UNIVERSITY OF LJUBLJANA
SCHOOL OF ECONOMICS AND BUSINESS

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AN ANALYSIS OF FACTORS OF THE ADOPTION OF AUTONOMOUS VEHICLES AMONG MILLENNIALS

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AUTHORSHIP STATEMENT

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To all who have tried to understand me and not given up on me in the last few years.

And …

I would not have come this far had over 15 years ago I not fallen in love with running, which has taught me so many lessons, built me up as a person, and often provided me with an escape from reality.

SUMMARY

Conversations in recent years about the transport industry and mobility have often included the topic of autonomous driving, which promises a revolution comparable to the one from horse-drawn carriages to the internal combustion engine in the early 20th century. Although the technology today already enables fully autonomous driving, before autonomous vehicles (hereafter: AVs) will appear on our roads in large numbers, several pressing dilemmas must be resolved, including understanding of the end users/potential adopters of AV. The contribution made by the doctoral dissertation lies precisely in the latter by examining the factors in the adoption of AVs among millennials, who are often considered to be early adopters of new technologies, with a view to answering three research questions concerned with what affects millennials' decisions to adopt Avs. Factors for an AV adoption model were identified in the literature, which also assisted while preparing the questionnaire as part of the survey. The questionnaire was administered in mid-2020 using a sample of 359 millennials attending a university business school. The analysis was performed using the LISREL software tool where the validity of the measurement model was first checked and the fit indices analysed. All 10 previously established hypotheses were confirmed and on that basis recommendations were made to key stakeholders in the transport industry.

The importance of safety was found to still prevail over other factors given its potential to reduce general concerns and directly influence consumers' willingness to adopt an AV. Although privacy concerns are less of a concern than safety, they nevertheless affect general concerns. Car manufacturers should thus continue to prioritise safety, present the vehicles' safety features, and via tests demonstrate that AVs are equal to, if not better than, human-operated vehicles. In terms of privacy, millennials in Europe may feel protected by the GDPR or may simply be unaware of what they are sharing, making it beneficial to increase consumers' awareness of privacy issues concerning not just AVs, but all services and products that invade privacy in any way. Further research into how privacy concerns arise and what triggers them would also be useful. General concerns, technological excitement and social factors affect attitudes to AVs to a similar extent. Social factors and technology enthusiasm were confirmed to positively influence attitudes to AVs, which can help determine the early target market for such vehicles – technologically enthusiastic highly-respected/influential millennials. Perceived benefits were found to be slightly less important with respect to forming a positive attitude to AVs. To increase awareness of the benefits and measures taken to ensure safety and reduce the concerns of millennials, car manufacturers should offer test and demonstration drives, especially in risky weather conditions, e.g., icy surfaces or heavy rain. A more positive attitude to AVs can also be encouraged by an appropriate supportive/facilitating environment and thus a similar incentive approach as used for electric vehicles could be applied to increase AV adoption, noting that governments are mainly responsible for regulatory frameworks that should be formulated cooperatively with different stakeholders. The results show the attitude to AVs depends on a wide range of factors, and given that a negative attitude is not easily turned around, car manufacturers should strive from the outset to create a positive attitude among millennials because, alongside greater facilitating conditions and higher perceived safety, it affects the intention to adopt an AV.

Keywords: autonomous vehicles, AV adoption, AV adoption factors, technology adoption

POVZETEK

V zadnjih letih se v pogovorih o transportni industriji in v povezavi z mobilnostjo večkrat srečamo s tematiko avtonomne vožnje, ki obljublja revolucijo, primerljivo s prehodom od konjskih vpreg do vozil na motor z notranjim izgorevanjem na začetku 20. stoletja. Hitrost tehnološkega napredka že omogoča popolnoma avtonomno vožnjo, preden pa bodo avtonomna vozila (v nadaljevanju: AV) množično prisotna na naših cestah, morajo biti rešene številne dileme, med katerimi je tudi razumevanje končnih uporabnikov/posvojiteljev AV. Prispevek doktorske disertacije je ravno v slednjem, saj preučuje dejavnike privzemanja AV med milenijci, ki se pogosto opredeljujejo za zgodnje posvojitelje novih tehnologij, z namenom, da odgovori na naslednja tri raziskovalna vprašanja: 1. Kateri dejavniki vplivajo na pripravljenost milenijcev za privzemanje AV? 2. Ali družbeni dejavniki in pomisleki glede zasebnosti v dobi avtonomnosti vplivajo na pripravljenost na privzemanje AV med milenijci? 3. Kakšen je učinek tehnološkega navdušenja pri privzemanju AV med milenijci? Dejavnike za model privzemanja AV smo identificirali iz obstoječe literature, ki je služila tudi za pripravo anketnega vprašalnika. Raziskavo smo izpeljali v sredini leta 2020 in v vzorec zajeli 359 milenijcev na univerzitetni poslovni šoli. Za analizo smo uporabili programsko orodje LISREL in najprej preverili veljavnost mernega modela ter analizirali fit indekse. Vseh 10 predhodno postavljenih hipotez smo potrdili in na njihovi osnovi podali priporočila ključnim deležnikom transportne industrije.

Ugotovljeno je bilo, da pomen varnosti še vedno prevlada nad drugimi dejavniki v njeni zmožnosti zmanjšanja splošnih skrbi in neposrednega vpliva na pripravljenost na privzem AV. Zaznati je tudi pomisleke glede zasebnosti, ki so manj zaskrbljujoči kot varnost, a prav tako vplivajo na splošne skrbi. Zato bi morali proizvajalci avtomobilov še naprej dajati prednost varnosti, predstavljati implementirane varnostne funkcije in s testi potrditi, da so AV enaki, če ne boljši od vozil s človekom za volanom. Kar zadeva zasebnost, se milenijci morda počutijo zaščitene z GDPR, ali pa se premalo zavedajo, kaj delijo, zato bi bilo koristno povečati zavedanje o zasebnosti med uporabniki, ne samo AV, temveč v splošnih storitvah/izdelkih, ki se kakor koli dotikajo zasebnosti. Koristne bi bile tudi nadaljnje raziskave o tem, kako nastanejo skrbi glede zasebnosti in kaj jih sproža. Splošne skrbi, tehnološko navdušenje in družbeni dejavniki v podobni meri vplivajo na odnos do AV. Potrjeno je bilo, da družbeni dejavniki in tehnološko navdušenje pozitivno vplivata na odnos do AV, kar lahko pomaga identificirati zgodnji ciljni trg tržnikov – to so tehnološko navdušeni visoko cenjeni/vplivni milenijci. Zaznane koristi so imele nekoliko manjši pomen za pozitiven odnos do AV. Da bi povečali ozaveščenost o prednostih in uporabljenih ukrepih zagotavljanja varnosti ter zmanjšanja skrbi, bi morali proizvajalci avtomobilov ponuditi testne in predstavitvene vožnje, zlasti v tveganih vremenskih razmerah, npr. ledeno cestišče ali močan dež. Bolj pozitiven odnos do AV je lahko tudi rezultat ustreznega podpornega/olajševalnega okolja, zato bi lahko bil za povečanje privzemanja AV uporabljen podoben pristop s spodbudami kot za električna vozila, vlade pa so v glavnem odgovorne za regulativne okvire, kjer bi morale sodelovati z različnimi deležniki. Glede na naše rezultate je odnos do AV odvisen od širšega nabora dejavnikov in upoštevajoč dejstvo, da negativnega odnosa ni enostavno spreobrniti v nasprotno, bi si morali proizvajalci avtomobilov že od samega začetka prizadevati za oblikovanje pozitivnega odnosa med milenijci, saj ta poleg boljših olajševalnih pogojev in višje zaznane varnosti vpliva na namero za privzem AV.

Ključne besede: avtonomna vozila, privzemanje avtonomnih vozil, privzemanje tehnologije, dejavniki privzemanja avtonomnih vozil

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LIST OF ABBREVIATIONS

sl. – Slovenian

χ^2 – chi-square test

ABS – anti-lock braking system

ADS – automated driving system

AGFI – (sl. prilagojen indeks primernosti); adjusted goodness-of-fit index

AIC – (sl. Akaike informativni kriterij); Akaike information criterion

AV – (sl. avtonomna vozila); autonomous vehicle

AVE – (sl. povprečno izračunana varianca); average variance extracted

CAIC – consistent Akaike information criterion

CFI – (sl. primerjalni indeks prileganja); comparative fit index

CTAM – Car Technology Acceptance Model

CR – (sl. kompozitna zanesljivost); composite reliability

DDT – dynamic driving task

DRS – driver steering recommendation

ESC – electronic stability control

EU – (sl. Evropska unija); European Union

FCW – front collision warning

GDPR – General Data Protection Regulation

GFI – (sl. indeks primernosti); goodness-of-fit index

LDW – lane departure warning

LISREL – linear structural relations

NFI – (sl. normirani indeks prileganja); normed fit index

NHTSA – National Highway Traffic Safety Administration

ODD – operational design domain

PDC – park distance control

PGFI – (sl. skromnostni indeks primernosti); parsimony goodness-of-fit index

PNFI – (sl. normirani skromnostni indeks prileganja); parsimony normed fit index

RMR – (sl. povprečni kvadratni ostanek); root-mean-square residual

RMSEA – (sl. koren povprečne kvadrirane napake); root-mean-square error of approximation

SAE – Society of Automotive Engineers International

SEM – (sl. modeliranje strukturnih enačb); structural equation modelling

SDGs – Sustainable Development Goals of the United Nations

SPSS – Statistical Package for the Social Sciences

SRMR – (sl. standardizirani povprečni kvadratni ostanek); standardised root-mean-square residual

TAM – (sl. model sprejemanja tehnologije); Technology Acceptance Model

USA – United States of America

UTAUT – Unified Theory of Acceptance and Use of Technology Model

UTAUT 2 – (sl. enotna teorija sprejemanja in uporabe tehnologije 2); Unified Theory of Acceptance and Use of Technology Model 2

VIF – (sl. factor inflacije variance); variance inflation factor

INTRODUCTION

Research problem and research area

It is widely believed that an autonomous future is inevitable. Still, it is not yet sure in what form, when and how it will become a reality. AVs are vehicles that contain some level of automation that either replaces or assists a human while driving (Narayanan et al., 2020, p. 1), and they are expected to significantly transform both the transport industry and everyday living (Shabanpour et al., 2018, pp. 463–464). AVs are defined on six levels, starting with level 0 which indicates no automation, while level 5 is a fully autonomous vehicle that can perform all driving functions even in the absence of a driver who then becomes a passenger or is even completely absent from the vehicle (SAE International, 2018, pp. 4, 33). There are however intermediary levels of autonomy that incorporate technologies which assist or replace the driver in their driving effort (Payre et al., 2014, p. 253), with some of these already in place today. Incumbent car manufacturers as well as new industry entrants are trying to position themselves in the market (International Transport Forum, 2015, p. 13; Skeete, 2018, p. 28), and despite them primarily being competitors, cooperation and partnerships among them could prove beneficial for them (Heineke et al., 2017, p. 8). This dissertation considers fully AVs of level 5 according to SAE International (National Highway Traffic Safety Administration, 2016, p. 9), namely, a more distant and controversial phenomenon that is a bigger cause of concern for most people. This means a thorough understanding of the factors that affect user acceptance is needed as they can determine the success of AVs in the marketplace (Nastjuk et al., 2020, p. 2). It was not clear in 2014 how AVs would develop (Howard & Dai, 2014, p. 8) and even today it remains unclear what types of vehicle business model(s) will enter the market. Therefore, this dissertation takes a similar position as Nastjuk et al. (2020, p. 2) by focusing on the general acceptance of AVs rather than a specific ownership scenario in order to first understand the basic influencing factors that can then be applied to particular scenarios.

AVs have been praised for the numerous benefits that could be realised, including their contribution to safety (Deb et al., 2017, p. 179; Xu et al., 2018, p. 321). Even though the literature points in both directions, i.e., increasing or decreasing safety on the roads, a recent review by Nascimento et al. (2019, p. 4931) showed that 81% of articles considered reported increased safety as a result of the artificial intelligence implemented in AVs. It is claimed that road conflicts/rage could fall from 12% to almost being fully eliminated depending on AV penetration rates (Papadoulis et al., 2019, p. 19; Virdi et al., 2019, p. 107). Nevertheless, promised safety is not necessarily the same as perceived safety as formed in the minds of potential adopters. Individuals would need at least 2 years after AVs have been introduced to the market before they would start considering using them (Othman, 2021, p. 357), and the risk of AVs would have to be four to five times lower before AVs would be accepted to a similar extent as human-operated vehicles (Liu, Yang, et al., 2019a, pp. 320–321).

Accordingly, safety can work to either facilitate or inhibit AV adoption. Other benefits that might persuade potential adopters to drive an AV are reduced congestion and the need for parking lots, their lower environmental impact, the more efficient in-vehicle time, the increased mobility of elderly and children, and shorter travel times (Ercan et al., 2022, p. 14; Y.-C. Lee & Mirman, 2018, p. 416; Stager et al., 2018, p. 134; Wadud et al., 2016, p. 5; Yang & Coughlin, 2014, p. 333). On the other hand, potential adopters' concerns refer to legal issues, hacker attacks, questionable safety, unexpected traffic situations, questionable liability, equipment or system failure, and increased dependency on technology and machines (Bansal et al., 2016, p. 3; Hulse et al., 2018, p. 9; M. König & Neumayr, 2017, pp. 43, 48; Kyriakidis et al., 2015, p. 136). Data sharing is needed for vehicle communication and coordination, which means a considerable amount of personal data is shared, raising privacy concerns and thus assurances must be given that the data are not used in an unauthorised way either against users or by hackers (Jadaan et al., 2017, pp. 642–643; Le et al., 2018, p. 18; T. Zhang et al., 2019, p. 211).

Like safety, legislation and infrastructure can also be on either side of the coin. If they are assured/present, they will act as a supporting mechanism for adoption, while if they are missing the idea of adopting an AV will be questioned by potential users. Regulatory changes are constantly lagging behind the progress made by technology (Juhasz, 2018, pp. 47–48), where it is noted that the United States of America (hereafter: USA) is well ahead Europe (Punev, 2020, p. 96). Nevertheless, sufficient, complete and supporting regulation is critical for enabling the introduction of AVs and to limit their negative side effects (Duranton, 2016, p. 194; S. H. Kim et al., 2020, p. 1; Wadud et al., 2016, p. 12). Legislation has to provide answers to questions about flexibility, standardisation, and the uniformity of policies, whether the policies on AVs should complement those for conventional vehicles or be separated, with respect to offering (dis)incentives and much more (International Transport Forum, 2015, pp. 26–27; Medina-Tapia & Robusté, 2018, p. 210; Skeete, 2018, p. 28). There is a need to redesign the current road infrastructure to enable road users to participate in road traffic, including cyclists and pedestrians (Narayanan et al., 2020, p. 26; Rouse et al., 2018, p. 14), where by observation we may add e-scooters, and to determine who or what (people or artificial intelligence) is liable in the event of accidents (Hulse et al., 2018, p. 2).

Perceived safety is one of the most important factors that individuals weigh up while deciding to adopt an AV or not (Osswald et al., 2012, p. 55), and positive perceptions of safety could be a driver of AV adoption (Montoro et al., 2019, p. 869; Moody et al., 2020, p. 643). Conversely, higher risk perceptions would negatively influence the intention to adopt an AV (Meidute-Kavaliauskiene et al., 2021, p. 14). Less strong yet still present are concerns about privacy (Kyriakidis et al., 2015, p. 133), and the absence of privacy and security could lead to lower consumer acceptance of AVs (Raj et al., 2020, p. 132; Waung et al., 2021, p. 336). Studies show that more tech-savvy/enthusiastic individuals will consider using an AV earlier on (Asmussen et al., 2020, p. 7; Tennant et al., 2019, p. 108). Individuals might also feel excited about the potential benefits brought by AVs, which would positively influence their attitudes and intentions (Herrenkind et al., 2019, p. 15; Nastjuk et al., 2020, p. 10). More hesitant individuals might come to view AVs positively if they are influenced by important others (T. Zhang et al., 2020, p. 223), whereas Herrenkind et al. (2019, p. 15) found that one's social network positively influences the attitude to autonomously driven public buses. These are just some of the possible influences individuals must consider while weighing up whether they are in favour of AVs or not. Although the adoption factors are not uniformly understood in the literature, the biggest issue to overcome before AVs can widely appear on our roads is their acceptance by end users where understanding how they view them is crucial for subsequently finding ways to make them see AVs in a more positive light.

Research purpose and goals

Early AV research generally focused on the technological aspects. A literature review by Rosenzweig and Bartl (2015, p. 9) concluded that over 90% of articles they considered focused on the technological aspects of AV, with a negligible 1.3% focused on the adoption perspective. In the last few years, the emphasis has shifted to more behavioural and consumer-centred aspects in order to deepen the understanding of how consumers view AVs from several perspectives. If potential users are not in favour of using the available technology, the promised benefits obviously cannot be realised (Asmussen et al., 2020, p. 2). Potential adopters' attitudes to AVs must accordingly be assessed (Ruggeri et al., 2018, p. 40) to ensure understanding of what affects AV adoption, how to fight the concerns, and what to invest in (Haboucha et al., 2017, p. 38; Osswald et al., 2012, p. 57). Once these are understood, it will also become easier for the authorities to work cooperatively to deliver individuals' visions, where failure to do so would make mass adoption impossible. A special value of this dissertation is that it contributes to understanding millennials, namely the rising working generation in the market, in terms of their perceptions and attitudes to AVs as this may hold important implications for car manufacturers, policymakers and investors in their future endeavours.

The goal of this dissertation is to identify the relevant factors influencing millennials' adoption of AVs and incorporate them in an AV adoption model. The adoption factors are deduced from the current literature and cover both encouraging and discouraging (acceptance and rejection) aspects, as suggested by certain authors (Davis, 1985, p. 133; Huang & Qian, 2021, p. 684). The proposed model will build firmly upon established adoption models, i.e., the Technology Acceptance Model (hereafter: TAM) and the Unified Theory of Acceptance and Use of Technology Model 2 (hereafter: UTAUT2), and consider the following relevant constructs used there: perceived usefulness/performance expectancy, attitude toward using, facilitating conditions, social influence, and behavioural intention, adapted to the AV context, since authors have stressed the need to consider the contextual factors of a technology in question (Dwivedi et al., 2019, p. 719; Kapser & Abdelrahman, 2020, p. 220). Moreover, specific factors only relevant to AVs will be added to the model, namely, perceived safety, privacy concerns in the AV era, general concerns, and technological enthusiasm.

Research questions

In this doctoral dissertation, the main area of research is AV adoption factors that affect millennials. The research problem was explored by considering three research questions:

– RQ1. Which factors affect millennials' willingness to adopt an AV?
– RQ2. Do social factors and privacy concerns in the AV era affect millennials' willingness to adopt an AV?
– RQ3. What is the effect of technological enthusiasm in millennials’ adoption of AVs?

The first research question (RQ1) arises from the need to define factors in the adoption of AV technology because it has been pointed out by many researchers as crucial to succeed in the marketplace and for reforming transportation and mobility systems (Liu, Guo, et al., 2019, pp. 306–307; Nastjuk et al., 2020, p. 2). The first step in the research was exploratory in nature to identify relevant AV adoption factors in the literature and test the proposed relationships. Considering that model development is an iterative process (Osswald et al., 2012, p. 58), the model was refined by modifying the initial model by excluding statistically non-significant factors and including additional factors – context-specific factors and factors that originate from well-established adoption models (i.e., TAM and UTAUT2), i.e., facilitating conditions, privacy concerns in the AV era, and social factors. These were proven relevant in the literature following the initial model proposition. By considering the refined model, that is, the model of AV adoption proposed in this dissertation, the second (RQ2) and third research questions (RQ3) were aimed at determining the role of three specific factors in the AV adoption process: technological enthusiasm, social factors, and privacy concerns in the AV era.

Data and methodology

The research entailed a literature review and the use of well-established adoption models to create and test an AV adoption model. The literature review was used to gain insights into the topic with a view to developing a model and preparing a questionnaire. The mentioned questionnaire was prepared specifically for the research purposes and relied on measurement items taken from the literature. A definition of AV and explanation of the various AV levels considered was also provided in questionnaires in order to avoid misinterpretation by the participants. In addition to demographic questions, the main areas of the questionnaire referred to attitudes to AVs, AV challenges, AV concerns, AV safety, AV benefits and AV privacy. Millennials were engaged to complete the questionnaire and the sample was drawn from among students attending a business school. Millennials comprise the generation born between 1981 and 2000 that is more familiar with modern technologies than any previous generation, open to change, and driven by keeping up with the latest trends (Bolton et al., 2013, p. 246; Brosdahl & Carpenter, 2011, p. 549; Ordun, 2015, pp. 42, 44). The fact they have been recognised among the early adopters of shared mobility services (Azimi et al., 2021, p. 2) justifies the research sample selection. The collected data were inspected, cleansed, and descriptively analysed. Multicollinearity, normality, and common method variance tests were conducted. The hypotheses were empirically verified using structural equation modelling (hereafter: SEM). Alongside testing the hypotheses, the measurement model and model fit were assessed.

