intelligence (AI) and smart cities domains have provided opportunities for new urban mobility innovations, where AV technology is a prominent one [171–175]. The culture of open innovation has also accelerated the opportunities for the development of smart mobility solutions [176–179]. The study at hand explored the highly multidimensional nature of AV acceptance and intention to use (Table 2) to provide a clearer picture of the individual factors influencing public attitudes towards AVs and their adoption decisions. The findings show that:

Public perceptions and adoption intentions vary significantly among different socio-demographic cohorts. In the light of the reviewed literature, it is anticipated that early adopters of AVs are likely to be males, young people, highly educated, with higher incomes and larger households, as well as living in a denser neighborhood. Their motivator would be knowledge of AVs, technology savviness, having fewer privacy concerns and positive safety perceptions. However, the current ownership of a vehicle with an advanced driving assistance system, commuting as a driver in carpool arrangements, having automobile collision history and currently commuting longer distances were also found to increase willingness to adopt AVs [8]. In a similar vein, the intention to use AVs differs from one place

to another. For instance, AVs are likely to be favorable modes for people in areas with high current crash occurrence since AVs are anticipated to reduce the car insurance rate differences on an age and gender basis, irrespective of future overall insurance rates [109].

Along with the highlighted findings, there is still a need for better understanding the effects of demographic characteristics—e.g., income, education and age—since AVs as first mile/last mile solutions are more likely to target transport-disadvantaged populations such as senior citizens and people with disabilities according to their special needs and preferences [74,112]. This is because, apart from driving, there are restricted mobility choices for senior citizen travelers (including cyclists, drivers, pedestrians, passengers), which may negatively affect people and their families, as well as the community at large [91]. Thus, improved mobility leads to enhanced quality of life and wellbeing outcomes [180].

Further research is also required to focus on the correlation between intention to use AVs and changes in travel behavior, especially for commuting purposes. This is because commuters' value different aspects concerning AVs, which shape their intentions on acceptance and adoption. Additionally, trip takers were found to be more likely to intend to ride fully AVs in monotonous driving conditions, for instance on highways, in traffic congestion [40] or for automatic parking [82]. Perceived benefits of AVs positively affect attitudes towards AVs, while perceived risk is a determinant of negative attitude towards AVs, signifying that if an individual perceives high risk in riding in an AV, there would be less willingness to use and pay for an such innovation, as an individual cannot accrue benefit from an AV; however, there is some variation among different user clusters.

Different policies and incentives are leading to different systemic impacts on promoting wider AV adoption [181–183]. Policymakers and planners across several disciplines—e.g., local, state and national governments, and urban and transport planners—could be involved in filling the gap in understanding how AVs impact other domains to introduce communal strategies for broad AV deployment. According to [20], the individual's distrustful views about AVs indicate that their opinions are unlikely to be simply influenced by promotions, although this negativity is mostly based on misconceptions and ignorance and does not have any real knowledge base. Consequently, direct experience of AVs along with education/communication will help change individuals' attitudes towards AVs and convince skeptical clusters of their merits, and thus change people's attitudes towards AVs in a positive way. In this regard, the role of the media in shaping public perceptions should have been taken into consideration.

Furthermore, understanding individual predictors of AV public acceptance and intention to use will inform decision-making in developing policies and actions to make more smart and sustainable mobility and urban systems in cities [184–190]. Lastly, when interpreting the findings, the following study limitations should be considered: (a) A risk of bias assessment and a quality appraisal of the included studies; (b) a lack of incorporation of the views of other stakeholders, who are potentially involved in using, operating, or determining the diffusion of this emerging technology; (c) there is no focus on the areas considering the global situation; (d) the selection of search keywords; (e) authors' unconscious bias, and; (f) the use of a manually handled literature review technique.

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