Structure of the doctoral dissertation

The dissertation is structured as follows. The first chapter introduces the technology that facilitates AV and defines the levels used to describe the extent to which an AV assist/replaces the driver. The chapter touches on the legislative aspects and explains the need created by AVs to change road and other infrastructure. The implications of the widespread introduction of AVs are reviewed both from positive and negative points of view with respect to their benefits, the possibilities of developing a new business model, the safety issues they raise, and general and privacy concerns. The second chapter first introduces adoption and adoption categories before continuing to describe different well-established adoption models relevant to the present study. The role of attitudes, intention, technological enthusiasm, social factors, and socio-demographic characteristics in AV adoption is then considered. In the third chapter, a research model of AV adoption is developed while the proposed relationships/hypotheses are justified. The fourth chapter details the methodological approach selected and presents the questionnaire with corresponding references, the sample selection and data collection process. The fifth chapter outlines the results, first, by explaining the characteristics of individuals and their views on AVs, and the representativeness of the sample. The preliminary analysis results are presented next, followed by detailed consideration of the measurement model and the model fit. The main hypotheses of the dissertation are tested in the final section of the chapter. The sixth chapter discusses the results in terms of their relevance, links to previous research, and practical implications. Moreover, the research questions are answered and scientific contributions summarised. The last part of the chapter acknowledges the limitations of the study and proposes several avenues for future research.

1 AUTONOMOUS VEHICLES

1.1 Introduction to autonomous vehicles and levels of automation

AVs are also known as automated vehicles or self-driving vehicles (Fagnant & Kockelman, 2015, p. 167; Hulse et al., 2018, p. 2) and are vehicles that contain some level of automation which either replaces the human driver or assists them while driving (Narayanan et al., 2020,

p. 1). Being a relatively novel technology, AVs are expected to bring dramatic changes to the transport industry once they enter into widespread use (Fagnant & Kockelman, 2015, p. 167; Haboucha et al., 2017, p. 48).Such vehicles have recently attracted the interest of the public and researchers and become a strategic focus of policymakers and automotive companies around the world (Adnan et al., 2018, p. 822; Narayanan et al., 2020, p. 1; Xu et al., 2018, p. 321). Several semi-autonomous features are already available (Daziano et al., 2017, p. 151) and automotive companies are either installing diverse automated driving systems into their vehicles or developing AVs that do not require any human input to drive (Fagnant & Kockelman, 2015, p. 352; Fleetwood, 2017, p. 167). To avoid misinterpretation in the dissertation, the different levels of AVs and corresponding terms are first outlined below.

Many references are made in scientific literature to the taxonomy and definitions provided by the Society of Automotive Engineers International (hereafter: SAE) and adopted by the National Highway Traffic Safety Administration (hereafter: NHTSA) (National Highway Traffic Safety Administration, 2016, p. 9). The NHTSA considered the standardisation of AV terminology to be essential if progress is to be made in the field because only clear and consistent terminology can ensure unambiguous findings on which to build (U.S. Department of Transportation, 2018, p. vi). The SAE proposed six levels of automation (SAE International, 2018, p. 19) defined according to the expected role of the three central actors in driving: the (human) user, the driving automation system, and other vehicle systems and components (SAE International, 2018, p. 2). First, AVs must be distinguished from conventional vehicles. A conventional vehicle is operated by a conventional driver for some or the whole of a journey. Such a vehicle can either have no driving automation features or incorporate some automation features that might be used to a limited extent and still require a human driver to be present and engaged in the driving (SAE International, 2018, pp. 4–5). Some features of automation can be incorporated into conventional vehicles, which explains why the NHTSA associates automation with features rather than vehicles (SAE International, 2018, p. 4). Before explaining the levels of automation, it is necessary to define the operational design domain (hereafter: ODD) and dynamic driving task (hereafter: DDT) given their importance for the subsequent discussion. The ODD defines the operating domain(s) in which the vehicle system is designed to operate and the corresponding capabilities (National Highway Traffic Safety Administration, 2016, p. 27). DDTs represent the real-time functions needed for a vehicle's operations on the road and can be divided into three categories (SAE International, 2018, p. 6):

- Operational functions, which only include lateral and longitudinal vehicle motion control. Lateral vehicle motion is motion along the Y-axis, i.e., left–right, and range from keeping the vehicle inside the lanes to regulating speeding and braking. Longitudinal vehicle motion is motion along the X-axis, i.e., forwards–backwards, and range from maintaining speed to controlling the distance from the AV to the vehicle ahead (SAE International, 2018, pp. 10–11).

- Tactical functions, which only include planning manoeuvres and enhancing conspicuousness, e.g., with the use of lighting, signalling and gesturing (SAE International, 2018, p. 6).
- Monitoring the environment and responding to objects and events are both operational and tactical functions. Monitoring entails monitoring the user, driving environment, vehicle's performance, and driving automation system's performance, on which basis appropriate actions are taken in response to what is detected by the monitoring (SAE International, 2018, pp. 12–14).

Second, there are six AV automation levels. On level 0, the driving-related tasks are entirely in the domain of the human driver (SAE International, 2018, p. 19). If level 0 of a driving automation system is engaged, the DTTs are not performed on a continuous basis (SAE International, 2018, p. 21). The engagement of the driving automation system begins with level 1 where it has solely an assistive role. Namely, on level 1 the driving system controls either the longitudinal or lateral vehicle motion but this can be overridden by the driver who take over the task from the system upon request. Accordingly, the driver is partly or fully responsible for the DDTs (SAE International, 2018, p. 21). The role of automation is growing as automation levels increase (National Highway Traffic Safety Administration, 2016, p. 9). On level 2, although the driver's role is the same as on level 1 the driving automation system becomes more important and its responsibility is not limited to just one of the two activities but both, that is, lateral and longitudinal vehicle motion control (SAE International, 2018, p. 21). Levels 3–5 are referred to as highly automated vehicles where the automated system monitors the environment and acts accordingly (National Highway Traffic Safety Administration, 2016, p. 9). On level 3, primary responsibility is transferred from the human to an automated driving system (hereafter: ADS) (National Highway Traffic Safety Administration, 2016, p. 9). An ADS is a system that can independently and continuously perform all DDTs (SAE International, 2018, p. 3). On levels 3 and 4, the ADS is permitted to operate only within its ODD, although it can perform all of the DDTs (SAE International, 2018, p. 22). On levels 4 and 5, the driver can become a passenger yet must be physically present in the vehicle in case an intervention is requested by the ADS (SAE International, 2018, pp. 22–23). A level-5 AV can act on the road in ways similar to conventional vehicle drivers and is not limited in terms of ODD (SAE International, 2018, p. 33). As soon as a destination is inputted, the AV can drive to it on its own (SAE International, 2018, p. 4). The typology with 6 levels from 0 to 5 is presented in Figure 1. This typology is also used by several European bodies, e.g., the International Transport Forum, which is part of the family of the Organisation for Economic Cooperation and Development[1] entities that have described the taxonomy as the most systematic (International Transport Forum, 2015, p. 13).

[1] The Organisation for Economic Cooperation and Development consists of different departments and special bodies, one of which is International Transport Forum (Organisation for Economic Co-operation and Development, n.d.).

Figure 1: AV automation levels

Level 0: No driving automation	Level 1: Driver assistance	Level 2: Partial driving automation	Level 3: Conditional driving automation	Level 4: High driving automation	Level 5: Full driving automation
The *driver* performs all of the DDTs, even when the vehicle is accompanied by *active safety systems*	The *sustained* and *ODD*-specific execution by a *driving automation system* of either the *lateral* or *longitudinal vehicle motion control* subtask of the DDT (but not both simultaneously) with the expectation that the *driver* will perform the remainder of the *DDT*	The *sustained* and *ODD*-specific execution by a *driving automation system* of both the *lateral* and *longitudinal vehicle motion control* subtasks of the *DDT* with the expectation that the *driver* will complete the *OEDR* subtask and *supervise* the *driving automation system*	The *sustained* and *ODD*-specific performance by an *ADS* of an entire DDT with the expectation that the DDT *fallback-ready user* is *receptive* to *ADS*-issued *requests to intervene* as well as to *DDT performance-relevant system failures* in other *vehicle* systems and will respond appropriately	The *sustained* and *ODD*-specific performance by an *ADS* of all of the *DDTs* and the *DDT fallback* without any expectation that a *user* will respond to a *request to intervene*	The *sustained* and unconditional (i.e., not *ODD*-specific) performance by an *ADS* of all the DDTs and the *DDT fallback* without any expectation that a *user* will respond to a *request to intervene*

Source: SAE International (2018, p. 19).

In a recent revision of the General Safety Regulation, the European Union (hereafter: EU) defined fully automated vehicles as motor vehicles that can move autonomously without being supervised (*Type-approval requirements to ensure the general safety of vehicles and the protection of vulnerable road users*, Regulation (EU) 2019/2144). This dissertation concentrates on the highest level of automation, i.e., level 5, for which the abbreviation AV is consistently used throughout unless otherwise stated. Level 5 was chosen for the following reasons. First, level-5 vehicles are currently the most controversial means of transport and their widespread adoption is furthest away in time. Accordingly, they cause the greatest concern and anxiety regarding how they will be integrated into our lives. Therefore, early and constantly refined research would help ensure that future development is tailored to the needs and preferences of potential adopters. If this is not the case, development could go in a direction that is not readily accepted by future adopters. As Wang et al. (2021, p. 1314) noted, pioneering research could help clarify self-learning, self-adaptation and self-transcendence with respect to AVs. Second, authors have described level-5 vehicles as being the most distinct from the other levels, explaining that it refers to a new type of vehicle that is no longer a traditional vehicle. For example, level-4 vehicles can operate in limited working conditions, whereas the system in level-5 vehicles must be able to handle driving scenarios that are unknown (Wang et al., 2021, p. 1316). If level-5 vehicles are indeed something that cannot be compared to traditional forms of transport, then research should be unable to draw parallels between conventional vehicles and them, but a new branch of research dealing exclusively with level-5 vehicles should be established. This suggests that research must distinguish the different levels, and this dissertation's focus on level-5 vehicles means that a gap in the literature is being filled, noting the literature review by Nastjuk et al. (2020, pp. 15–20) which showed that only a small share of studies concentrate on these vehicles. Third, given that there are many difficulties concerning why level-5 vehicles are not yet a reality, the ongoing research into the technology that we are least familiar with may reveal areas that call for further research and development. Betz et al. (2019, p. 138) also point out that all the knowledge gathered regarding level-5 vehicles will be used as an innovative input for future AVs, and that much can be learned from AVs in motorsport, considering that many ideas initially tested in motorsport are later transferred to road/passenger vehicles. Even though some might argue that it is too early or even irrelevant to research level-5 vehicles at the moment, we must bear in mind the iterative nature of technology development. Especially early research findings may prove valuable for the ongoing development and add to the likelihood of market success rather than failure, further justifying the level chosen.

1.2 Role of automated driving systems

AVs are guided by various technologies and computer systems that collect and share information from vehicles and the environment, and make decisions based on that information (Hulse et al., 2018, p. 2; International Transport Forum, 2015, p. 11). The supporting technologies are constantly evolving, and in this regard the International

Transport Forum (2015, p. 13) sees two development paths. First, incumbent automakers like Tesla, Mercedes and Audi are gradually equipping conventional vehicles with automated driving systems (International Transport Forum, 2015, p. 13; Skeete, 2018, p. 28), thereby making vehicles less dependent on a human driver (Duranton, 2016, p. 195). In some cases, a system assists a driver; in others, it replaces the driver (Payre et al., 2014, p. 253). Second, fully AVs are being developed, especially by new entrants to the industry (International Transport Forum, 2015, p. 13; Skeete, 2018, p. 28). These are expected to expand the market, which is often referred to as a revolution (International Transport Forum, 2015, p. 11). Incumbent manufacturers have recognised the threat posed by the new entrants and would probably aim to prevent full automation of the industry (Duranton, 2016, p. 195). Nevertheless, despite primarily being competitors, they should form partnerships and work together in strategically important areas (Heineke et al., 2017, p. 8). Greater standardisation of AV design and manufacturing would facilitate communication between the different parties and stakeholders involved (Raj et al., 2020, p. 133). Such cooperation should even extend to the mobile telecommunications industry (Jadaan et al., 2017, p. 645).

The assistive technologies and self-driving features found in vehicles available today are an intermediate solution between conventional vehicles and full automation that can help build positive attitudes to the technology and thereby increase the likelihood of AVs' market success (M. König & Neumayr, 2017, p. 51). Established technologies that passively assist the driver and are thus not considered as automation (level 0) include anti-lock braking system (ABS), driver steering recommendation (DSR), electronic stability control (ESC), emergency braking, front collision warning (FCW), lane departure warning (LDW), and park distance control (PDC) (International Transport Forum, 2015, pp. 18–19; Payre et al., 2014, p. 253). Partial automation starts with level 1 and refers to adaptive cruise control (ACC), basic park assist (PA), lane keeping system (LKS), and a stop and go device (International Transport Forum, 2015, p. 22; Payre et al., 2014, p. 253). The transition from conventional vehicles to AVs would potentially follow the gradual steps described in Table 1 with corresponding levels of autonomy. These are expected to be stepwise incorporated into private vehicles in addition to the currently established technologies until full automation is achieved (International Transport Forum, 2015, pp. 18–19). The technologies listed can help improve safety compared to vehicles controlled solely by humans, albeit Reagan et al. (2018, pp. 181–186) note that they are often turned off in vehicles, depending on the technology and automaker in question. Nevertheless, the greatest contribution to safety will only be reaped with full automation (Günthner & Proff, 2021, p. 587), as discussed in more detail in Chapter 1.5.3.

Table 1: Current and future technologies in automation

Technology	Level	Description
Park Assist	2	With this system, a vehicle performs the parking manoeuvres by itself. A driver does not need to be in the vehicle and can remotely control a manoeuvre with a smartphone, adapted remote key, or similar device.
Traffic Jam Assist	2	The system is intended for use when the speed is below 30 km/h in order to control forwards/backwards/sideways movements.
Traffic Jam Chauffeur	3	The system is intended for use in more highly congested road situations and when the speed is below 60 km/h. It is the driver who decides to activate or switch off the system for controlling the forwards/backwards/sideways movements. When active, it does not need to be constantly monitored.
Highway Chauffeur	3	The system is intended for use on motorways and similar roads where it operates on all lanes from entrance to exit as well as performing overtaking. It can only be used for speeds below 130 km/h and the driver must active the system. The driver does not need to monitor the system at all times, but can decide to take over control or switch it off, or the system requests for control to be taken over if its operational limits are reached.
Highway Pilot	4	The system is intended for use on motorways and similar roads where it operates on all lanes from entrance to exit while also performing overtaking. It can only be used for speeds below 130 km/h and the driver must activate the system. The driver does not need to monitor the system at all times, but can decide to take over control or switch it off, whereas the system does not request for control to be taken over if it operates within its normal operations.
Parking Garage Pilot	4	With this system, a vehicle performs the manoeuvre of parking in a garage by itself. The driver need not be present nearby and can remotely control the manoeuvre by smartphone, an adapted remote key or similar device.
Fully automated private vehicle	5	The system can perform the entire driving task from point A to point B without the need for any input from a human. The driver can take over control of the system or switch it off.

Source: International Transport Forum (2015, pp. 21–22).

1.3 Challenges of implementing AVs

1.3.1 AV legislation and policies

Article 8 of the Vienna Convention on Road Traffic states that every moving vehicle shall have a driver who is physically and mentally capable of driving the vehicle, possesses the knowledge and skills needed to drive the vehicle and is capable of controlling the vehicle

(*Convention on Road Traffic*, 1968, pp. 11–12). The automated technologies that have become part of vehicles today would no longer comply with this article had it not been amended in 2014 (Inland Transport Committee, 2014, p. 9). For example, if a driver does not have the ability to align well while parallel parking, their efforts can be supplemented by the parking assist system. This is an automated technology designed to help the driver perform the driving function, but it is not in accordance with the old Article 8. The provisions in the amendment state that "systems which influence the way vehicles are driven" and "systems that can be overridden or switched off by the driver" are also in line with Article 8 (Inland Transport Committee, 2014, p. 8). Despite this amendment, a driver is still required to be present in the vehicle, whereas a fully AV would not require a driver at all. Therefore, fully automated vehicles still do not fit within this article, suggesting that further regulatory change is needed, while noting that the regulations are constantly lagging behind the progress made by technology, mainly because its fast pace in the automotive industry creates additional barriers to regulatory changes (Juhasz, 2018, pp. 47–48).

Nonetheless, policymakers need to adapt regulatory policies and urban infrastructure in a way that supports the deployment of AVs to ensure the more widespread adoption of AVs (Medina-Tapia & Robusté, 2018, p. 210; Raj et al., 2020, p. 132) since a sufficient and complete legacy system and regulation are among the key enablers of automated driving that can positively influence the way AVs are perceived (International Transport Forum, 2015, p. 28; Zhu et al., 2020, p. 89). To achieve more efficient coordination and control in the early stages of AVs' development, governing bodies should be organised centrally rather than decentrally, as J. H. Lee et al. (2014, p. 97) suggested for smart city initiatives. Hesse et al. (2019, p. 100) emphasised the importance of coordination also in terms of financing. Further, on one hand, regulation should support AVs' introduction in terms of system management, transport planning, and land use policies (S. H. Kim et al., 2020, p. 1) while, on the other, regulations should limit the negative side effects of vehicle automation (Duranton, 2016, p. 194; Wadud et al., 2016, p. 12), which points to the importance of ex ante research to identify areas of concern and address them appropriately. Regulators could also benefit from simulating different development scenarios for planning future autonomous transport (Nielsen & Haustein, 2018, p. 49).

With respect to regulation, the USA is well ahead of Europe, although in neither place does a uniform legislative framework for AVs exist (Punev, 2020, p. 96). Moscholidou and Pangbourne (2020, p. 170) reached a similar conclusion in the context of smart mobility initiatives, namely, bike-sharing, car-sharing and ride-sharing, where they compared London and Seattle with regard to the extent to which regulation supports smart mobility initiatives to achieve strategic goals. Seattle's regulatory change processes were found to be much more flexible and rapid, thereby providing greater support for achieving strategic goals and regulating potential impacts to enhance the positive impacts and reduce the negative ones (Moscholidou & Pangbourne, 2020, p. 175). This is another case in favour of the US legislation over the European legislation. While welcoming the enthusiasm of the states in the USA to set regulations, Fagnant and Kockelman (2015, p. 176) also warned of the problems that different regulation could bring if each state were to design them separately. For example, inconsistent certification could lead to different standards for the same type of service (Moscholidou & Pangbourne, 2020, p. 175) along with uncertainty and overlapping regulations, whereas car manufacturers could face extended time schedules as well as additional production and testing costs (Fagnant & Kockelman, 2015, pp. 176–177). The lack of standards and testing procedures also makes it difficult for developers and regulators to create clear safety certifications (Shladover & Nowakowski, 2019, p. 125) and develop liability rules and physical infrastructure (Raj et al., 2020, p. 132). According to Raj et al. (2020, p. 131), whose study also considered the US context, the lack of standards is the second-most important adoption barrier followed by regulation and certification. By addressing these, governments and other authorities could play a vital role in increasing the market penetration of AVs (Raj et al., 2020, p. 131).

In the European context, Skeete (2018, p. 28) confirmed the important requirement for legislation to be standardised, e.g., concerning data access, and that intelligent transport systems would have to operate across borders, indicating the need for international cooperation. However, the EU is not putting enough emphasis and focus on specific AV-related legislation, even though the development of legislation must be prioritised to better reap the benefits of AVs (Punev, 2020, pp. 97–98). Policies should be formed in a way that enables the changes rather than blocks them (International Transport Forum, 2015, p. 6). Moreover, public policies have to be aligned with the public interest (Skeete, 2018, p. 27). The directions taken while developing the legislation must be multi-layered (e.g., the conditions of on-road testing and operation, vehicle and driver licensing, automated on-demand mobility systems), while there is the question of whether all existing laws should be adapted to the automation context or specific standalone rules should be implemented exclusively for automation (International Transport Forum, 2015, p. 26). Punev (2020, pp. 100–101) mentions that AV legislation would have to be strongly separated from the existing regulatory frameworks, albeit some countries are nevertheless building on the regulation already in place, e.g., Sweden and Norway (Hansson, 2020, p. 7). Establishing the future regulation of AVs should mainly be a concern on the level of the EU (Punev, 2020, p. 98), yet national legislators are also expected to take their part (Juhasz, 2018, p. 57). National legislators are supposed to act as secondary legislators (Punev, 2020, p. 101) and countries that lag behind should learn from the leaders in this respect, e.g., the USA or Germany (Juhasz, 2018, p. 57), Sweden or Norway (Hansson, 2020, p. 7). Indeed, Hansson (2020, p. 7) reports that the latter two countries benefited from benchmarking and the learning experiences of other countries. Moreover, to develop an effective legal framework, regulators and developers should cooperate in both formal and informal discussions on an ongoing basis (Hansson, 2020, p. 8; International Transport Forum, 2015, pp. 26–27) and reflect on ethical as well as social issues (Fleetwood, 2017, p. 533). Including the general public and educating about AVs may further benefit the development of regulations (International Transport Forum, 2015, pp. 28–29), while continued AV adoption could further pressure the authorities to make the regulations clearer and more mature (Raj et al., 2020, p. 132).

Other unsettled questions relate to decisions regarding flexibility or uniformity and ex-ante or ex-post regulation formation, where each has its own strengths and weaknesses (International Transport Forum, 2015, p. 27). The formation of regulation today chiefly follows the development of AVs instead of leading it (Bartolini et al., 2017, p. 793). The consideration that all people must be treated equally regardless of race, religion, gender, disability, age, national origin, sexual orientation, gender identity, or gender expression (The Institute of Electrical and Electronics Engineers, 2022, p. 36) means that ethical and thus legal issues cannot easily be resolved, but are an inevitable step to be addressed before individuals can more realistically judge whether they are willing to use an AV or not (Othman, 2021, pp. 368, 373). Medina-Tapia and Robusté (2018, p. 210) proposed four focus areas for policy design that would support the implementation of AVs and help mitigate the current urban problems. Policies and actions should address the diverse characteristics of cities (e.g., from size and density perspectives) and implementation approaches (e.g., complete urban redesign or adaptation of current urban systems), include different types of AVs implemented from private to public, and their complementarity with other transport systems (Medina-Tapia & Robusté, 2018, p. 210). Medina-Tapia and Robusté (2018, p. 210) also stated that policies should offer either incentives or restrictions regarding transportation and share the view of Kaltenhäuser et al. (2020, p. 908) who emphasised the role of government in incentivising the potential users of AVs as well as suppliers of services related to AVs. By way of further encouragement to increase AV usage, incentives could be legally regulated, e.g., lower vehicle registration fees, reduced taxes when buying a vehicle (Faisal et al., 2019, p. 57; Talebian & Mishra, 2018, p. 372), or the possibility of using special lanes. Further, disincentives to make conventional vehicles less appealing may need to be introduced (Rouse et al., 2018, p. 30), especially for those unwilling to give up driving (Punev, 2020, p. 101). Since the implementation of AV could lead to increased driving mileage, which would hold negative consequences for the environment/society (e.g., higher emissions and congestion), policies and restrictions must also aim to eliminate or mitigate these in the early stages of development (Bansal et al., 2016, p. 12; Wadud et al., 2016, p. 12). In this regard, Bansal et al. (2016, p. 12) and Kaddoura et al. (2020, p. 61) proposed congestion-based pricing. However, regardless of the approach taken, no approach will necessarily be what potential adopters are looking for. For example, M. König and Neumayr (2017, p. 48) reported that people have little interest in tax incentives and special lanes, meaning that feedback should be actively sought from potential adopters to help find the approaches that suit them best.

1.3.2 Supporting infrastructure and liabilities

In addition to regulatory measures, policymakers should pay attention to the urban infrastructure to support the widespread adoption of AVs (Medina-Tapia & Robusté, 2018,

p. 210). Infrastructure development has two aspects: physical infrastructure (Rouse et al., 2018, p. 6) and communication-supporting infrastructure (Dey et al., 2016, p. 169). Whittle et al. (2019, p. 311) found that in some cases the availability of physical infrastructure can encourage a shift in habits even before attitudes change. Tengilimoglu et al. (2023, pp. 6–7) identified 13 features related to physical infrastructure that will require attention and development throughout the AV implementation phases. The aspects to be addressed are: road alignments, road cross-sectional elements, road surfaces, road markings, traffic signs and control signals, junctions and roundabouts, parking facilities, structures (e.g., bridges, tunnels), facilities for vulnerable road users, roadside equipment, lighting, drainage systems, and the assessment and maintenance of road infrastructures (Tengilimoglu et al., 2023, p. 7). For example, intersections and lanes will have to be redesigned to allow the simultaneous use of conventional and autonomous vehicles, together with other road users, e.g., cyclists and pedestrians (Narayanan et al., 2020, p. 26; Rouse et al., 2018, p. 14), where by observation we may add e-scooters, and provide space for intervention lanes and restricted areas (Benevolo et al., 2016, p. 6). Traffic lights and signals will become redundant (Duranton, 2016, p. 193) and tolling systems will need to be adapted (Bahamonde-Birke et al., 2018, p. 22). It will be also necessary to check the capacity of existing bridges, tunnels and underpasses to determine areas requiring additional investment (Tengilimoglu et al., 2023, p. 20).

Second, it is sensors and wireless technologies that enable communication between vehicles, vehicles and infrastructure, and between vehicles and other road users (Dey et al., 2016, p. 169; Jadaan et al., 2017, p. 642; Merat & Lee, 2012, p. 681). Vehicles will no longer be isolated from the outside world, but share information with and within it (Le et al., 2018, p. 18). The connectedness of AVs and seamless communication between them is a critical factor for the successful operation of connected vehicle technologies (Dey et al., 2016, p. 169) and a precondition for reaping the full benefits (Dey et al., 2016, p. 182). This is one area that requires a high degree of standardisation (Hesse et al., 2019, pp. 101–102; Raj et al., 2020, p. 131). Equipped with sensors, cameras, scanners and the like, AVs recognise and evaluate the environment, e.g., read traffic signs, recognise other road users, adapt to the traffic, and make decisions based on this (Deb et al., 2017, p. 179). For example, in a test scenario in a real traffic environment, S.-W. Kim et al. (2017, pp. 3515–3516) equipped their testing vehicle with a camera, laser scanner, low- and high-level controllers and devices responsible for positioning and maps. Similarly, Tesla's vehicles are equipped with sensors, GPS, radar, ultrasound and eight cameras that enable fully autonomous driving (Stilgoe, 2017, p. 43). Next, an important role is played by the ability of automated technologies to make judgements about road signs and traffic density using cameras, lasers, radar scanners and sensors (Deb et al., 2017, p. 179). Judgments of the environment are supported and enhanced by intelligent transportation systems that are responsible for data exchange in different situations (Benevolo et al., 2016, p. 7). The large amounts of data generated while driving and extracted from the environment are used to learn from experience (Fleetwood, 2017, pp. 533–534), whereas humans might continuously repeat the same mistakes (National

Highway Traffic Safety Administration, 2016, p. 5). Indeed, data can be analysed ex post to improve future decisions made by AVs (Fleetwood, 2017, pp. 533–534) and the overall transport system not only in terms of traffic flow but accident prevention as well (Hashem et al., 2016, p. 752). Stilgoe (2018, p. 25) described this as society learning about the technology and the technology learning about society. Consequently, safety is expected to improve considerably after the widespread introduction of AVs. Nevertheless, even if full automation takes the human element out of the driving equation, humans will still be responsible for programming, algorithms, and code development to ensure that an AV acts safely and according to what it perceives in the environment (Hulse et al., 2018, p. 2; Mueller et al., 2020, p. 312). This raises the question of liability in the event of collisions and casualties (Hulse et al., 2018, p. 2), which insurance companies are naturally afraid of (Raj et al., 2020, p. 132). Questions especially pertain to fatal accidents when it must be decided whether to save the life of a passenger or a pedestrian, a passenger or an animal, and so on (Fleetwood, 2017, p. 534). If the pre-programmed decisions concerning how to act in specific situations are against an individual's beliefs and expectations, this might be discouraging for them, while encouraging for others and never satisfactory to everyone (Othman, 2021, p. 368).

Merat and Lee (2012, pp. 683–684) consider it more problematic when responsibility for simpler tasks is shifted from the driver to the vehicle, meaning the driver must then take control in more challenging situations, which can prove to be even more critical for less skilled or mentally absent drivers. Responsibilities might further change when all traffic signals become digital instead of physical (Skeete, 2018, p. 28). Legislators are hence expected to develop guidelines for determining accountability, else a lack of certification and regulation could increase uncertainty (Raj et al., 2020, p. 132), and to find ways to resolve potentially competing goals between conventional vehicles and AVs and between several AVs (Merat & Lee, 2012, p. 684). Importantly, a single entity must be designated to determine liability in the case of victims (Punev, 2020, p. 101). AVs will also require insurance policies (Fagnant & Kockelman, 2015, p. 177) and toll systems (Bahamonde-Birke et al., 2018, p. 22) to be modified. Drivers will be less and less responsible for accidents when the level of automation rises (Marchant & Lindor, 2012, p. 1326), while insurance premiums could fall as the risks associated with human drivers dissipate (S. H. Kim et al., 2020, p. 3515). The International Transport Forum (2015, p. 6) suggests expanding public insurance and facilitating private insurance to ease the burden on the insurance claims system, whereas Punev (2020, p. 99) believes that a no-fault insurance system, in which manufacturers would be held liable, is the correct solution that would also mitigate the rapid increase in insurance costs.

The implementation of AVs not only concerns drivers/passengers in the vehicles, but entails larger considerations to do with the external environment and other road users (Deb et al., 2017, pp. 179–180). These include cyclists, pedestrians, people on wheelchairs, and passengers on two-wheelers, where by observation we may add e-scooters, who are considered vulnerable road users (Deb et al., 2017, p. 179; European Parliament & Council, 2019, p. 8). This makes it important to distinguish the perspectives held by different road participants (Deb et al., 2017, p. 179) because the effects of AVs on various road groups will differ (Fagnant & Kockelman, 2015, p. 173). Hulse et al. (2018, p. 7) showed that pedestrians consider AVs to be less risky than human-operated vehicles, while the opposite is true for passengers. Pedestrians with a perception of greater safety are less concerned about AVs and more likely to cross the street in front of an AV, making them more accepting of them (Deb et al., 2017, p. 185). From the passenger point of view, a major problem arises when determining liability in the event of an accident if the car would primarily save the life of a pedestrian over a passenger (Hulse et al., 2018, p. 7).

1.4 Broader view of the implications of AVs appearing on our roads

The emergence and implementation of AVs has been referred to as a revolution or paradigm shift in transportation and mobility (Keszey, 2020, p. 1; Medina-Tapia & Robusté, 2018, p. 204). Significant changes range from electric to hybrid vehicles, shared mobility through to connected and autonomous driving (Kaltenhäuser et al., 2020, p. 882). Skeete (2018, p. 31) and Hresko Pearl (2020, p. 471) compare the emergence of AVs to the transition from horse-drawn carriages to the internal combustion engine early in the 20th century, while Bansal et al. (2016, p. 1) and Haboucha et al. (2017, p. 37) describe it as the biggest step forward, and a unique and promising technological solution in transportation. Hresko Pearl (2020, pp. 440–445) draw several other parallels between the current and earlier shifts in transportation. For example, he mentions that even a century ago, the construction of new roads, parking lots, and other supporting infrastructure was required (Hresko Pearl, 2020, p. 444). Vehicles were also then too expensive to be affordable for the masses, and consumer resistance was high and strongly focused on suppressing the change (Hresko Pearl, 2020, pp. 441–442), even though it made it possible to solve many problems with horse-drawn transport. Today, AVs similarly offer a solution to the problems caused by human-operated vehicles powered by the internal combustion engine (Haboucha et al., 2017, p. 37), e.g., traffic safety and congestion (Meidute-Kavaliauskiene et al., 2021, p. 16).

AVs will again supposedly change people's daily lives (Shabanpour et al., 2018, pp. 463–464). The changes will relate to the operation of the transport system and travel behaviour (Fagnant & Kockelman, 2015, p. 167) and also affect other products and services in general (Smith, 2013, p. 1793) since vehicle automation is only one part of a broader automation and connectivity trend (International Transport Forum, 2015, p. 6). AVs will be a constituent part of the concept of smart mobility in smart cities in which automated driving is one of the means of transport for both public and private mobility (Benevolo et al., 2016, pp. 8, 11; Kaltenhäuser et al., 2020, p. 883; Noy & Givoni, 2018, p. 3) and an alternative to the current means available (Wang & Zhao, 2019, p. 216). Benevolo et al. (2016, p. 2) consider smart mobility to be one of the most important and promising topics associated with smart cities which, together with other smart services, hold great potential to improve living standards, quality of life, and well-being in cities (Benevolo et al., 2016, p. 3; Ismagilova et al., 2019, p. 96; Yigitcanlar et al., 2018, p. 155). However, these different projects should not be considered individually but in an integrated manner, while learning from past projects and having a future-oriented vision (Benevolo et al., 2016, p. 7). The transportation system in future smart cities will be smarter, safer, more connected, and more sustainable (Bansal et al., 2016, p. 12). AVs will contribute to greater sustainability with technological innovations that support urban transport systems (Lopez-Carreiro & Monzon, 2018, p. 685).

High investments are being made around the world to develop AV technologies and smart mobility solutions (Keszey, 2020, p. 1; T. Zhang et al., 2019, p. 207). Moreover, the field has gained in importance in the area of transportation planning and research (Nielsen & Haustein, 2018, p. 49). Indeed, research findings on the topic could help the transportation system become more efficient and sustainable by addressing the problems facing the transportation system today (Bansal et al., 2016, p. 1). Although the shift is expected to be revolutionary, it will also be gradual, entailing the coexistence of AVs and conventional vehicles during the transition period, and bring electro-autonomous vehicles that replace human-operated vehicles propelled by internal combustion engines (Medina-Tapia & Robusté, 2018, p. 204). This makes it necessary to understand how AVs will become part of the existing transport system (Skeete, 2018, p. 31), especially because their presence will be long-term once they are widely accepted in the market (International Transport Forum, 2015, p. 29) and, at least until the next big change, they are anticipated to dominate the automotive market in the next decades (Shabanpour et al., 2018, p. 463). There is nevertheless no consensus on when AVs will be found in large numbers on our roads. AVs are expected to be safe and reliable by 2025 (Litman, 2020, p. 38), a mature technology by 2030 (Adnan et al., 2018, p. 833), but not affordable by the masses until 2045/2050 (Litman, 2020, pp. 38–39). According to Litman (2020, p. 30), 10%–20% of the vehicle fleet will be autonomous by 2040, while with 25% Yuen, Wong, et al. (2020, p. 1) are more optimistic. Further, although Adnan et al. (2018, p. 834) believe AVs will dominate the auto market by 2050, Litman (2020, p. 39) does not expect half of the vehicle fleet to be autonomous before 2060. The penetration rate will also depend on cutting the prices of AVs. If the annual price reduction is 5%, penetration of just 15% is expected by 2050. In contrast, with an annual price reduction of 20%, 90% penetration is expected by 2050 (Talebian & Mishra, 2018, p. 373). Still, such predictions have been criticised for being overly optimistic, claiming that the relevant authorities lack strategic development plans (Keszey, 2020, p. 1). The very optimistic predictions might also be unlikely due to high costs (Kyriakidis et al., 2015, p. 906). Another commonly stated reason for incorrect predictions about the diffusion of innovations is inadequate understanding of customer needs and the drivers of their adoption (Keszey, 2020, p. 1).

In addition to individuals benefiting from AVs (presented in Chapter 1.5.1), many individuals who enjoy driving by themselves will lose the pleasure of driving once AVs are broadly implemented (Duranton, 2016, p. 193), which might act as a factor against AVs

(Nielsen & Haustein, 2018, pp. 52–53). This is especially true for professional drivers (Bansal et al., 2016, p. 13). Accordingly, individuals who find driving enjoyable, i.e., driving enthusiasts, might experience anxiety if forced to change their driving habits (Asmussen et al., 2020, p. 6) and be unwilling to give up their use of their current vehicle in favour of adopting an AV (Haboucha et al., 2017, p. 45; M. König & Neumayr, 2017, p. 43; Whittle et al., 2019, p. 309). Kyriakidis et al. (2015, p. 132) reported that the majority of individuals still prefer manual driving because of the joy it brings, although there are also individuals who find autonomous driving more enjoyable (Kyriakidis et al., 2015, p. 138). For some, the loss of control of the driving would mean the loss of self-identity and in turn increase the likelihood of driving a conventional vehicle instead of an AV (Asmussen et al., 2020, p. 3). Yet, some people may find new meaning in an AV as a personal mobility robot and continue to adhere to the norm of private vehicle ownership (Bösch et al., 2018, pp. 84–85).

1.5 Effects of AV implementation

1.5.1 Benefits and negative effects of AVs

Despite the actual outcomes being hard to determine, the fact that AVs are still in the testing phase (Fagnant & Kockelman, 2015, p. 172) means the benefits they provide stem almost directly from the weaknesses of the existing transport system, as found by Noy and Givoni (2018, p. 8) in a survey of the main actors in the area of smart mobility. Those weaknesses particularly referred to environmental impacts, system design, system use and its consequences (Noy & Givoni, 2018, p. 8). The literature on AV benefits is broad and the numerous benefits that AVs are expected to bring can apply to either the individual or society. Some authors who distinguish the individual- and society-related benefits are Fagnant and Kockelman (2015, p. 174), Manfreda et al. (2021, p. 5) and Zmud et al. (2016b, p. 11).

First, end users and local communities in societies will benefit in several ways from: the number and severity of road accidents decreasing (Rezaei & Caulfield, 2021, p. 486; *Type-approval requirements to ensure the general safety of vehicles and the protection of vulnerable road users*, Regulation (EU) 2019/2144), improved energy efficiency (Stager et al., 2018, p. 134), less road congestion and associated fuel losses (Wadud et al., 2016, p. 5) the reduced need for parking lots (Bansal et al., 2016, p. 12; Kaltenhäuser et al., 2020, p. 908), and smaller environmental impact in terms of emissions (Ercan et al., 2022, p. 14; Jones & Leibowicz, 2019, p. 290; Y. Li et al., 2022, p. 7). Second, personal benefits range from more efficient time use for those who possess a driver's licence (Bansal et al., 2016, p. 2) and increased mobility opportunities for those unable to drive, e.g., children (Y.-C. Lee & Mirman, 2018, p. 416) and elderly (Yang & Coughlin, 2014, p. 333), financial and time savings arising from finding a parking space (Fagnant & Kockelman, 2015, p. 174), to shorter travel times. Shorter travel times can be the outcome of either numerous smart services and data collection devices (Ismagilova et al., 2019, p. 93) or more optimised driving (Kaltenhäuser et al., 2020, p. 908), more efficient traffic flows (Papadoulis et al., 2019, p. 12), a smaller number of conflicts/road rage (Papadoulis et al., 2019, p. 19), greater accuracy while predicting travel times (Papadoulis et al., 2019, p. 20), the need for smaller safety distances between vehicles (Fagnant & Kockelman, 2015, p. 170; Jadaan et al., 2017, p. 643), more efficient and optimised route choices (Fagnant & Kockelman, 2015, p. 170; Hashem et al., 2016, p. 750), and more intelligent routing to avoid congestion (Kaltenhäuser et al., 2020, p. 908), or AVs being allowed to use lanes exclusively reserved for them (Shabanpour et al., 2018, p. 474). Moreover, users would be given an opportunity to be picked up and dropped off by an AV at the desired location (Fagnant & Kockelman, 2015, p. 171; Haboucha et al., 2017, p. 40; Narayanan et al., 2020, p. 26).

Respondents in an Irish sample in a study by Acheampong and Cugurullo (2019, p. 371) and respondents from various countries in a survey by Schoettle and Sivak (2014, p. 7) believed that most of the benefits attributed to AVs are more likely to occur than not. It is also expected that individuals will value the personal benefits they provide more than the benefits for society (Zmud et al., 2016b, p. 11). The most positively perceived benefits include reduced greenhouse gas emissions, lower fuel consumption, and fewer road accidents (Woldeamanuel & Nguyen, 2018, p. 49). The latter was also mentioned by Bansal et al. (2016, p. 13) as among the most important benefits of AVs. M. König and Neumayr (2017, p. 46) found that improved mobility of elderly and disabled people and engaging in other activities instead of driving were the two most positively perceived benefits of AVs. Respondents in a study by Nielsen and Haustein (2018, p. 52) identified the greatest benefits as arriving relaxed at the destination and without the need to search around for parking, and the ability to do other activities while driving. The least importance was ascribed to the social recognition that would be acquired and the shorter travel times or time savings (M. König & Neumayr, 2017, p. 46; Nielsen & Haustein, 2018, p. 52). Yet, none of these benefits will emerge if the technology is not adopted by consumers (Zhu et al., 2020, p. 81), as discussed in Chapter 2.3.

It is also necessary to make a distinction between direct and indirect benefits. Bahamonde-Birke et al. (2018, p. 12) name them first- and second-order systemic effects or benefits of wide AV use. The former are direct and usually positive (Bahamonde-Birke et al., 2018, p. 13). The latter are a result of changes in travel behaviour (Bahamonde-Birke et al., 2018, p. 15) and rarely taken into account, although they could counterbalance the initial positive benefits (Bahamonde-Birke et al., 2018, p. 12). This is exactly what one simulation study predicted for environmental effects, i.e., energy consumption and emissions. The study considered automation to have a positive effect on the environment both directly and indirectly through the changed design of the transportation system, e.g., vehicle operation, vehicle design, and transport system design (Wadud et al., 2016, pp. 2, 12). Stager et al. (2018, p. 131) simulated a small-scale smart city to determine the potential of energy savings resulting from widespread AV implementation. Coordinating vehicles based on sensors and the introduction of the alternating merging of vehicles into traffic with the elimination of stop-and-go driving led to an around 20% time reduction for vehicle merging, which further led to greater battery efficiency (Stager et al., 2018, pp. 134–135). Authors have also found potential for fuel consumption savings in increased acceleration time, albeit more efficiency could be gained if the highway speeds did not continue to increase since higher speeds on highways increase the intensity of energy use (Wadud et al., 2016, p. 6). Still, not all savings will be able to be attributed solely to automation, but will emerge from the parallel occurrence of the shifts to electrification and vehicle autonomy, at least to some extent. For example, Benevolo et al. (2016, p. 10) stated that a reduced environmental footprint is a by-product of other smart city-related initiatives, of which AVs form part, that are further contributing to increased living standards (Benevolo et al., 2016, pp. 10–11). Further, some benefits will only be realised with full automation, i.e., the level-5 AVs focused on in this dissertation, especially the smoother flow of traffic and higher capacity of intersections (Duranton, 2016, pp. 194–195). Benefits will also depend on penetration rates and levels of automation. Fagnant and Kockelman (2015, p. 174) compared benefits for different penetration rates and showed that the benefits arising from reduced congestion and accidents with a penetration rate of 90% would be more than double those with a penetration rate of 10% (Fagnant & Kockelman, 2015, p. 174). Wadud et al. (2016, p. 12) concluded that even lower levels of automation could already bring significant improvements, but full automation might have an adverse effect due to increased overall travel.

The mentioned authors thus emphasise that the negative effects should not be overlooked because they could outweigh the benefits. Travel costs might rise considerably for several reasons: decreased driver's time cost due to better use of time in the vehicle, more trips being taken by new groups of travellers/passengers, and the emergence of new mobility service models causing more vehicles to run empty after dropping off passengers and on the way to picking them up (Wadud et al., 2016, pp. 8–10). The latter was included as one of the scenarios simulated to determine the effect of AVs on parking demand. Millard-Ball (2016, pp. 100–101) simulated three scenarios related to changing parking strategies and their prices, i.e., a vehicle round-tripping between the passenger's destination and the parking lot, a vehicle returning home and later returning to pick up the passenger, and cruising in the area at very low speeds while waiting for the passenger. The W. Zhang et al. (2015, p. 42) simulation revealed the potential for a 90% parking demand reduction in case of shared AVs or even higher following the introduction of a ride-sharing service. The impact of AVs on parking-related issues may be two-fold. They could reduce the need for parking lots and simultaneously save individuals' time and money spent on finding parking, yet vehicle mileage and hence congestion could increase if an AV needs to return to its base or circle around after dropping off a passenger (Fagnant & Kockelman, 2015, pp. 171–172; Narayanan et al., 2020, p. 26). Fagnant and Kockelman (2015, pp. 170–171) note that the increased vehicle mileage could be substantial if not managed properly, but still believe that the benefits will exceed the externalities caused by the greater mileage.

1.5.2 Newly emerging transport opportunities

1.5.2.1 AVs in public transportation

AVs promise potential in both private and public transport. Their characteristics mean that the driver has the advantage of being a passenger and can use their time productively, also because there is no need to search for a parking space, making AVs similar to public transport, even perhaps more appealing than it (Miller & Heard, 2016, p. 6119). Kaltenhäuser et al. (2020, pp. 885–886) studied four scenarios of autonomous driving – combinations of private or shared and with or without a steering wheel. Their simulation showed that most private vehicles will be equipped with a steering wheel, while AVs without a steering wheel will less likely be found in the short to medium term because people will prefer to switch to autonomous taxis as a shared alternative (Kaltenhäuser et al., 2020, p. 906). In the long term, as large numbers of people shift from private transport to public transport, e.g., autonomous taxis or on-demand services, vehicle ownership will also decline (Duranton, 2016, p. 193; Kaltenhäuser et al., 2020, pp. 887, 904–905). Once people no longer own a vehicle, this will offer additional potential to lower the personal costs associated with transportation as vehicle ownership is known to be prohibitively expensive due to the high fixed costs (National Highway Traffic Safety Administration, 2016, p. 5; Wadud et al., 2016, p. 10). Schoettle and Sivak (2015, pp. 8–9) estimated that vehicle ownership could fall by up to 43% in an ideal situation at the expense of increased annual mileage per vehicle.

Since AVs will change an activity humans have engaged in over a century – driving (Fagnant & Kockelman, 2015, p. 167), new business models are likely to emerge. Companies can either decide to develop a new business model from scratch for something that did not previously exist, change their current business model, or find new revenue streams from their existing products/services. It is expected that especially in transport new business processes and new business models will evolve with the widespread implementation of AVs. The connectedness of devices or the 'Internet of Things', which AVs will also use for their operations, gives an opportunity for companies to establish new ways of creating value and forming new business models, which Dijkman et al. (2015, p. 672) see as a necessity. For example, a prosumer business model is relevant for mobility services (Brown et al., 2019, p. 9), which will be electro-autonomous in the future. Car rental services could benefit from the autonomous relocation of vehicles to fulfil as many bookings as possible (Conejero et al., 2016, p. 112).

It will be necessary to precisely define the role of urban passenger transport (Kenesei et al., 2022, p. 390). Researchers mention shared autonomous public transport as a future alternative to the current system (Jadaan et al., 2017, p. 647). The literature discusses two scenarios involving the introduction of AVs; namely, individual ownership or ride-sharing services, with some hybrid scenarios that will require different approaches in terms of manufacturer business models and road infrastructure development (Pettigrew et al., 2019, pp. 13–14). Since there are many hybrid scenarios, the consequences of AV implementation will vary (Pettigrew et al., 2019, pp. 13–14). Shared mobility is a service where users share, for example, one of the following means of transport: public transport, taxi, car-sharing, ride-sharing, or shuttle (S.-W. Kim et al., 2017, p. 3514). About half of all AVs are expected to be public and the other half privately-owned (Fagnant & Kockelman, 2015, p. 172). Shared AVs could be more affordable than taxi fares and privately-owned vehicles (Skeete, 2018, p. 29) and would offer more dynamic charging for transportation services on a pay-as-you-go basis (Bansal et al., 2016, p. 12).

In the long run, the current public transport could be completely replaced by autonomous buses and taxis. Mezei and Lazányi (2018, p. 374) found potential in autonomous trams and metro lines and confirmed this in the case of Budapest, Hungary. The participants in that study who were in favour of autonomously driven trams and metro lines perceived safety significantly higher than those who were against them (Mezei & Lazányi, 2018, p. 373). Similarly, S.-W. Kim et al. (2017, p. 3521) demonstrated the feasibility of an autonomous taxi system operating on the campus of the Seoul National University in real traffic already in 2015, which turned out to be a successful project. The participating customers evaluated it as safer and more reliable than the campus shuttles, but missed the voice signals to report on travel status and described autonomous taxis as slower due to them respecting the speed limits (S.-W. Kim et al., 2017, pp. 3524–3525). While a campus is a more closed environment than an open entire city, it also has its own challenges that cannot be neglected (e.g., location, layout, demand, patterns). There can even be intersections that have no signals despite heavy traffic (S.-W. Kim et al., 2017, p. 3519) and hence a campus can act as a useful venue for a pilot example while planning city transportation.

1.5.2.2 AVs in freight transportation

There are numerous ways AVs could be incorporated into freight transportation and goods delivery. One possibility the current literature has hardly considered is using private AVs for goods delivery after they have completed their primary tasks (Schlenther et al., 2020, p. 521). In contrast, one can find many solutions for last-mile delivery services. Van Meldert and De Boeck (2016, pp. 20–21) summarised potential ideas that could become a reality by 2030 as follows: autonomous grocery shopping, home delivery logistics network, autonomous parcels, pack-station-based solutions, and vehicles for letter and parcel deliveries. Introducing AVs for same-day delivery could increase the number of customers served 3–5 fold (Ulmer & Streng, 2019, p. 10). AVs were also identified as one of the nine emerging technologies that will serve freight transportation (Dong et al., 2021, p. 390) while AVs could be a solution for the driver shortages seen in freight transport (Liachovičius & Skrickij, 2020, p. 462). In addition, autonomous shuttles within the concept of an autonomous shuttle as a service have been mentioned as a valuable alternative to support the transport of people and goods in last-mile mobility in cities, which could offer services better tailored to inhabitants'/visitors' needs and preferences, and contribute to pollution and noise reduction (Bucchiarone et al., 2020, pp. 3791–3792). Potential adopters hold different views on the use of autonomous delivery vehicles. For example, participants in a survey by Kapser and Abdelrahman (2020, pp. 217–219) were neutral regarding the acceptance of autonomous delivery vehicles, attributing the greatest importance for acceptance to price sensitivity, followed by usefulness and enjoyment. On the other hand, participants in a survey by Gramatikov et al. (2019, pp. 3–4) were positively inclined to accept new AV technology for delivering online orders. Individuals would greatly value fast delivery and only be slightly concerned about losing control over personal data and/or security (Gramatikov et al., 2019, pp. 3–4).

1.5.2.3 Role of AVs in increasing the mobility of less mobile individuals

The next area where AVs will advance mobility and transportation is the mobility of disadvantaged groups. AVs could increase the mobility of previously limited demographic groups and individuals who today drive less than they would like to (Wadud et al., 2016, p. 8; Whittle et al., 2019, p. 311). These potential adoption groups might see AVs as an opportunity to engage in road transport again (M. König & Neumayr, 2017, p. 49) and specific services could be developed for the less mobile and for those who take care of them (Pettigrew et al., 2019, p. 19). Multi-member households would be more interested in AVs as this would ease the driving obligations of those holding a driver's licence who currently transport those without a licence (Shabanpour et al., 2018, p. 475). Two groups that are particularly limited in their mobility are children and the elderly (Y.-C. Lee & Mirman, 2018, p. 416; Yang & Coughlin, 2014, p. 333). Children who do not hold a driver's licence frequently depend on others, e.g., their parents, to transport them to the desired location (Y.-C. Lee & Mirman, 2018, pp. 415–416). AVs are thus seen as a transport solution that could improve their mobility at least to and from school (Jing et al., 2021, p. 11), if not even beyond. Considering the many concerns that parents have with regard to transporting their children, the autonomous transportation of children still seems a fairly distant phenomenon. The elderly are also more likely to hold negative rather than positive attitudes to AVs (Hassan, 2016, p. 6), although they are known to be another potential group that could benefit from AV use as they could stay mobile as they age (Nielsen & Haustein, 2018, p. 54). Due to their reduced mobility resulting from deteriorating sensory and cognitive abilities, e.g., vision, hearing, and information processing (Baldwin, 2002, p. 311; Yang & Coughlin, 2014, p. 335), governments often provide taxi services to the elderly to improve their mobility, and AVs could replace this service, especially in less accessible and remote locations (Pettigrew et al., 2019, p. 19). The need for additional training for the elderly regarding the use of any such new technologies that would otherwise be required is thereby avoided (Yang & Coughlin, 2014, p. 336).

1.5.2.4 AVs beyond the mere transfer of people

AVs will not only offer transfers from point A to B, which is a characteristic of conventional vehicles, but travel journeys will become a diverse environment in which passengers will be able to engage in a wide range of activities, which Pettersson et al. (2016, p. 1) named the "living room on the move". Although it is not yet entirely clear how AVs will affect people's travel behaviour (S. H. Kim et al., 2020, p. 2), time in vehicles could definitely be spent differently, e.g., working on a laptop, eating, reading books, watching movies (Fagnant & Kockelman, 2015, p. 168). These activities are currently classified by the NHTSA as distracted driving and should be reduced because they are risky, unsafe, and can have serious negative consequences (National Highway Traffic Safety Administration, 2016, p. 45). Once AVs are introduced, it will become possible to safely engage in these activities. Moreover, since driving is usually considered a waste of time AVs could increase efficiency without compromising safety.

Time spent in the vehicle during travel/the commute is referred to as in-vehicle time, which can be spent either productively or unproductively. Activities performed during travel can be grouped into several categories depending on where on the scale between "wasted" and "ultra-productive" time they fall (Lyons & Urry, 2005, p. 270). Public transport already offers passengers an opportunity to participate in more productive activities, e.g., working and reading (Lyons & Urry, 2005, pp. 263–264). In contrast, privately-owned, human-operated cars are limited in this respect, but the introduction of AVs could change this since drivers (who will then be passengers) will be able to put some of their travel time to productive use, i.e., by multitasking in an AV and performing activities previously limited to a specific physical location (Hamadneh & Esztergár-Kiss, 2021, p. 13; Malokin et al., 2019, p. 83). If time spent in vehicles is used more productively, individuals might be motivated to spend more time in vehicles as the cost of their travel time and travelling would decrease (Duranton, 2016, p. 193; Wadud et al., 2016, p. 8). Thus, they would drive more and overall energy consumption would increase (Wadud et al., 2016, p. 8). Bansal et al. (2016, p. 12) and S. H. Kim et al. (2020, p. 10) also addressed the issue of increased amounts of travel when individuals move their home locations to more distant locations as a result of the ability to use their time travelling in the vehicle more efficiently, which would become another reason for increased overall mileage. This could also be an incentive to adopt an AV especially for those who drive many miles (Shabanpour et al., 2018, p. 475). The fact that people would start spending longer times in AVs would encourage the redesigning of vehicle interiors to better support passengers' needs (Sun et al., 2021, p. 1). Das et al. (2017, p. 13) concluded that people who face long commutes would be interested in having an AV equipped with an Internet connection and an interior adjusted to ensure comfort while using computers, displays for watching media and relaxing seats for sleeping. The impacts brought by AVs will thus not be limited to the transport sector (Das et al., 2017, p. 13).

Through use of semi-structured interviews, Pettersson and Karlsson (2015, p. 896) were able to identify several activities that individuals would like to do while in an AV: relax, work, sleep, read, socialise, eat, care for children, drink alcohol, watch videos, play games, and use social media. Some authors studied how open people are to performing certain activities in an AV. Woldeamanuel and Nguyen (2018, pp. 47–49) examined millennials' views on the activities passengers might engage in while driving in level-4 AVs in the US context, and Ljubi and Groznik (2021, p. 154) looked at the interest shown by millennials in in-vehicle activities in level-5 AVs in the Slovenian context. While both studies are survey-based and hence not generalisable, and the authors also did not investigate precisely the same activities, the results may still act to guide which options are feasible for and expected by future passengers of AVs. The greatest potential was found for talking, texting and communicating on the phone; consuming food or non-alcoholic beverages; and relaxing, resting, or de-stressing (Woldeamanuel & Nguyen, 2018, p. 48); listening to music or the radio; chatting with co-passengers; and observing the environment (Ljubi & Groznik, 2021, p. 157). While according to Woldeamanuel and Nguyen (2018, p. 48), resting was among the most interesting activities for participants, it is interesting that Ljubi and Groznik (2021, p. 157) and Bansal et al. (2016, p. 6) established it to be one of the least interesting activities for participants. Another difference is worth noting, namely, that Slovenian millennials were most enthusiastic about activities that could already be conducted while driving a conventional vehicle (even if at the expense of endangering road users) and the least enthusiastic about those that completely absorb the driver's attention (Ljubi & Groznik, 2021, p. 156). On the other hand, American millennials showed stronger interest in some activities currently unfeasible in conventional driving (Woldeamanuel & Nguyen, 2018, p. 48). The difference here might be due to cultural differences and/or the varying levels of AV legislation development in Europe and the USA, yet to be able to draw firm conclusions a separate study would be needed. Bansal et al. (2016, p. 6) considered a narrower range of activities and found that potential users would be interested in writing emails and surfing the web while in an AV, although they indicated they were not currently doing so very much while driving. Talking to friends or texting and looking out the window were the two most popular desires (Acheampong et al., 2021, p. 8; Bansal et al., 2016, p. 6). Bansal et al.'s (2016, p. 6) study was also conducted in the USA. Even though Schoettle and Sivak (2014, pp. 17–18) did not focus specifically on millennials, their survey revealed that respondents from China, India, Japan, the USA, the United Kingdom, and Australia were most likely to watch the road even while not driving. Other activities were not of much interest (mostly below 10%) (Schoettle & Sivak, 2014, p. 18).

Next, AVs will not only not need a driver, but will have the capacity to drive without a human present and move from task to task, which will decrease idle time of individuals and cause the number of miles they travel to increase (Wadud et al., 2016, p. 11). In Haboucha et al.'s (2017, p. 42) study, about half the participants expressed being comfortable with an AV picking up their groceries without a human present in the vehicle, while just over 10% were comfortable with their children being picked up by an AV without human involvement. The latter was also seen as an activity that an AV would be least used for, according to Ljubi and Groznik (2021, p. 157), whose study also shows that interest in AVs fell when envisioning AVs being used without a person being present compared to self-use of an AV while also participating in in-vehicle activities (Ljubi & Groznik, 2021, p. 157). Their study found that participants' technological enthusiasm affected neither their interest in in-vehicle activities nor their reasons for using AVs, regardless of the presence of a person, which may be due to people's inability to fully imagine these situations despite their openness to technology (Ljubi & Groznik, 2021, p. 158). The authors Ljubi and Groznik (2021, p. 157) established the three most salient reasons for choosing AVs to perform an activity instead of an individual: doing other things at home, resting or relaxing, or opportunity to keep working.

1.5.3 Impact of AVs on safety

A driver not fully concentrated on the road ahead is classified as a distracted driver, and they can bring about undesirable consequences. The problem is particularly relevant in lower-level AVs that require considerable driver engagement (National Highway Traffic Safety Administration, 2016, p. 45) given that a high proportion of accidents is due to human factors, which can be among the primary causes of an accident (Fagnant & Kockelman, 2015, p. 169; S. Singh, 2015, p. 1). Many of these accidents could be avoided if the driving function were transferred to an AV, either a semi- or fully automated vehicle (European Parliament & Council, 2019, p. 5; Fagnant & Kockelman, 2015, p. 169; National Highway Traffic Safety Administration, 2016, p. 45) since AVs are not affected by distractions, inattention, alcohol impairment, or incapacitation (Mueller et al., 2020, p. 310). AVs may thus be seen as a leap forward in road safety (Deb et al., 2017, p. 179; Xu et al., 2018, p. 321), namely, one of the most key AV benefits noted in the majority of literature. AV safety can be looked at from three levels: vehicle, transportation system, and society. On the vehicle level, the uncertainty regarding the impacts of their implementation is at its lowest level, with this aspect chiefly relating to the driver's reasons for mistakes and critical situations on the road. On the level of the transportation system feature road conflicts and accidents, and here the degree of uncertainty of the impacts is greater. On the society level, the uncertainty of the impacts is greatest when the question is about the effects of widespread AV implementation on public health (Sohrabi et al., 2021, p. 2).

It is necessary to distinguish assured safety from perceived safety. The former is what a manufacturer assures and promises, as well as AV tests show. The latter, however, addresses the question of how safe AVs are in the eyes of potential users. Bagdasarov et al. (2020, p. 6) pointed out this difference when it comes to working in the presence of robots, where the acceptance of a robot depends, among other things, on how safe it is perceived by people. Osswald et al. (2012, p. 55) stated that the perceived aspect of safety is something that individuals evaluate in hazardous situations while considering their driving skills and the feeling of safety when surrounded by other drivers. A recent Pew Research Center survey found mixed perceptions of AVs' impact on traffic fatalities, split almost evenly between "increase", "not make much difference" and "decrease" (Pew Research Center, 2022, p. 64), while Moody et al. (2020, p. 639) found that one-quarter of respondents were unsure, another quarter perceived them as not very safe, and about one-third regarded them as somewhat safe. Despite numerous studies showing greater safety when roads are heavily populated by AVs, individuals may perceive that AVs are not safe enough due to the lack of a human driver, which could discourage their widespread use (Fagnant & Kockelman, 2015, p. 177). Thus, even if car manufacturers offer and promise safety but potential adopters do not accept these reassurances, this could lead to a rejection of the technology. Othman (2021, p. 357) emphasised the importance of safety for public perceptions and AV acceptance, arguing that AVs will not be desirable, regardless their benefits, if they are not (seen as) safe (Othman, 2021, p. 358). Individuals who attribute higher safety to AVs are more likely to acquire one in the future (Montoro et al., 2019, p. 869).

In terms of safety, although AVs are often compared to conventional vehicles Merat and Lee (2012, p. 685) stressed that automation is not simply the replacement of the human driver; instead, safety will depend on the successful cooperation of the human and the automation, whereby humans will take on new roles. Nevertheless, comparative research showing results in favour of AVs could increase perceptions of safety in the eyes of potential adopters. In their systematic literature review, Nascimento et al. (2019, p. 4931) found that 81% of articles reported increased safety as a result of the artificial intelligence in AVs and the remaining 19% decreased safety. They identified five topics that point to lowered safety risks (sensors and perceptions, navigation and control, fault prevention, the human factor, and conceptual model and framework) and three topics that refer to increased safety risks (fault forecasting, ethics and policies, and dependability and trust). Further, a recent scoping review grouped AV safety quantifying approaches into six categories: target crash population, road test data analysis, traffic simulations, driving simulators, system failure risk assessment, and AV safety effectiveness (Sohrabi et al., 2021, p. 8). An experimental study by Muhrer et al. (2012, p. 706) showed that already an automated system installed in a conventional vehicle, without full automation, could avoid traffic accidents mainly due to the faster reaction times than a human driver. Another reason for improved safety could be better compliance with speed limits and other desired driving behaviours (Bansal et al., 2016, p. 12). A test case of an autonomous taxi in real traffic on a campus showed that a taxi behaved comparably to what was desired (planned) in terms of steering wheel angle and speed limit respect (S.-W. Kim et al., 2017, p. 3521). Further, Brell, Philipsen, et al. (2019, p. 353) compared conventional vehicles, which they characterised as an old technology, with connected and autonomous vehicles, which they characterised as a new technology. The results revealed differences between the new and old technologies, but not among new ones (Brell, Philipsen, et al., 2019, p. 353). Conventional vehicles were perceived in an almost contradictory way compared to connected and autonomous vehicles in the attributes studied, although only half the findings regarding them were significant. On the other hand, the differences between connected and autonomous vehicles were not high, albeit still significant, except for comfort, time savings, novelty, and fascination. Conventional vehicles were rated significantly lower in terms of risks, e.g., more protective, controllable, trustworthy, and less frightening, than connected and autonomous vehicles (Brell, Philipsen, et al., 2019, pp. 350–351). This points to the discrepancy between assured and perceived safety, with potential users perceiving safety as lower than is actually assured by manufacturers or shown in studies. With a higher penetration rate of AVs, there will be fewer traffic accidents (and road rage) and thereby a greater contribution to safety. A remarkable reduction in conflicts between vehicles at priority intersections and roundabouts could be achieved with as little as 20% penetration of connected AVs even though the remaining 80% would constitute conventional vehicles (Virdi et al., 2019, p. 107). With a penetration rate of 90%, almost all road conflicts at priority intersections, divergent diamond intersections, and roundabouts could be eliminated, while the reduction at signalised intersections could be around 50% (Virdi et al., 2019, p. 107). Papadoulis et al. (2019, p. 19) also found that the rate of penetration heavily determines the extent to which conflicts on the road would be reduced. For example, a penetration rate of 25% would cause a 12%–46% reduction in such conflicts, while ones of 75% and 100% would respectively cause reductions in the range of 82%–92% and 90%–94%.

The improved safety AVs will bring about also supports the Sustainable Development Goals of the United Nations (hereafter: SDGs) (UN General Assembly, 2015, p. 21). Specifically, according to the SDGs future transport systems should meet the following criteria: safety, affordability, accessibility and sustainability (UN General Assembly, 2015, p. 21). The safety focus is especially on improving the road safety of those in vulnerable situations and the goal was to reduce the number of traffic accidents with a fatal outcome and injuries by 50% on the global level by 2020 (UN General Assembly, 2015, p. 21). While the mentioned goal was not achieved (UN General Assembly, 2021, p. 3), AVs hold great promise here. Yet, safety might not necessarily increase, and even become degraded (Merat & Lee, 2012, p. 684). For as long as AVs share the road with human-operated vehicles, which is not expected to end any time soon, the safe and cooperative interaction of the two forms of travel must be designed in order to avoid collisions and excessive road congestion (Aoki et al., 2021, p. 35). AVs will have to understand explicit traffic rules as well as implicit traffic culture (Aoki et al., 2021, p. 36). Another challenge may be the diverse weather conditions that can impact sensors' ability to detect the surroundings (S.-W. Kim et al., 2017, p. 3522) and thereby create additional problems. Fog, snow, and road reflections caused by rain and ice could be especially problematic (Fagnant & Kockelman, 2015, p. 169). In the event of more complex and unusual situations, safety becomes even more critical as a machine is not capable of the same information processing as the human brain, which may make people more inclined to use a conventional vehicle instead of an AV (Asmussen et al., 2020, p. 7).

In conventional vehicles, the driver is primarily responsible for safety, followed by other road users. In AVs, individuals must trust a vehicle to ensure their safety (Ma et al., 2020, p. 2023). Artificial intelligence can significantly add to the (feeling of) increased safety (Nascimento et al., 2019, p. 4931), although the number of years before people find vehicles safe enough to drive on the road depends, among others, on the current perception of their safety (Moody et al., 2020, p. 639). Liu, Yang, et al. (2019a, pp. 320–321) concluded in their study that individuals would require the risk of AVs to be four to five times lower than that of human-operated vehicles for both types of vehicles to be similarly accepted. Further, most people would need more than 2 years after AVs' widespread commercial introduction to start considering to use one (Othman, 2021, p. 357). Governments could play an important role in setting clear quality and safety standards that car manufacturers should adhere to (Kaltenhäuser et al., 2020, p. 908). Moreover, efforts should be made to reduce the fears perceived by highlighting positive aspects and reduce the risks perceived through media, by way of marketing posts and activities, and test-drive presentations (Liu, Guo, et al., 2019, p. 315; Zhu et al., 2020, p. 89). On the other hand, Kalra and Paddock (2016, p. 191) concluded that the number of test miles that would need to be driven to demonstrate AVs' reliability in terms of fatalities and injuries would amount to hundreds of millions or billions, i.e., tens or hundreds of years, and would be practically unfeasible. Therefore, AV developers will have to develop more innovative methods to demonstrate their products' safety, but even these might not be sufficient to fully address the concerns of potential adopters (Kalra & Paddock, 2016, p. 191).

1.5.4 AV-related concerns

1.5.4.1 General concerns and barriers to adoption

M. König and Neumayr (2017, p. 49) noted that among the many concerns troubling potential AV users the greatest include legal issues, hacker attacks, and unexpected traffic situations (M. König & Neumayr, 2017, p. 48). Other studies also listed hacker attacks (Hulse et al., 2018, p. 9; Kyriakidis et al., 2015, p. 136) and legal issues (Kyriakidis et al., 2015, p. 136). Vehicle automation will increase dependence on technology and machines, which is another concern in itself (M. König & Neumayr, 2017, p. 43). Other common concerns are questions to do with liability (Bansal et al., 2016, p. 3), safety (Hulse et al., 2018, p. 9), and equipment or system failure (Bansal et al., 2016, p. 3). A survey on level-4 AVs by Woldeamanuel and Nguyen (2018, pp. 50–51) revealed the biggest concerns as: AVs not driving as well as human drivers, data privacy, and individuals' inability to learn how to use an AV. In contrast, Bansal et al. (2016, p. 6) found that inability to learn is the least likely concern, while M. König and Neumayr (2017, p. 46) established that AVs not driving as well as human drivers and job losses to be the smallest concerns. Although the biggest difference between a conventional vehicle and an AV is the presence or absence of a steering wheel/driver, M. König and Neumayr (2017, p. 46) did not find this to be overly problematic in the eyes of potential users, albeit the perceptions were still more on the negative than the positive side. However, concerns about the absence of a steering wheel could have been reduced if passengers had the option to take over control in an emergency situation and even more strongly reduced if they could so at any time (M. König & Neumayr, 2017, p. 46), which is similar to the findings by Nielsen and Haustein (2018, p. 52) who reported that sceptics and indifferent groups of people perceive AVs with a backup driver more positively than AVs without one (the same was not true for the group of enthusiasts). In the medium future, vehicles with steering wheels will still lead the way, while in the longer term, more and more AVs without steering wheels will be found on our roads (Kaltenhäuser et al., 2020, p. 886).

Even though different concerns and barriers are usually studied individually, Raj et al. (2020, p. 133) emphasised that the barriers to adoption interact with each other and cannot be isolated from each other. If the concerns and barriers are not properly understood, this could slow down the adoption rate of AVs (Bansal et al., 2016, p. 12). In the case of more complex and unusual situations, the concerns regarding safety may become even more important since a machine is incapable of the same information processing as the human brain, which might make people more inclined to use a conventional vehicle instead of an AV (Asmussen et al., 2020, p. 7). The concerns, more precisely the losses associated with the concerns, could lead many people to reject the technology because they overestimate the large losses possible, despite them being very unlikely to occur (Wang & Zhao, 2019, p. 219). Keszey (2020, p. 10) confirmed a negative influence of technological anxiety, which represents concerns and fears from a content perspective, on behavioural intention to use AV. On the other hand, experience with driver assistance systems was shown to reduce risk perceptions concerning connected and autonomous vehicles for risks related to passengers, vehicles and traffic, but not data and privacy (Brell, Philipsen, et al., 2019, p. 352). The latter does not seem to be affected by increased experience in either conventional driving or in connected and autonomous driving (Brell, Philipsen, et al., 2019, p. 352). Whereas Whittle et al. (2019, p. 309) established actual experience, e.g., test drives, as a factor in overcoming initial barriers to adoption as well as for creating expectations, Brell, Philipsen, et al. (2019, p. 353) did not find that perceived barriers would be significantly reduced with greater experience. Perceived concerns regarding AVs might be constantly changing as experience increases until AVs are widely adopted (M. König & Neumayr, 2017, p. 51), and thus the contradictory results are not surprising.

1.5.4.2 Data security and privacy in the AV era

Security and privacy have become ever more important issues in the era of connected devices that also encompass the intelligent transportation system (Le et al., 2018, p. 18). Automated and connected vehicles are equipped with numerous sensors needed to communicate with other vehicles and infrastructure, e.g., to maintain an appropriate distance from other vehicles (Jadaan et al., 2017, pp. 642–643). Both the complexity and interconnectivity of future vehicles will continue to grow (Le et al., 2018, p. 18). AVs will generate and share much more data than in the era of conventional vehicles (Smith, 2013, p. 1792). Data sharing and communication aspects represent a challenge from the privacy perspective (Le et al., 2018, p. 18). It is therefore necessary to avoid using such data for purposes beyond the primary purpose of vehicle coordination, e.g., for tracking and monitoring individuals or targeted advertising (European Parliament & Council, 2019, p. 3; Fagnant & Kockelman, 2015, p. 178). Potential users should receive clear and transparent information regarding how their data is handled (Schmidt, Philipsen, Themann, et al., 2016, p. 1348) since privacy risks are associated with the possibility that travel or behavioural data ends up shared with the government, vehicle developers and/or insurance companies in an unauthorised way, or used against users' interests or by hackers (T. Zhang et al., 2019, p. 211). To ensure privacy, car manufacturers must prevent hacking attacks that could lead to traffic accidents (Habeck et al., 2014, p. 33).

The privacy and data sharing aspects were addressed in studies by Brell et al. (2016, p. 61), Brell, Biermann, et al. (2019, p. 353) and Schmidt, Philipsen, Themann, et al. (2016, p. 1346). There are differences in what private data vehicle users are willing to share, and views between potential users and non-users vary (Brell, Biermann, et al., 2019, pp. 356–357). Individuals would be unwilling to share driver-related data (e.g., their demographic data and data about their psychological state) in vehicle-to-infrastructure systems, while the sharing of vehicle-related data (e.g., current movement) would be more acceptable; yet, still more on the neutral/negative side than on the positive side, except for intention to move (Brell et al., 2016, p. 63; Schmidt, Philipsen, Themann, et al., 2016, p. 1347). Panagiotopoulos and Dimitrakopoulos (2018, p. 778) reported a high level of privacy concerns with slightly more than one-quarter of individuals being very concerned about data privacy and 40% being moderately concerned. Potential users would be more willing to share data in situations/circumstances where non-sharing could entail greater negative consequences (Schmidt, Philipsen, & Ziefle, 2016, pp. 156–157). Brell et al. (2016, pp. 63–64) noted that privacy is the second-most important concern after safety. Regarding the duration of data storage, respondents find the collection and immediate processing of data most acceptable, while the permanent storage of data is the least acceptable (Brell et al., 2016, p. 63). Concerns about data protection also vary widely from country to country. According to a survey by Schoettle and Sivak (2014, p. 11), 13% of respondents in Japan compared to 51% of respondents in India were very concerned about privacy. Being less comfortable with the transmission of data also describes individuals from higher-income countries in comparison to lower-income ones (Kyriakidis et al., 2015, p. 134).

Privacy concerns might even become so worrisome that potential users would refuse to use connected vehicles (Habeck et al., 2014, p. 11). This would make it necessary to consider the privacy aspect in legislation (Wu et al., 2019, p. 43) and strike a balance between sharing as much as necessary to improve the traffic flow and not too much to risk data being misused (Fagnant & Kockelman, 2015, p. 178). Fagnant and Kockelman (2015, p. 178) identified several unresolved issues regarding data protection in AVs: ownership and control of the data generated by an AV, the type of data stored, identification of entities given access to AV datasets, the means of providing data, and the purposes of data use. The latter was also highlighted by Adnan et al. (2018, p. 830). Keszey (2020, p. 6) mentioned that data privacy concerning consumers is an increasingly important issue around the world, yet could not confirm in her study that it has a significant impact on behavioural intention to use an AV (Keszey, 2020, p. 10). In comparison, Raj et al. (2020, p. 132) found a negative relationship between consumer acceptance and lower security and privacy. Lower security and privacy can lead to lower consumer acceptance, and they can even reinforce each other (Raj et al., 2020, p. 132). A study by Brell, Philipsen, et al. (2019, p. 351) established that individuals attribute the greatest risk of connected and autonomous vehicles to data, while concerns about the traffic environment, vehicles and passengers are lower than data concerns and at similar levels. Moreover, these are also significantly higher for connected and autonomous vehicles than conventional vehicles. Kyriakidis et al. (2015, p. 133) concluded that individuals who already use automated systems in their vehicles are less concerned about the transmission of data with AVs. Accordingly, considering that more experience with automated systems is a factor of technological enthusiasm, technologically more enthusiastic individuals might also be less concerned. On the other hand, Zmud et al. (2016b, p. 6) concluded that individuals with stronger privacy concerns regarding Internet-enabled technologies would be less likely to use an AV. Kyriakidis et al. (2015, p. 136) even detected some differences in perceptions of concerns between individuals depending on their personality traits. Specifically, the higher the neuroticism, the lower the comfort with data being transmitted, and conversely for agreeableness.

2 AV ADOPTION

2.1 Technology adoption and millennials

The literature does not agree on use of the terms acceptance and adoption while referring to decisions made about new technologies. In this dissertation, the term adoption is used upon reference to two English dictionaries. According to the Cambridge English Dictionary, adoption means “accepting or starting to use something new” (Cambridge English Dictionary, n.d.). According to the Oxford Learner’s Dictionaries, adoption is “the decision to start using something such as an idea, a plan or a name” (Oxford University Press, n.d.). Considering the former, adoption seems to be a broader term that includes acceptance. Moreover, it is not yet clear in which form AVs will be used, whether publicly or privately, whether owned or shared etc., and hence adoption without reference to the form of use is more appropriate for the context of this dissertation. Herein, AV means “something new” and AV adoption means “accepting or starting to use AV”. While deciding whether to accept or start using an AV, potential adopters weigh up several factors, e.g., the ease of trial use, their personal attitude to AVs, the observability of the innovation, and its advantages over the alternatives (Pettigrew et al., 2019, p. 14). Indeed, Yuen, Wong, et al. (2020, p. 8) showed that relative advantage is an influential factor in the perceived value of AVs. It is precisely these relative advantages that distinguish an AV from a human-operated vehicle, on top of the unique advantages of an AV, that may convince potential adopters to stop using their existing vehicles and adopt an AV instead (J. Lee et al., 2019, pp. 413, 419).

Potential adopters can be classified in the following categories depending on when they are prepared to adopt an innovation: innovators, early adopters, early majority, late majority, and laggards (Rogers, 2010, p. 22). Innovators refers to those who lead their peers in the adoption of a new technology and represent 2.5% of all individuals (Rogers, 2003, pp. 281–282). The role of an early adopter is to approve a new technology and thereby help to reach a critical mass of adopters (Rogers, 2003, p. 283). A critical mass is the point at which the innovation has been adopted by so many individuals that any further adoption rate is self-sustaining (Rogers, 2003, p. 343). Early adopters represent 13.5% of all individuals. Representatives of the early majority and late majority each account for 34% of all individuals (Rogers, 2003, p. 281). The early majority is neither the earliest nor the last to adopt a new technology and requires a longer innovation-decision period, while the late majority is more sceptical and adopts a new technology only after most others have done so (Rogers, 2003, p. 284). Finally, representing 16% of all individuals the laggards are guided by traditional values and tend to make their decisions based on patterns similar to what has been decided in the past. Therefore, they postpone adoption until they are certain about not failing by so doing (Rogers, 2003, pp. 281, 284–285). Individuals found more on the early adoption end of the continuum are better when dealing with abstraction (Rogers, 2003, p. 289), which is a favourable characteristic in the AV context since the lack of familiarity with the technology makes it difficult to think concretely about it.

Pettigrew et al. (2019, pp. 16–17) proposed similar classes of adopters as Rogers, and referred to individuals who are the most open to adopting an AV, either their own or a shared one, as first movers. The other groups were labelled as follows: likely adopters, AV ambivalent, ride-sharing only, and non-adopters (Pettigrew et al., 2019, p. 17). The first movers differed significantly from the non-adopters, but only in substance and not as polar opposites (Pettigrew et al., 2019, p. 18). In contrast, no significant differences were found between the other groups (Pettigrew et al., 2019, p. 15). Kerschner and Ehlers (2016, pp. 143–147) introduced a spectrum of adopter categories that ranges from more technologically enthusiastic individuals who see the technology as a good thing to less technologically enthusiastic individuals who are more sceptical. They mentioned that determining precise boundaries between the categories is difficult, although the two extreme groups are clearly distinct (Kerschner & Ehlers, 2016, p. 147) and hence require different approaches to persuade them to adopt the technology. Nielsen and Haustein (2018, p. 51) divided individuals into three groups only with respect to their AV attitude: enthusiasts (25%), indifferent stressed drivers (37%), and sceptics (38%). Panagiotopoulos and Dimitrakopoulos (2018, p. 778) presented respondents with three adoption groups in their survey, with 26.5% of individuals categorising themselves as early adopters, 62.1% as late adopters and 11.4% as laggards. Zmud and Sener (2017, pp. 2506–2507) division indicated that half the respondents were likely to use an AV. Enthusiasts who were extremely likely to use an AV represented 14% of the sample, pragmatists who were somewhat likely to use an AV represented 36%, conservatives who were somewhat unlikely to do so represented 32%, while rejecters who were extremely unlikely to use an AV accounted for 18%.

Asmussen et al. (2020, p. 19) even highlighted the need to consider various groups in terms of their demographic characteristics, e.g., age, because they entail different habits and consumption patterns. They may prefer different AV features and perceive them differently (Shabanpour et al., 2018, p. 464). The ability to associate habits and patterns with a particular group can therefore enable messages to be tailored to each target group, who are at varying levels of receptivity to the technology (Asmussen et al., 2020, p. 19; Pettigrew et al., 2019, p. 18). This is critical to attracting individuals by spotlighting the potential positive outcomes valued by a certain group and lowering any concerns about potential negative outcomes it might have (Pettigrew et al., 2019, p. 13), ultimately working to increase acceptance and/or reduce rejection of AVs (Asmussen et al., 2020, p. 19). Researchers also state that studies are needed to distinguish different age/generational groups rather than looking at the population as a whole. Generational differences exist in the way people interact with technology (Calvo-Porral & Pesqueira-Sanchez, 2020, p. 2768) and identifying the perceptions held by various market groups, especially by taking their differences into account, would allow incentive schemes and ways for promoting the adopting of AVs to be designed more effectively (Shabanpour et al., 2018, p. 475). Further, differentiation could be an effective way for tailoring marketing strategies to suit a target generation (Calvo-Porral & Pesqueira-Sanchez, 2020, p. 2768), which companies and/or policymakers must consider.

Therefore, this dissertation focuses on one specific segment of the future AV market: generation Y or millennials. The generation of millennials is often seen as early adopters of new, digital and modern technologies, which include AVs. Millennials' efforts to keep up with the latest trends can make them "leaders" among their peers (Ordun, 2015, p. 44). This is the generation born roughly between 1982 and 2000 (Brosdahl & Carpenter, 2011, p. 549) or 1981 and 1999 (Bolton et al., 2013, p. 246). While authors propose different boundaries, Ng and McGinnis Johnson (2015, p. 121) noted that the exact boundaries are not as important as the historical events that members of the same generation have gone through. Millennials have been well exposed to modern technologies for most of their lives and mastered them (Bolton et al., 2013, p. 248). They are therefore open to new technologies and have a high level of competence in using them. Moreover, they are often characterised as leading technology enthusiasts and even they themselves perceive their interaction with technology as separating them from other generations (Ordun, 2015, p. 42). These characteristics have seen millennials participate in studies on the adoption of not only various new technologies but also autonomous driving technologies specifically. For example, Au-Yong-Oliveira et al. (2018, p. 955) were interested in understanding millennials in the context of a teaching process to determine how the process could be adapted to serve millennials given that their behaviour, communication and interactions are not the same as in previous generations. Similarly, Kelana et al. (2017, p. 349) examined the TAM in millennials' adoption of e-payments, Mirza and Mir (2020, p. 2) were interested in millennials' perceived travel behaviour in an AV, while A. König et al. (2021, p. 4) studied millennials in shared autonomous mobility-on-demand services. In contrast, Shabanpour et al. (2018, pp. 466–467) focused on different demographic groups, not specifically millennials, and aimed to identify the attributes that influence AV adoption behaviour. They reported differences across generations, with millennials being more interested in adopting an AV than other age groups (Shabanpour et al., 2018, p. 475). C. Lee et al. (2017, pp. 9–10) similarly found that interest in and positive attitudes regarding AVs across multiple aspects (e.g., usefulness, reliability, interest, behavioural intention) were stronger as age decreases, i.e., the younger the generation, the more positive the views.

Other authors reported generational differences between millennials and non-millennials concerning the benefits and concerns of AVs (Woldeamanuel & Nguyen, 2018, p. 52), between millennials and generation X concerning AV ride-sourcing services (Azimi et al., 2021, p. 27), between millennials and more mature consumers concerning innovative mobile app services (Hur et al., 2017, p. 359), but did not always show similar findings. Liljamo et al. (2018, p. 30) were also unable to confirm the direction of differences among various age groups. They only confirmed that the age group 24–34 years was significantly different from other groups, whereas the differences between all age groups generally were not statistically significant (Liljamo et al., 2018, p. 30). Indeed, while older age does not necessarily mean a lower propensity to adopt AVs, young people's greater openness here may be because they are digital natives by nature (Ruggeri et al., 2018, p. 42). Although it is beyond the scope of this dissertation to describe these differences, broadly speaking, earlier adopters of AVs in the Australian context are assumed to be younger, generally more educated, and in particular more knowledgeable about AVs, which may lead to them having more positive perceptions of the benefits (Pettigrew et al., 2019, p. 17). This is consistent with the characteristics of millennials and justifies the sample selection.

Millennials currently constitute the biggest share of the labour market (Ordun, 2015, p. 40). Their purchasing power has risen and will continue to rise in the coming years as they advance in their professional careers (Bernardi, 2018, p. 52; Skeete, 2018, p. 27). Millennials' openness to innovation and technologies suggests they could be among the early adopters of shared mobility services (Azimi et al., 2021, p. 2). Next, considering that users of smart city transport services are expected to be curious and innovative (Mezei & Lazányi, 2018, p. 370), a match may be seen between the characteristics sought in the smart services context and the personality characteristics of millennials, making them potential early adopters of AVs. Further, it is argued that younger people may perceive an AV as more usable because they have greater cognitive abilities and can therefore process more information without becoming overwhelmed (Asmussen et al., 2020, p. 17). Nevertheless, the exceptions among the supposed late adopters should not be ignored as they might instead belong to the early adopters and potentially encourage their peers to follow suit (Ruggeri et al., 2018, p. 42), although it is primarily the early adopters whose adoption must be facilitated at the beginning. The question of how AVs will be adopted by the millennials generation remains unclear mainly because it is a novel technology with which potential users have little or no experience. In addition, most research focuses on the entire population without distinguishing the generational groups, even though intergenerational differences should be considered (Asmussen et al., 2020, p. 19).

2.2 Models of new technology adoption

In 1989, Davis (1989, pp. 319–320) proposed the TAM, after noting that practitioners often use unvalidated and subjective bases for predicting and explaining technology use. Those measures have low usage correlations and can misinform practitioners while making decisions (Davis, 1989, p. 320). He proposed the TAM that consists of two fundamental constructs for the adoption or rejection of a given technology, i.e., perceived usefulness and perceived ease of use, as derived from previous theories and studies (Davis, 1989, p. 320). Perceived usefulness was defined as "the degree to which a person believes that using a particular system would enhance his or her job performance", and perceived ease of use as "the degree to which a person believes that using a particular system would be free of effort" (Davis, 1989, p. 320). The TAM is regarded as the most frequently cited and influential model for information systems acceptance (Y. Lee et al., 2003, p. 752) and AV research (Jing et al., 2020, pp. 7–8), and continues to prove its validity and explanatory power also in relation to digital and modern technologies, either in its original form or with extensions. Scherer et al. (2018, p. 8) found that the TAM is commonly used in digital technology adoption by teachers, mainly with the two original TAM constructs. Al-Emran et al. (2018, p. 398) reported an increasing trend of studies using the TAM from the early 2000s to the late 2010s in mobile learning adoption. The studies they reviewed increasingly included additional variables to expand the TAM beyond its original two variables, depending on the study context (Al-Emran et al., 2018, p. 399). A review paper on the TAM by Marangunić & Granić (2015, p. 89) also revealed that the TAM is applicable to different technologies and found it particularly useful due to the constant development of new technologies as the model can easily be adapted or upgraded to suit a technology's specific features. Numerous studies related to AVs have expanded the TAM, e.g., Xu et al. (2018, p. 322) and T. Zhang et al. (2019, pp. 209–210). In contrast to others, Nastjuk et al. (2020, p. 4) derived additional autonomous driving adoption factors by conducting semi-structured interviews among a diverse German sample. The consideration of the modified models instead of the original one is in harmony with what Davis (1989, p. 334) himself already emphasised, namely that it is important to study the interaction between external variables and the TAM constructs.

A decade after the TAM first appeared, Venkatesh and Davis (2000, p. 187) added some constructs related to social influence processes and cognitive instrumental processes to the TAM as part of 'TAM2'. The constructs added were as follows: subjective norm, image, job relevance, output quality, result demonstrability, experience and voluntariness (Venkatesh & Davis, 2000, pp. 187–188). Further, due to the numerous theoretical models that found their way into user acceptance literature, Venkatesh et al. (2003, pp. 446–447) integrated the findings of eight previously established acceptance models to formulate a unified model, namely the Unified Theory of Acceptance and Use of Technology Model (UTAUT), in which they synthesised four main constructs (performance expectancy, effort expectancy, social influence, facilitating conditions), and four moderating variables (gender, age, experience, voluntariness of use). An empirical test of the model showed that it explains around 70% of variance in behavioural intention and around 50% of variance in usage behaviour (Venkatesh et al., 2003, pp. 465–466), representing a slight improvement over the eight stand-alone models (Venkatesh et al., 2003, pp. 440–441). Further, the UTAUT has been extensively used since its inception and demonstrated wide applicability in various fields. For example, Zuiderwijk et al. (2015, p. 434) applied the UTAUT in the context of open data source technologies acceptance and explained 45% of the variability with the model's constructs, while Cimperman et al. (2016, p. 27) explained 77% of variance in home telehealth services as future (currently non-existing) services with the UTAUT containing three additional context-specific constructs. According to a review by Dwivedi et al. (2019, p. 721), only 25% of studies did not modify the original UTAUT model/constructs. They argued that not every relationship in the UTAUT model fits all contexts; conversely, some might have been neglected or overlooked in the initial model (Dwivedi et al., 2019, p. 719), meaning that extensions and adaptations are welcome. The latter was confirmed by their meta-analysis-based modifications of the UTAUT that outperformed the original UTAUT model in the variance explained, which rose from 21% to 27% and 38% to 45% for user behaviour and behavioural intention, respectively (Dwivedi et al., 2019, pp. 726–727).

The UTAUT model from 2003 was further extended by Venkatesh et al. (2012, p. 158) to better explain technology acceptance in a consumer context given that the UTAUT was primarily not developed for a consumer context but an organisational one. The consumer-oriented UTAUT2 model is based on a voluntary decision to use a new technology and, on top of the existing UTAUT constructs, it introduces additional constructs that are of little or no importance in the organisational context, i.e., hedonic motivation, price value and habit (Venkatesh et al., 2012, p. 159). The newly proposed model demonstrated a substantial increase in the variance then explained (74% for the UTAUT2 and 56% for the UTAUT for behavioural intention) (Venkatesh et al., 2012, p. 169). This supports the authors' emphasis on developing context-specific models that should also be at the heart of future adoption models (Venkatesh et al., 2012, pp. 170–171). The authors agree that relevant context-specific constructs should be identified and incorporated into traditional adoption models (Keszey, 2020, p. 12; Venkatesh et al., 2012, p. 173). Context-specific adoption models have already found their way into the automotive industry or more specifically the AV field. For example, Osswald et al. (2012, p. 53) proposed a car technology acceptance model (CTAM), but did not empirically test it. Other researchers focused specifically on AVs and proposed adoption models with diverse factors. Studying AV adoption separately from other similar modern (transportation) technologies is in line with what Brell, Biermann, et al. (2019, p. 353) stressed with regard to influential adoption factors. They noted that while the biggest factors in acceptance are known, a deeper understanding of adoption by users requires an in-depth investigation to consider factors that might be specific to the field under study (Brell, Biermann, et al., 2019, p. 353). This dissertation therefore goes beyond the traditional adoption models, reconsiders their constructs, and introduces additional constructs that should not be overlooked when it comes to AVs. The selected constructs/factors and corresponding hypotheses are justified in more detail in Chapter 3.

2.3 The importance of understanding views on AV adoption

While research on AVs is one of the fastest growing areas of research in transportation systems (S. H. Kim et al., 2020, p. 1), many uncertainties and assumptions about AVs nevertheless remain, which need to be clarified (Whittle et al., 2019, p. 308). Considering the newness of the AV research field as a scientific research field, a more pronounced rise in articles only followed in the early 2010s (Adnan et al., 2018, p. 831; Rosenzweig & Bartl, 2015, p. 6). Most attention was paid to the technological aspects of AVs, accounted for over 90% of the articles in Rosenzweig and Bartl's (2015, p. 9) literature review on autonomous driving, while only a negligible 1.3% focused on the adoption perspective. Their review focused on autonomous driving in general, while a review by Adnan et al. (2018, p. 828) looked specifically at user acceptance and ethical implications and established that articles were mostly concerned with the social acceptance and implications of the technology. While the early studies generally used descriptive statistics, the more recent studies attempted to more comprehensively identify the reasons underlying AV adoption (Shabanpour et al., 2018, p. 464). Adnan et al. (2018, p. 829) even noted that most published scientific articles are concentrated in the USA, with fewer in Europe and Asia. Although there are also few or no comparative and longitudinal studies, it would be valuable to observe people's perceptions and attitudes in different countries over time as people become more familiar with AVs (Liljamo et al., 2018, pp. 36–37).

The scientific branch that deals with AV adoption, e.g., willingness to pay and socio-economic aspects of adoption, is called behavioural analysis (Wang & Zhao, 2019, p. 217), and this is precisely one of the fields in autonomous driving that calls for additional research (M. König & Neumayr, 2017, p. 43). Even though technology plays a crucial role in smart-mobility-related innovation that fosters change and progress (Lopez-Carreiro & Monzon, 2018, p. 693), it is still not the technology itself that will bring benefits if people are unwilling to use it (Mezei & Lazányi, 2018, p. 370). Despite the current development of technology already enabling full automation (Daziano et al., 2017, p. 151), AVs cannot appear widely on our roads if there is low acceptance by end users. It is exactly people-related areas that might spell the doom or boom of the new technology among end users (Konya-Baumbach et al., 2019, p. 385), while the numerous concerns and opposing views make it critical to deepen the understanding of different stakeholders (Ruggeri et al., 2018, pp. 39–40). It is only when potential users are willing to start using the available technology that the promised benefits can be realised (Asmussen et al., 2020, p. 2), and technology development must thus be people-centric (Adnan et al., 2018, p. 829). Similarly, van der Laan et al. (1997, p. 1) stated that investing in technology development and its design is of little value if the technology is not used by the final user. A parallel can be drawn here with the findings of

Noy and Givoni (2018, p. 10) who explored the perspectives of key players (entrepreneurs and innovators in the transport sector) in the smart mobility field regarding the desirability and likelihood of implementing scenarios related to the future transport system. Most of the development scenarios that expect a desirable level not to be achieved before 2050 are related to behaviour and habit change rather than the technological aspects (Noy & Givoni, 2018, p. 10), which means that changing human habits is a harder nut to crack. Therefore, the attitude of potential users regarding AVs must be assessed (Ruggeri et al., 2018, p. 40).

Once what affects user acceptance is understood, this can drive the success of AVs in the marketplace (Nastjuk et al., 2020, p. 2). Davis (1989, p. 335) and earlier authors he cites emphasised the importance of studying new technologies during their development and deployment already decades ago. However, this is even more important in today's rapidly changing environment where technologies can pass through different stages of development even faster. Payre et al. (2014, p. 253) also stressed the importance of 'a priori acceptance' research which refers to assessing attitudes and intentions regarding the adoption of a technology before people interact with it, which is especially relevant for technologies that are not commercially available like AVs (Payre et al., 2014, p. 253). Kapser and Abdelrahman (2020, p. 217), who conducted research on autonomous delivery vehicles, also pointed out the need for early-stage research on new technologies. Early-stage findings can then be incorporated into ongoing development and thereby increase early-stage adoption (Kapser & Abdelrahman, 2020, p. 217; Schmidt, Philipsen, Themann, et al., 2016, p. 1344). If potential users do not accept a technology, the technological innovation cannot itself reform the transport and mobility systems (Liu, Guo, et al., 2019, pp. 306–307). Individuals' attitudes to AVs accordingly drive demand for the technology as well as the directions of public policymaking and infrastructure investment initiatives (Haboucha et al., 2017, p. 38; Wadud et al., 2016, pp. 15–16). New technologies must be studied in advance with regard to their acceptability and barriers in order to select the right policies, strategies, and draft legislation that will be socially acceptable and boost the adoption of the technology (Davis, 1989, p. 335; Hesse et al., 2019, p. 102). In a report by Hesse et al. (2019, p. 98), it was additionally noted that robust research would complement the existing development initiatives. Moreover, AVs should not be studied isolated from other mobility initiatives, but as part of them (Kassens-Noor et al., 2020, p. 332). There is a need to focus on understanding how to support the development of the technology and its promotion to reduce the adoption barriers and support decision-making processes (Osswald et al., 2012, p. 57), together with the influential factors in the forming of trust in AVs (Ma et al., 2020, p. 2021; T. Zhang et al., 2019, p. 208), and consumer sensitivity to different attributes related to AVs (Shabanpour et al., 2018, p. 464). Consumer acceptance can also serve as a basis for predicting adoption rates (Daziano et al., 2017, p. 151).

The novelty of autonomous driving technology has seen current research mainly focusing on expectations of AVs rather than actual experience with them when assessing attitudes (Tennant et al., 2019, p. 114). Yet, as experience and penetration rates of AV rise, attitudes will evolve (Tennant et al., 2019, p. 114), which is similar to Davis' (1989, p. 335) proposition offered back in 1989 that a systematic approach to investigating user acceptance and a critical assessment of existing models is what will lead to progress (Davis, 1989, p. 335). Studying adoption behaviour and proposing a model based on it is indeed an iterative process (Osswald et al., 2012, p. 58), i.e., some factors may lose relevance and some will gain it, which is calls for the constant reassessment of attitudes to provide a supportive foundation for the authorities while preparing their strategies. Once individuals become more comfortable with AVs and clarify their awareness and understanding of AVs and their role in road transport (Tennant et al., 2019, p. 113), it will also become easier for the authorities to work together to deliver individuals' visions. This is an area where knowledge of the adoption factors could be added value. Authors have also repeatedly called for extra factors to be included and tested in the models. For example, J. Lee et al. (2019, p. 412) attached additional importance to psychological factors, e.g., social influence, and suggested that more specific risk-related aspects be examined, e.g., privacy (J. Lee et al., 2019, p. 421). Kapser and Abdelrahman (2020, p. 220) reaffirmed the need to consider contextual factors for the technology in question and provided important practical guidance for future development.

Researchers have further called for additional research with practical implications that would help policymakers formulate strategy to support the adoption of autonomous driving technologies (Bansal et al., 2016, p. 2), traffic engineers and transport planners in transportation planning, and car manufacturers while assessing profit margins (Asmussen et al., 2020, p. 2). The practical implications could also benefit the industry by addressing its concerns and desires (Ruggeri et al., 2018, p. 40) as well as planning promotional information and safety campaigns (Asmussen et al., 2020, p. 2). The right approach could be chosen much more effectively if industry, policymakers and the general public cooperate (Ruggeri et al., 2018, p. 40). Considering that transport policymakers are the leaders in this respect (Kassens-Noor et al., 2020, p. 332), they should rely on perceptions of the public to align their policies with them. Car manufacturers should also increase the dissemination of AV-related information to the public to enable them to make more informed judgements of the technology (Pettigrew et al., 2019, p. 18) and form perceptions (Zhu et al., 2020, p. 89). The information provided should be concrete and tangible, and communication with the public open as well as proactive (Liu, Guo, et al., 2019, p. 315). Yet, while there are many suggestions as to what further research should deal with, a comprehensive model of the AV adoption factors is still missing. One reason for this may be attributed to the newness of the field, which means that some AV-related research areas are under-researched or the findings are contradictory. In recent years, several models have been proposed that look at the adoption from different angles, and this dissertation seeks to contribute to the field in this respect. The model proposed in this dissertation is presented and justified in Chapter 3, and relies on the most popular adoption models, e.g., the TAM and the UTAUT2 (presented in Chapter 2.2).

2.4 Attitudes and intentions

Attitudes represent an individual’s inner feelings (Y. K. Singh, 2006, p. 207). Attitude to a technology reflects an individual’s reaction to use of and belief in a system, which is not functionality-related but fun- and likeability-related (Osswald et al., 2012, p. 54). Attitudes can express either positive or negative feelings regarding the use of a technology (T. Zhang et al., 2019, p. 210). Fishbein and Ajzen (1975, in Davis, 1985, p. 16) defined an attitude as “an individual’s degree of evaluative affect toward the target behaviour”. Affect is one of the components of attitude and thus Davis (1985, p. 24) also classified attitude as an affective response. Attitudes can also be seen as “individual's expectation of the outcomes of an activity, and the personal values that are attached to them” (Ajzen, 1991 & Sutton et al., 2003, in Acheampong et al., 2021, p. 3) or the “predispositions to respond in a favorable or unfavorable manner to a target act” (Eagly & Chaiken, 1993, in Christian et al., 2012, p. 256). In the AV context, Nastjuk et al. (2020, p. 22) defined attitude as the “degree to which an individual has a favorable or unfavorable evaluation of using autonomous driving”. Although the most recent research on AVs does not consider attitude as a predictor of behavioural intention, Rondan-Cataluña et al. (2015, p. 798) emphasised the importance of including attitude in consumer adoption models since it can improve the explanatory power of behavioural intention of use. Dwivedi et al. (2019, p. 720) also proposed including attitude in their revised original theoretical UTAUT model, and confirmed it as a predictor of behavioural intention as well as usage behaviour. Other older established theories which considered attitude as a predictor of behavioural intention are the Theory of Reasoned Action (Fishbein & Ajzen, 1975), the Theory of Planned Behaviour (Azjen, 1980), and the Extended IS Success Model (Sabherwal et al., 2006). Attitudes are an important construct in the implementation of AVs because understanding public and individual attitudes and preferences concerning AVs enables an exploration of changes in travel behaviour and can help direct technology demand, policies and future infrastructure investments (Acheampong et al., 2021, p. 2; Haboucha et al., 2017, p. 38).

Since attitude to a technology is not necessarily the same as attitude towards using the technology (Davis, 1985, p. 57), behaviour should be observed through a different construct that shows the individual's subjective likelihood of performing a certain behaviour, i.e., behavioural intention (Fishbein & Ajzen, 1975, in Davis, 1985, p. 16). Ajzen and Fishbein (1980, in Moore & Benbasat, 1991, p. 196) distinguish between an attitude to something and actual behaviour, yet this doctoral dissertation adopts the view that actual behaviour cannot be measured for technologies without first-hand experience. Therefore, behavioural intention is considered instead of actual behaviour, namely, similarly to the approach taken in other studies (e.g., Zmud et al. (2016b, p. 4)). Behavioural intention reflects an individual’s intention to perform a specific behaviour (Keszey, 2020, p. 14) and is a crucial component of the adoption process (Keszey, 2020, p. 1). Behavioural intention can also be seen as a measure of a person’s strength in terms of intention to perform a given behaviour (Dwivedi et al., 2019, p. 724). In the context of AVs, Nastjuk et al. (2020, p. 22) defined usage intention as an “individual's motivational readiness to use or not to use autonomous driving”. Since AVs are not yet commercially available, individuals lack first-hand experience (Hulse et al., 2018, p. 7; Tennant et al., 2019, pp. 112–113; Zmud et al., 2016b, p. 3), and hence it may be inconceivable for individuals to realistically express their views and intentions because it is difficult to tangibly imagine an autonomous future. In view of this, it is more appropriate to consider AV adoption intention rather than actual behaviour, as also proposed by Keszey (2020, p. 7), van der Laan et al. (1997, p. 61) and Nastjuk et al. (2020, p. 6).

Studies report diverse intentions of potential users to adopt AVs as a new technology. For example, Liu, Yang, et al. (2019, p. 334) findings on behavioural intention to adopt AVs are more on the negative-to-neutral side, whereas Ribeiro et al. (2022, p. 628) and Zhu et al.'s (2020, p. 86) respondents expressed more positive intentions to adopt AVs in general as well as public AVs. Similarly inconsistent results apply to attitude to AVs. Tennant et al. (2019, p. 101) in their review study as well as their own data collection study reported more negative than positive attitudes to AVs, either driving alongside an AV or using one. Conversely, individuals in a study by Payre et al. (2014, p. 258) expressed more positive than negative intentions to use AVs and more positive than negative attitudes to AVs. Similarly, Acheampong et al. (2021, p. 6) found that more than half the individuals in their study believed fully AVs are a good and exciting idea. To contribute to positive attitudes regarding AVs, researchers suggest working on increasing the experience of (potential) users in the roles of various road participants, exposure to mass media and information campaigns (Tennant et al., 2019, pp. 102, 114), and providing transparent test drives or showrooms organised by car manufacturers to fill the knowledge and experience gap (Hulse et al., 2018, p. 7; M. König & Neumayr, 2017, p. 50). Greater familiarity with technology has indeed been shown to be a factor behind more positive attitudes to AVs (Liu, Guo, et al., 2019, p. 314). In addition, the gradual installation of automated features in conventional vehicles could help to boost people’s trust in automation (M. König & Neumayr, 2017, p. 50). This would indirectly increase people’s experience, and more experience/knowledge about AVs can lead to a more positive attitude to them.

2.5 The role of technological innovativeness and enthusiasm in AV adoption

Although innovativeness is the degree to which an individual adopts new ideas earlier than other members of society, individuals should not be characterised as more-than-average innovative or less-than-average innovative, but instead according to which adopter category they belong (see the categories presented in Chapter 2.1) (Rogers, 2010, p. 22). The concept of innovativeness can also be studied from the perspective of personal innovativeness and linked to technological enthusiasm or tech-savviness, which the literature often considers relative to the adoption of a new technology. Personal innovativeness is an individual’s willingness to try out new information technology (Agarwal & Prasad, 1998, p. 207). Tech-savviness is the extent to which an individual embraces and uses a technology for different purposes (Astroza et al., 2017, p. 20) or the individual's familiarity and affinity with technology (Asmussen et al., 2020, p. 7). Technological enthusiasm is based on technological optimism (Kafaee, 2020, p. 970) and is less emotionally charged and more encompassing than technological optimism (Kerschner & Ehlers, 2016, p. 144). Technological enthusiasm can refer to an individual's interest in realising the potential of technology solely due to the existence of that potential (Slotten, 2014; in Kafaee, 2020, p. 970) or their inclination to take on new technological possibilities or challenges (Van de Poel & Royakkers 2011; in Kafaee, 2020, p. 970), and can hold considerable implications for human behaviour while developing technology (Kafaee, 2020, p. 978). Technology enthusiasts find technology to be inherently good and only accidentally misused (Kerschner & Ehlers, 2016, p. 144). Accordingly, various individuals in terms of their innovativeness, among which are willingness to try, familiarity with or interest in new technologies, will be open in different ways to adopting a new technology, e.g., an AV. Nevertheless, not many studies include such a general attitude towards technology, even though it could be beneficial (Tennant et al., 2019, pp. 101–102). Moreover, exploring current technological awareness can help in understanding the future adoption intentions of consumers concerning smart transport technologies (Bansal et al., 2016, p. 4).

Personally more innovative individuals might possess better knowledge of a particular technology and thus express greater confidence that what is promised will also be delivered in terms of vehicle operation, yet at the same time hold greater privacy concerns, knowing the negative consequences that could result from a breach of privacy (Keszey, 2020, p. 12). Hur et al. (2017, p. 355) believed that more innovative consumers would be more willingly to accept a new technology as well as gain greater satisfaction and pleasure from using it, and confirmed that in mobile app usage higher technological innovativeness leads to higher perceptions of ease of use, usefulness, and joy of use (Hur et al., 2017, p. 358). Astroza et al. (2017, p. 27) showed that more tech-savvy individuals would use smartphones to a greater extent to access travel information; moreover, smartphone ownership would increase the likelihood of using multiple modes of transportation (Astroza et al., 2017, p. 28). These findings have two implications. First, more tech-savvy individuals would be more open to use a modern technology. Second, the findings show the importance of tech-savviness as well as smartphone use as a predictor of technology adoption, which is especially relevant in the context of modern smart services that require the use of smartphones (or similar technologies) to (remotely) control these services. Asmussen et al. (2020, p. 7) stated that more tech-savvy individuals would be more likely to purchase an AV and further characterised men, younger and higher-income individuals as more tech-savvy when it comes to AVs (Asmussen et al., 2020, pp. 9–10). Higher tech-savviness is also expected to lead to more frequent use of AVs, which Bansal et al. (2016, p. 9) showcased for shared AVs, and a higher likelihood of adoption/use of car-sharing and ride-sourcing services, as well as future adoption of an AV as confirmed by Lavieri et al. (2017, p. 8). In addition, individuals with more positive attitudes to technology generally and with a wider range of advanced technological features in their vehicles would perceive AVs more positively

(Tennant et al., 2019, p. 108). Keszey (2020, p. 11) reported differences in perceptions of individuals with different levels of personal innovativeness related to technological anxiety, which represents concerns and fears from a content perspective, and data privacy concerns. Specifically, for individuals scoring higher for personal innovativeness it is not expected that technological anxiety will negatively influence their behavioural intention and, vice versa, for individuals scoring lower for personal innovativeness (Keszey, 2020, p. 11). On the other hand, data privacy concerns negatively influence the behavioural intention of individuals scoring higher for personal innovativeness (Keszey, 2020, p. 11).

Nielsen and Haustein's (2018, p. 51) study distinguished three adoption groups that varied in terms of openness to technology and attitudes to AVs. The sceptics showed the lowest affinity for AVs and the most positive attitude to conventional vehicles. The "indifferent stressed drivers" expressed the most negative attitude to conventional vehicles and were in the middle in terms of enthusiasm/scepticism. The enthusiasts expressed being 2 to 3 times more open to technology compared to the other two groups and revealed the most positive attitude to AVs, while their attitude to conventional vehicles was in between the sceptics and the indifferent stressed drivers (Nielsen & Haustein, 2018, pp. 51–52). Ljubi and Groznik (2021, p. 157) did not find significant differences between technologically less enthusiastic individuals and technologically more enthusiastic individuals with respect to in-vehicle activities and the activities AV can perform instead of an individual in fully AVs, while Ljubi and Manfreda (2020, p. 12) established statistically significant differences between the two groups for different AV adoption factors for semi and fully AVs. The effect of technological enthusiasm might however not always be direct. For example, Montoro et al. (2019, p. 871) found only a mediating effect of individuals' interaction with information and communication technology, which can be an indicator of technological enthusiasm, on intention to use an AV through perceived safety and value attributed to AVs, which were positively influenced by individuals' interaction with information and communication technology.

2.6 Influence of the external environment on the individual

A century ago, when the automotive industry experienced its first major shift with the introduction of the combustion engine, automobiles quickly became seen as a status symbol (Hresko Pearl, 2020, p. 470). Not only was it important that an individual owned a vehicle, but also what type of vehicle they owned to express their identity (Hresko Pearl, 2020, pp. 469–471). In the digital era of today, this has become ever more important since sharing opinions, showing belongings and the like is a common practice as well as easily made viral. In terms of different social factors, the technology adoption literature has considered numerous concepts/constructs in the last decades, ranging from subjective norms through to social factors, image, social influence, and social norms (Venkatesh et al., 2003, p. 452). These were summarised in detail by Venkatesh and Davis (2000, pp. 187–190) in a proposition of the TAM2 model and are presented below. First, considering subjective norms, an individual's perceptions are formed based on what the majority of (important) people ("referents") think the individual should do (or not) in terms of their behaviour (Fishbein & Ajzen, 1975, in Venkatesh & Davis, 2000, p. 187), even though this might be in contrast with their but they are sufficiently motivated to follow what their referents advocate (Venkatesh & Davis, 2000, p. 187). Second, an individual's perceptions to use a new system are formed under social influences because important others think they should do so (Venkatesh et al., 2003, p. 451), and different processes and mechanisms lie behind the forming of perceptions (Venkatesh & Bala, 2008, p. 4). Normative social influence is distinguished from informational social influence (Deutsch & Gerard, 1955, p. 629). The former refers to conforming to someone's positive expectations, while informational social influence represents the acceptance of information gathered by somebody as evidence of reality (Deutsch & Gerard, 1955, p. 629). An individual will more likely use a technological innovation if important others do so and when important others believe that the individual should use it (Wagner, 2017, p. 266). Third, an individual might adopt a technology to gain some sort of social recognition or their image in society. Moore and Benbasat (1991, p. 195) defined image as "the degree to which use of an innovation is perceived to enhance one's image or status in one's social system". Fourth, social norms reflect what people think they should do, which influences their behaviour (Triandis, 1971, in Thompson et al., 1991, p. 126). Fifth, Triandis (1971, in Thompson et al., 1991, p. 126) introduced the term social factors, which refers to internalising the subjective cultures (e.g., norms, roles, values) of a reference group and interpersonal agreements with the reference groups.

Given the above, a social perspective seems to entail various nuances that are measured by different constructs. Venkatesh et al. (2003, pp. 451–452) stated that these constructs of "social influence" behave similarly and have found their way into research on autonomous driving as a contextual factor. The relevance of contextual factors is in line with Dwivedi et al. (2019, p. 719) who underscored the importance of specific technology-related factors depending on the technology studied beyond solely focusing on factors taken from established models. Even though most of the above constructs were proposed in an organisational context, their further applicability was also shown in a consumer context. For example, the UTAUT2 confirmed social influence in a voluntary setting and in a similar vein proposed that status gains be tested as a technology adoption driver (Venkatesh et al., 2012, pp. 170–172). Examples of AV research considering different social factors are listed below. Bansal et al. (2016, p. 2) stated that individuals would be more encouraged to adopt an AV if AVs have already been adopted by their neighbours and friends, which would give them additional confidence in the technology. Further, more tech-savvy individuals, males, and individuals who drive more would rely less on external opinions, i.e., friends and family, while older and licensed drivers would be more dependent on the adoption rate of their family and friends (Bansal et al., 2016, pp. 11, 13). According to Acheampong and Cugurullo (2019, p. 373), an individual's adoption intentions would increase if their friends and relatives were to use AVs. Whittle et al. (2019, p. 308) noted that in the case of electric vehicles different social factors may be at the forefront of the various stages of the product lifecycle and hence concentrating too specifically on the social factors could lead to some relevant aspects being omitted. The authors also noted that social status symbols are changing through time and that car ownership is no longer important a status symbol like it used to be. Some people might be values-motivated (e.g., they value environmental protection over car ownership), while others would be necessity-driven and would opt for a shared service due to an inability to afford a private service (Whittle et al., 2019, p. 310).

In the digital era, one should not neglect the changes brought about by social and other online media where the influence of other referent groups/individuals has become more noticeable. An individual's decision to adopt a new technology might be influenced by mass media advertising as well as peer-to-peer communication (Talebian & Mishra, 2018, pp. 366–367). Moreover, social image has become more important as one's belongings can easily be displayed outwardly to others through social media platforms, and people are more encouraged to do so to show which products they are loyal to. Millennials in particular believe that their personality or image is reflected in what they value in life (Ordun, 2015, p. 44). In addition, social media reach a much wider range of consumers and therefore offer more interactions and information sharing than offline media (Wagner, 2017, p. 266). In this way, social media have become a valuable channel for learning about others' attitudes and behaviours (Wagner, 2017, p. 266). Zmud et al. (2016b, p. 7) even found that the use of social media, smartphones and smartphone apps is a positive predictor of intention to use an AV, while social influence is an even stronger predictor of AV intention to use. Next, media reports have also appeared in the autonomous driving sphere where especially the negative announcements made in the media about accidents involving AVs make people less trustworthy of AVs and indicate why safety is so important. When news of a fatal Tesla accident spread in June 2016, 6 weeks after the accident (Stilgoe, 2017, pp. 26, 36), it sparked a major controversy. Elon Musk, one of Tesla's owners, considered the accident as just one accident among many drives, while the public and Tesla's competitors immediately called it irresponsible and unacceptable (Stilgoe, 2017, pp. 38–39). Penmetsa et al. (2021, p. 485) studied how two other accidents that caused fatalities in 2018 affected posts on social media. It was shown that an incident causing the death of either a pedestrian or a driver, resulted in considerable increased public discussion on social media on the topic with a slightly higher and statistically significant increase in negativity in shared posts related to the keywords studied (Penmetsa et al., 2021, pp. 488–489). Such accidents can significantly negatively impact perceptions of AV safety and add to people's concerns. Anania et al. (2018, p. 222) indeed confirmed that the more negative the information regarding AVs, the less willing people are to ride in one. Schaefers et al. (2016, p. 574) even found that social risk, defined as the extent to which an individual is concerned that their purchasing decision will be judged by others and will affect their social status, has a direct positive impact on the use of access-based services as well as a negative impact on ownership. If individuals are more concerned with the social risk associated with purchasing a car, i.e., they worry about the negative social consequences of owning a car, they will be more likely to use access-based services, e.g., car-sharing (Schaefers et al., 2016, pp. 574–575). They would nonetheless be less likely to give up vehicle ownership, which may be due to them considering vehicle ownership as a status symbol (Schaefers et al., 2016, p. 575). In a similar vein, J. Li et al. (2019, p. 109) confirmed that individuals would be less prepared to use public transport due to the symbolic value of owning a car.

In any case, while AVs are a technology that has yet to be deployed on our roads and thus people do not have experience to share with others, public/mass and/or social media are channels responsible for keeping individuals abreast of developments in this area (Zhu et al., 2020, p. 82). T. Zhang et al. (2020, p. 229) that for technologies which most people have not yet had an opportunity to try first-hand, such as AVs, social influence, including media reports and other people's opinions, plays an even more important role than for other commercially available technologies that are physically available for testing. On the other hand, Rogers (2010, p. 286) found mass media channels acted more as a way of sharing information, not so much for persuading people to adopt, whereas interpersonal networks could have a more persuasive role in the adoption or rejection of a technology. However, his book was written before the proliferation of social media and hence today this might not apply to the same extent. More recently, Talebian and Mishra (2018, pp. 373–374) studied the impact of marketing activities on AV market share increases. Marketing activities half a year before the introduction of the technology did not pay off because a small proportion of individuals would be willing to invest a high initial amount of money to buy an AV, while the influence of marketing activities after the technology was introduced was significant and positive; albeit, only to a certain level (Talebian & Mishra, 2018, pp. 373–374). As regards different media channels, mass media positively influence both perceived usefulness and perceived risks, whereas social media only negatively influence perceived risks (Zhu et al., 2020, p. 88), suggesting that communication channels must be selected depending on the purpose and information to be made viral. Different educational campaigns, the media and social networks might also prove beneficial to turn attitudes to AVs to become more positive and accordingly increase the probability of choosing an AV over a conventional vehicle (Haboucha et al., 2017, p. 47).

2.7 Effect of socio-demographic and individual-related characteristics on AV adoption

Individuals' socio-demographic characteristics might also affect attitudes and views concerning different AV aspects. Several demographic and driving characteristics have proven important for predicting willingness to pay, namely gender, age, residential location, driving alone or accompanied, and experience with traffic accidents (Bansal et al., 2016, pp. 8, 11). It was shown that male, younger, and urban-resident individuals, and those who perceive AVs as less risky are expected to have a more positive attitude to AVs (Deb et al., 2017, pp. 188–189; Hulse et al., 2018, p. 6; M. König & Neumayr, 2017, p. 46). Nevertheless, the results of studies considering age and gender differences are inconsistent. For instance, Acheampong et al. (2021, p. 12) and Madigan et al. (2017, p. 62) did not find statistically significant differences between gender in terms of preferences regarding AVs, while other studies did find them. Females perceive all types of vehicles to be riskier than males do (Hulse et al., 2018, p. 5), express higher safety concerns (Asmussen et al., 2020, p. 9; Deb et al., 2017, p. 188), a less positive attitude to AVs (Liljamo et al., 2018, p. 30), are less inclined to accept AVs from the pedestrian perspective (Deb et al., 2017, p. 186), and would be less interested in owning or sharing an AV (Lavieri et al., 2017, p. 6). It has been also shown that gender affects perceived benefits and fears, but not perceived risks and trust, with males expressing more positive perceptions (Liu, Guo, et al., 2019, p. 314). Further, males and more educated parents, and those living in an urban location would earlier transport their children in AVs (Koppel et al., 2021, p. 148; Y.-C. Lee et al., 2020, p. 291).

As regards the age of potential adopters, Hulse et al. (2018, p. 5) and Madigan et al. (2017, p. 62) did not observe age-related differences, whereas Günthner and Proff (2021, p. 597) and Haboucha et al. (2017, p. 45) did find them. Most of the findings show the younger population as being more open to AVs from different perspectives, e.g., Deb et al. (2017, p. 187) for AV acceptance, Haboucha et al. (2017, p. 45) for attitudes to AVs, Kaltenhäuser et al. (2020, p. 907) for willingness to use autonomous taxis, and Moody et al. (2020, p. 639) for more favourable perceptions of AVs. Even though millennials as one of the demographic groups concerning age are considered to be less worried about AV technology in most of the literature, some studies report mixed results. Woldeamanuel and Nguyen (2018, pp. 50–51) in their exploratory survey found non-millennials were less concerned in most of the AV driving scenarios than millennials (e.g., AV taxis, public AV, commercial AV, and fully AV) (Woldeamanuel & Nguyen, 2018, pp. 49–50). On the other hand, the concerns held by non-millennials about potential issues related to AV technology/implementation were higher than those of millennials (e.g., AVs not driving as well as humans and their interaction with other road users, AVs becoming confused in unexpected situations and weather conditions, learning how to use an AV, data privacy, hacking, and system failure (Woldeamanuel & Nguyen, 2018, pp. 50–51). However, while the sample was overrepresented by millennials (Woldeamanuel & Nguyen, 2018, p. 52), which could bias the results somewhat, the study still suggests age differences, mainly in favour of youngers being more positive about AVs.

Individuals will also make decisions about adopting vehicles based on trust in AVs and previous knowledge about them, along with driving experience and involvement in traffic accidents. Building trust in new technologies is much more difficult than in existing ones (Whittle et al., 2019, p. 309), and neither too high nor too low trust is desirable since it may respectively lead to misuse or unwillingness to use (M. König & Neumayr, 2017, p. 44). Previous experience with automated functions and better knowledge of a technology can reduce concerns and thereby increase trust in automation, as well as lead such individuals to attribute greater safety benefits to AVs (M. König & Neumayr, 2017, pp. 49–50). The effect of trust on behavioural intention to use AVs can however be direct or indirect through perceived ease of use and perceived usefulness (Dirsehan & Can, 2020, p. 5). Individuals with more driving experience, greater involvement in accidents and individuals with higher education perceive AVs in a more positive manner, namely, as safer and attribute more benefits to them (Montoro et al., 2019, p. 871). On the other hand, being a driver or not was not confirmed as a predictor of attitudes to AVs (Hulse et al., 2018, p. 6).

Individual-related characteristics explain the majority of differences in perceptions of AVs, and only minor statistically significant differences arise from the country level as shown by Moody et al. (2020, p. 640) using a 51-country sample. In contrast, Kerschner and Ehlers (2016, p. 139) reported increasingly diverse attitudes towards science and technology across the EU based on Eurobarometer data from 2013, which could indicate the elevated importance of national differences. Further, a comparison of attitudes to AVs made by Hudson et al. (2019, p. 164), which used Eurobarometer data from 2014, found substantial differences in attitudes across EU countries. Poles, Dutch and Swedes expressed the most positive attitudes, whereas Slovenians were below the average and in the bottom third of countries with the least positive attitudes to AVs (Hudson et al., 2019, p. 169). These differences reveal that results cannot simply be generalised from country to country, but that cultural and historical backgrounds must be considered, and perceptions may need to be determined separately by country. This also demonstrates the importance of examining different national contexts. Ismagilova et al. (2019, p. 96) suggested that a distinction even needs to be made between established and emerging economies. Considering that Haboucha et al. (2017, p. 43) established differences between the USA and Israeli in some respects, and Kyriakidis et al. (2015, p. 134) confirmed national differences in 40 countries studied concerning several aspects relating to AVs, it is necessary to differentiate countries in research because cultural differences can also shape perceptions (Nielsen & Haustein, 2018, p. 50).

3 RESEARCH MODEL AND HYPOTHESES DEVELOPMENT

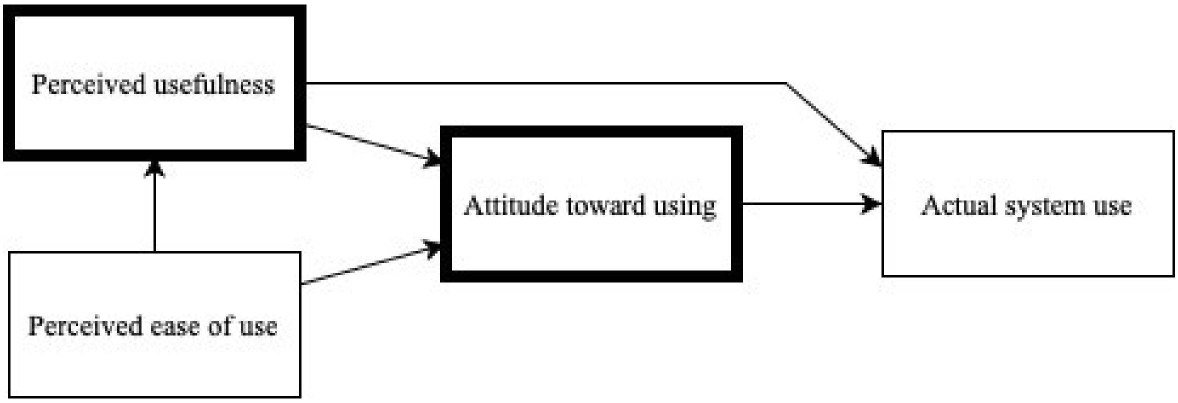
3.1 Model origins

The willingness of an individual to join in the mobility transition depends on several factors, e.g., subjective preferences and values, emotional and socio-economic factors, psychological and cultural factors, and infrastructure (Whittle et al., 2019, p. 313). Understanding user acceptance perspectives and drivers as well as the underlying impediments is what current literature must progress in (Rosenzweig & Bartl, 2015, p. 10). Therefore, this dissertation aims to contribute to the AV adoption literature by proposing an adoption model. The proposed model is based on the current literature from which influential factors were derived and integrated into it. The model is not necessarily comprehensive since it focuses particularly on refining the model proposed by Manfreda et al. (2021, p. 5) by adding new adoption factors, namely, privacy concerns in the AV era, social factors, facilitating conditions, and attitude to AVs. At the same time, two adoption factors – perceived security and perceived mobility-related efficiencies – were excluded from the model after not being shown to be significant in Manfreda et al.'s paper (2021, p. 7) and since there is little evidence in the literature for the relationships. To the best of the author's understanding of the literature, no other studies have considered mobility-related efficiencies or equated them with AV-related benefits. Thus, including two overly similar constructs could lead to confusion. As regards perceived security, the recent meta-analysis by Gopinath & Narayanamurthy (2022, p. 8) considered 58 articles and did not report a security construct as a standalone factor but instead an umbrella construct consisting of trust, perceived safety and privacy risk (Gopinath & Narayanamurthy, 2022, p. 15). Moreover, it has been noted that scientific articles do not define the studied concepts clearly and uniformly, nor clearly differentiate between the safety and security aspect, adding another reason against including the security construct given that too many concerning aspects (safety, privacy, general concerns) could cause confusion. The literature indeed does not distinguish well between safety and security. Some studies equate privacy with security risks while other studies equate security with safety risk, or even supposedly study one type of risk yet argue in relation to another (Kenesei et al., 2022, pp. 383, 388; Meyer-Waarden & Cloarec, 2022, pp. 4–5; Waung et al., 2021, p. 336).

Schreiber et al. (2006, p. 334) noted the lack of a sound link with theory in the articles that were the subject of their review, while Jing et al. (2020, pp. 7–8) reported a lack of behavioural theory utilisation also specifically for AVs in most research papers they looked at. Those that did apply a model mostly used the TAM, while the UTAUT2 was rarely used despite it being specific to the consumer context and therefore includes factors that may be relevant also in the AV context. To overcome this shortcoming, this dissertation builds on the firmly established TAM and UTAUT2 models from which some variables are adopted and synthesised to create a new AV-specific framework. The relevant constructs used in this dissertation taken from the two models are shown in bold in Figure 2 and Figure 3 to make it easier to follow the rationale for the proposed model outlined below. Several authors have already suggested adapting models to the research context (e.g., Dwivedi et al. (2019, p. 719)). Taking the specific characteristics of the technology under study, i.e., AVs, into account may thus lead to the higher predictive power of the model.

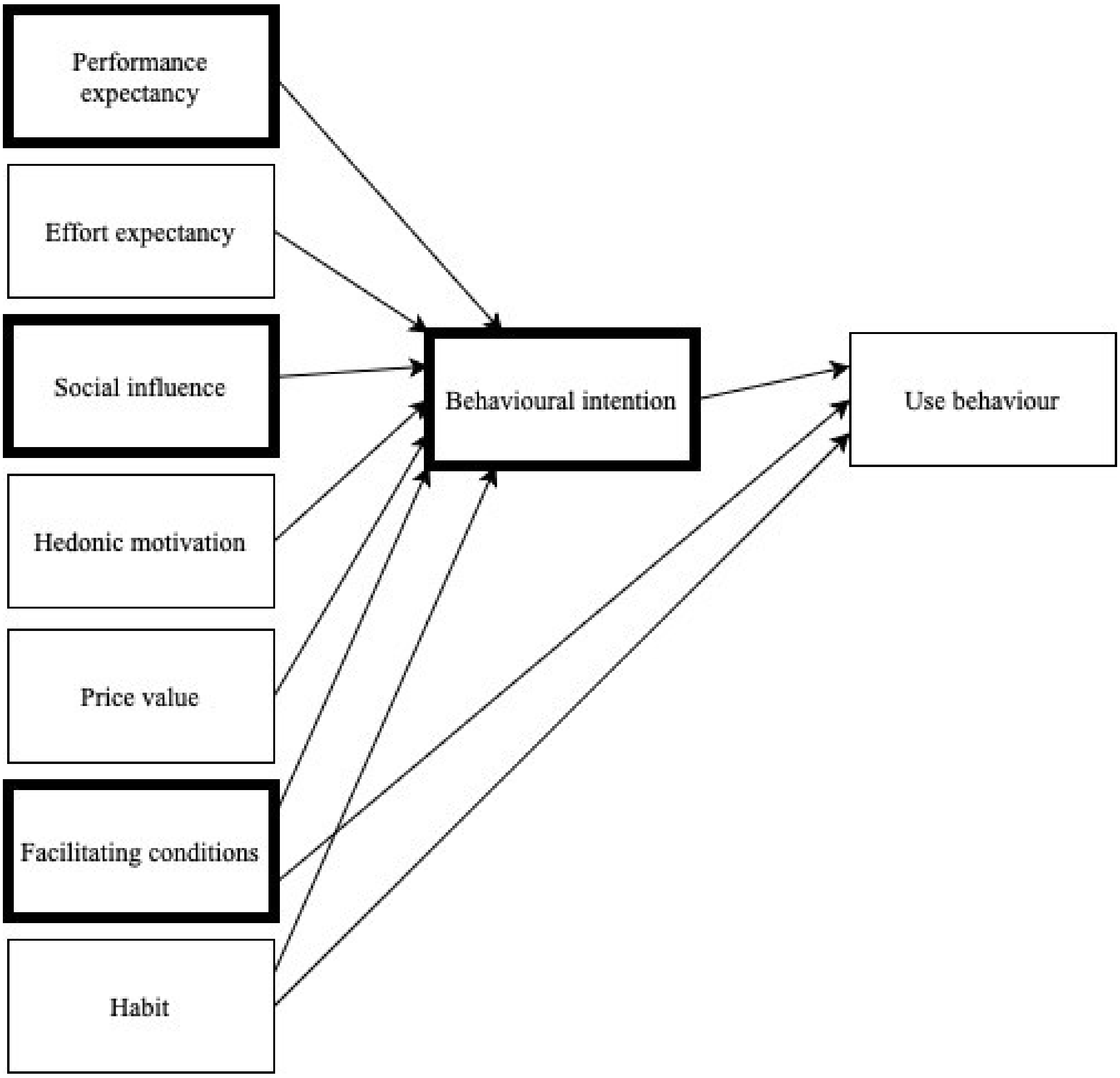
The proposed model introduces the construct of attitude to AVs that comes from the original conceptualisation of the TAM but has been neglected in recent research. In their meta-analysis, Yousafzai et al. (2007, p. 286) reported a negligible share of studies examining the relationship between attitude and other model constructs. Attitude is considered to be the successor of other adoption factors, i.e., it is formed based on perceptions of other factors, and is a precursor to intention to adopt an AV. This step is exploratory in nature and used to confirm the relationship in the AV literature. Actual system use or use behaviour was not considered because the unavailability of the AV technology for the layman makes it difficult to test AVs and thus imagine what it would be like to use them in everyday life. Consequently, statements about whether people would actually use AVs could be biased and might not realistically reflect the actual use perspective.

Figure 2: Constructs and relationships in the TAM model



Source: Davis (1985, p. 195).

Figure 3: Constructs and relationships in the UTAUT2 model



Source: Venkatesh et al. (2012, p. 160).

Next, for the main two constructs in the TAM (i.e., perceived ease of use and perceived usefulness) researchers have drawn a parallel with two constructs from the UTAUT. Namely, perceived usefulness corresponds to performance expectancy and perceived ease of use corresponds to effort expectancy (Scherer et al., 2018, p. 15). The dissertation considers perceived usefulness and/or performance expectancy as adapted to the AV context in the sense that the focus is on expected AV benefits that might be attractive to potential adopters. In so doing, the interest in the study concerns how individuals perceive the potential benefits since higher-rated benefits can contribute to forming a positive attitude to AVs. Previous authors already captured the potential benefits/advantages of AVs in the performance expectancy and in the process transformed perceived usefulness into AV benefits (e.g., Ma et al. (2020, p. 2023), Meidute-Kavaliauskiene et al. (2021, p. 5), and Nordhoff et al. (2020, p. 289)).

Perceived ease of use from the TAM and/or the effort expectancy from the UTAUT were not considered as a single construct, but as several negative aspects that potentially influence the acceptance of AVs, as is explained in the following paragraphs, while before then an explanation of why the aforementioned constructs were not included is given. First, Davis (1989, pp. 329, 331) found in two of his studies that ease of use had a significantly lower correlation with system usage than perceived usefulness, suggesting the former is less important. Therefore, it is not surprising that not all subsequent studies which considered perceived ease of use in their models found the relationship with ease of use or effort expectancy to be significant, which is the second argument for not considering it. Several studies revealed that ease of use or effort expectancy have a smaller impact on attitude or behavioural intention than other factors (e.g., Wu et al. (2019, p. 42) for autonomous electric vehicles), while others even showed their non-significant effect. Examples of the latter are: Andrews et al. (2021, p. 7) for artificial intelligence adoption by librarians, S.-Y. Chen (2016, p. 155) for public bikes, Kapser and Abdelrahman (2020, p. 218) for autonomous delivery vehicles, Jain et al. (2022, p. 5) for electric vehicles, J. Lee et al. (2019, pp. 418–419) for AVs, and Madigan et al. (2017, p. 61) for automated road transport systems. Third, future users who are more familiar with technology might find it easy to give directions to an AV and then travel to their destination as passengers (Nordhoff et al., 2016, p. 62). They might draw a parallel to the way they use navigation apps on smartphones today, e.g., Google Maps, and therefore consider it as easy and not worrying. Further, they might not question the ease of use since the driving task would be performed autonomously without requiring any engagement (J. Lee et al., 2019, p. 419). On the other hand, potential users who are less tech-savvy might have difficulties imagining how much effort would be required to use the system given that the innovative new technology represents a revolutionary leap that they have not experienced before, meaning they are unable to form perceptions in this regard and are not (yet) concerned about it and thus measuring it would introduce bias.

As an alternative to ease of use, other AV-context factors were introduced that might have a negative influence on adoption so as not to rule out any adoption perspective, noting that

Davis (1985, p. 133) emphasised that both the encouraging and discouraging (acceptance and rejection) perspectives of adoption of the technology under study must be considered. Huang and Qian (2021, p. 684) presented a similar point of view by including the "reasons for" and "reasons against" adopting an AV. Moreover, Kassens-Noor et al. (2020, p. 332) stressed that research frequently overlooks the challenges while focusing on the benefits associated with the technology under consideration, indicating that special attention must also be paid to them. Given the importance of safety shown in previous AV adoption studies, it was inevitable that this factor would have to be included, which may facilitate or deter interest in AV adoption. The inclusion of perceived safety was also proposed by Madigan et al. (2017, p. 62). It may be assumed that people's perception of general concerns would be intensified when AVs are perceived as less safe and vice versa. Further, not much research distinguishes the different forms of concerns, while this dissertation considers both general concerns and privacy-related concerns, namely, a similar approach to that taken in the studies by Ma et al. (2020, p. 2022) and T. Zhang et al. (2019, p. 211). Perceived safety and privacy concerns in the AV era are hypothesised to be antecedents of general concerns, with the former influencing them positively and the latter negatively. Social influence and facilitating conditions taken from the UTAUT2 were considered. Social influence was expanded into social factors since Venkatesh et al. (2003, pp. 451–452) stated that constructs of "social influence" behave similarly, while facilitating conditions include the infrastructure that supports AV implementation, which has been repeatedly mentioned as extremely important in the AV adoption process (e.g., by Medina-Tapia and Robusté (2018, p. 210) and Raj et al. (2020, p. 132)). Finally, the current literature puts considerable emphasis on the role of technological enthusiasm, which is expected to have a positive influence in the technology adoption process.

There are three other constructs from the UTAUT2 that were not considered: hedonic motivation, price value, and habit. Hedonic motivation was omitted because it could overlap too much with the attitude construct, noting that Venkatesh et al. (2012, p. 161) defined hedonic motivation as the "fun or pleasure derived from using a technology", which is very close to the definition used in this study of attitude to AVs. Second, Othman (2021, p. 373) stated that individuals are unable to assess the price and affordability of an AV until the ethical and regulatory issues have been addressed satisfactorily. Given that the development of AVs is leading the legal sector and not the other way around (Bartolini et al., 2017, p. 793), still some time must pass before this is settled. Third, commuting in itself is an everyday activity and hence it is argued that including a habit construct was not necessary. The author's previous studies (Ljubi and Groznik (2021, p. 155), Ljubi and Manfreda (2020, p. 8) and Manfreda et al. (2021, p. 6)) indeed reported a high share of individuals driving on a frequent basis, as did other authors (e.g., Koppel et al. (2021, p. 144), Montoro et al. (2019, p. 868) and T. Zhang et al. (2020, p. 225)). In addition, moderating variables were not included, following the approach taken by Dwivedi et al. (2019, p. 729) who stated that moderators are not necessarily relevant in every context and many studies therefore omit them. This means the way a raw model behaves can be observed, making including the moderating variables a simple task. Below, the development of the hypotheses divided by dependent variables is elaborated.

3.2 Antecedents of general concerns

General concerns[2] are those without an objective underlying reason specific to situations that may be encountered while in an AV, e.g., being without driver controls, moving unoccupied from location to location, confusion in unexpected situations, and flawed driving compared to human drivers. General concerns in this study are hypothesised to have two antecedents, i.e., perceived safety and privacy concerns in the AV era. It has been emphasised that general concerns must be distinguished from specific types of concerns (Keszey, 2020, p. 12). While the literature distinguishes different types of concerns to some extent, they are rarely combined in a single model (Kenesei et al., 2022, p. 380). A similar approach to Ma et al.'s (2020, p. 2022), T. Zhang et al. (2019, p. 211) and/or Kenesei et al. (2022, p. 380) is thus adopted where perceived safety, privacy-related concerns, and general concerns are distinguished. It is necessary to speak about perceived safety rather than just safety because perceptions are what are formed in individuals' minds and this is not necessarily the same as what car manufacturers consider under 'safety'.

Perceived safety[3] is considered to be "a climate in which drivers and passengers can feel relaxed, safe and comfortable, while driving" (Xu et al., 2018, p. 323). Perceived safety is critical while driving a car (Osswald et al., 2012, p. 53), and even more so when driving an AV as it is a new technology unknown first-hand from a practical perspective. Individuals must entrust their safety to an AV (Ma et al., 2020, p. 2023), meaning that how they perceive safety is clearly without a doubt among the critical factors to predict the behavioural intention to use AVs (Osswald et al., 2012, p. 55). Othman (2021, p. 357) emphasised the importance of safety on public perceptions and AV acceptance. Participants in Schmidt, Philipsen, Themann, et al.'s (2016, p. 1346) study in the context of vehicle-to-infrastructure technology recognised that safety was highly likely to increase following the implementation of AVs. Still, until the safety aspect is deeply positively ingrained in individuals' minds, the view of AVs may be more worrisome, while greater positive perceptions of safety may reduce perceived concerns regarding AVs. Moody et al. (2020, p. 643) suggested that positive perceptions of safety could be a driver of early AV adoption, while higher perceptions of risk would reduce the likelihood of intending to use an AV (Meidute-Kavaliauskiene et al., 2021, p. 14). Deb et al. (2017, p. 185) found that higher perceived safety positively influences two scenarios in relation to pedestrians' receptivity of AVs. Namely, pedestrians with a stronger perception of safety are more likely to cross the street in front of an AV, showing that they are more accepting of them in the neighbourhood (Deb et al., 2017, p. 185). Hulse et al. (2018, p. 7) indeed confirmed that AVs are no longer seen as riskier from the pedestrian perspective, only the passenger perspective. Ma et al. (2020,

[2] The definition can be found in Table 2 (page 62) and the measures used for the construct in Appendix 3.
[3] The definition can be found in Table 2 (page 62) and the measures used for the construct in Appendix 3.

p. 2025) found a positive effect of perceived risk of traffic safety, which corresponds to the construct of perceived safety in this dissertation, on the forming of trust among adults and children. Montoro et al. (2019, p. 869) established that individuals who attribute higher safety to AVs are more likely to acquire an AV in the future. Individuals who perceive AV safety on a higher level also believe AVs will be safe to drive on public roads sooner (Moody et al., 2020, p. 639); namely, their concerns with AVs are therefore lower, which could speed up the adoption process. On the other hand, in the presence of a lack of trust and the absence of standards, regulations and certifications, doubts concerning accountability arise (Raj et al., 2020, p. 132), which can make the safety aspect questionable and trigger greater concerns. Indeed, Manfreda et al. (2021, p. 7) confirmed that perceived safety affects AV adoption indirectly through concerns. Considering safety as a major concern related to AVs (Jing et al., 2020, p. 13; Zandieh & Acheampong, 2021, p. 7) leads to the hypothesis that more positive perceptions of safety could lower concerns regarding AVs:

H1: *Perceptions of greater safety reduce concerns regarding AVs.*

In addition to safety and other concerns, privacy-related concerns are another questionable area affecting AV adoption (T. Zhang et al., 2019, p. 211) and must be dealt with if AVs are to be widely adopted (Manfreda et al., 2021, p. 4). Privacy concerns in the AV era[4] are referred to as an individual's concerns concerning the collection and use of personally identifiable information (Le et al., 2018, p. 18; Nastjuk et al., 2020, p. 21). Software applications are increasingly computerised and connected, which allows improvements in road traffic, but at the same time brings privacy concerns to the fore due to all the data that are collected (Le et al., 2018, p. 18). Data sharing could benefit transport system operators and designers as well as law-related aspects, but concerns remain about how the same data could be misused (Fagnant & Kockelman, 2015, p. 178). Authorities, e.g., NHTSA, therefore stress that personal data and consumer privacy must be protected and propose practices to prevent misuse by manufacturers (National Highway Traffic Safety Administration, 2016, p. 18). Without addressing these, the automotive industry will not be able to progress (Le et al., 2018, p. 18).

A survey by Habeck et al. (2014, p. 11) revealed that around one-third of consumers would have greater concerns with connected cars due to privacy concerns. On one hand, Qu et al. (2019) detected privacy issues among the greatest concerns, whereas in their survey Kyriakidis et al. (2015, p. 133) concluded that, while privacy-related concerns do exist, they might not be among the strongest concerns. Nastjuk et al. (2020, p. 11) and Keszey (2020, p. 10) could not confirm any influence of privacy concerns on attitudes or behavioural intentions, respectively, and hence called for additional research on this topic. Nevertheless, greater concerns with privacy lead to a lower likelihood of AV adoption (Waung et al., 2021, p. 336; Zmud et al., 2016a, p. 13). Zmud and Sener (2017, p. 2508) reported that just 5% of respondents in their survey did not have any privacy concerns, and that more privacy-

[4] The definition can be found in Table 2 (page 62) and the measures used for the construct in Appendix 3.

concerned individuals would be less likely to use AVs. Brell et al. (2016, p. 63) noted that privacy is the second-most important concern after safety, while Habeck et al. (2014, p. 11) stated that privacy concerns might be so great that potential users may refuse to use connected vehicles. Privacy might become even more questionable if video cameras are installed in AVs, as Jing et al. (2021, p. 10) suggested for the case where children are transported alone. Raj et al. (2020, p. 132) found a relationship between consumer acceptance and lower security and privacy, with absence of the latter leading to reduced consumer acceptance. Accordingly, it is hypothesised:

H2: *Stronger privacy concerns in the AV era increase concerns regarding AVs.*

3.3 Antecedents of attitude to AVs

Attitude to AVs[5] is considered to refer to favourable or unfavourable feelings/stances concerning AVs and is formed as a result of other perception factors of AVs. Nordhoff et al. (2019, p. 686) proposed four explicitly defined stages while studying AV adoption in their decision-making model and there was also one that was not explicitly defined, i.e., attitude formation, but only stated in the text. Attitude is formed as a result of stage 2 that considers different AV adoption factors and is reflected in the intention to use an AV (Nordhoff et al., 2019, p. 686). Accordingly, attitude is formed according to perceptions of the factors, and acts as a precursor to behavioural intention to adopt an AV. Attitude seems to be a final reference point for deciding whether (or not) to adopt the technology in question, e.g., an AV. Venkatesh et al. (2003, p. 455) defined attitude to using a technology as an "individual's overall affective reaction to using a system". Overall attitude is expected to determine if a potential user will accept or reject a new technology (Davis, 1985, p. 24). Attitude is regarded in this study as individuals' favourable or unfavourable evaluation of AV use (Nastjuk et al., 2020, p. 22) and it is proposed that the following adoption factors affect attitude to AVs: technological enthusiasm, general concerns, social factors, perceived benefits, and facilitating conditions.

An individual's attitudes to technology, or their enthusiasm for technology, is a frequently mentioned factor in the literature concerning the adoption of new technologies and characterised by different – comparable – terms in the literature. This dissertation considers technological enthusiasm[6] as an individual's interest in realising the potential of the technology solely due to the existence of that potential (Slotten, 2014, in Kafaee, 2020, p. 970). C. Lee et al. (2017, p. 10) found that individuals who are generally more experienced with technology and more confident about new technologies will express stronger interest in AVs. Asmussen et al. (2020, p. 7) showed that more tech-savvy individuals are more likely to purchase an AV. Higher tech-savviness is also expected to lead to more frequent shared AV usage (Bansal et al., 2016, p. 9). Tennant et al. (2019, p. 108) showed in their

[5] The definition can be found in Table 2 (page 62) and the measures used for the construct in Appendix 3.
[6] The definition can be found in Table 2 (page 62) and the measures used for the construct in Appendix 3.

survey that more positive attitudes to new technology in general can bring about more positive perceptions of AVs. Moreover, the attitude of earlier adopters is expected to be more favourable than the attitude of later adopters (Rogers, 2003, p. 290). According to a study by Deb et al. (2017, p. 187), personal innovativeness positively influences the safety contributions of AVs, interaction with AVs in terms of whether individuals would cross the road in the presence of AV, and the compatibility of AVs with the existing traffic environment from a pedestrian perspective. Benleulmi and Ramdani (2022, p. 233) also confirmed personal innovativeness as a positive influential factor of behavioural intention. Interest in technology was found to increase intentions to adopt an AV (Acheampong et al., 2021, p. 13; Haboucha et al., 2017, p. 44). C. Lee et al. (2017, p. 10) reported that individuals with greater experience and confidence in using technology will be more interested in AVs and purchase them earlier. Further, the effect of technological enthusiasm has been shown to be both direct and indirect, i.e., through fears and anxieties, and also through perceived benefits (Acheampong & Cugurullo, 2019, p. 360). Ljubi and Manfreda (2020, pp. 12–13) confirmed that the technological enthusiasm of individuals is a differentiating factor with respect to various AV adoption factors, whereas the results concerning in-vehicle activities in an exploratory study by Ljubi and Groznik (2021, p. 158) were mixed. This calls for additional research into the effects of technological enthusiasm, leading to the following hypothesis:

H3: *More technologically enthusiastic millennials have a more positive attitude to AVs.*

Alongside technological enthusiasm, perceived safety and general concerns are reported in the literature as AV adoption factors (Manfreda et al., 2021, p. 7). Specifically, perceived risks used in three studies to measure general AV-related concerns were revealed to have a negative influence on adoption intentions (J. Lee et al., 2019, p. 419; Meidute-Kavaliauskiene et al., 2021, p. 13; Zhu et al., 2020, p. 89). Similarly, perceived risks stemming from concerns have a negative influence on behavioural intention (Kapser & Abdelrahman, 2020, p. 218). In the case of strong negative concerns, people will develop a negative attitude towards AVs. Individuals with heightened concerns will be less likely to adopt either shared or owned AVs (Lavieri et al., 2017, p. 6). Liu, Guo, et al. (2019, p. 315) showed that willingness to adopt (pay for) an AV diminishes with greater perceived risks and concerns. Their attitude is accordingly expected to be more negative. Similarly, concerns were found to negatively affect parents' attitudes, intentions, and willingness to transport children in AVs, which may be more pronounced when children are driven unaccompanied than when they are accompanied by their parents (Jing et al., 2021, p. 10; Y.-C. Lee et al., 2020, p. 292). On the other hand, perceived risks (concerns) were not always confirmed as a predictor of behavioural intention (Choi & Ji, 2015, p. 700), which leaves the question of whether it has an indirect effect through other factors unsettled. The concerns, or more precisely the losses associated with the concerns, may lead many people to reject a technology because they overestimate the large losses possible, despite them being very unlikely to occur (Wang & Zhao, 2019, p. 219). Potential concerns range from equipment or system failure and hacking through to interactions between human-operated vehicles and AVs and other legal aspects (Bansal et al., 2016, p. 6; Kyriakidis et al., 2015, p. 136). Nielsen and Haustein (2018, p. 51) found that individuals holding stronger concerns about AVs are more sceptical of them, meaning they are less enthusiastic and positive about AVs. The impact of such general concerns related to AV operations on the attitude to AVs is hypothesised to be negative:

H4: *Stronger general concerns regarding AVs negatively influence the attitude to AVs.*

The role of collectivity and class in consumption was noted by Ostergaard & Jantzen (2000, pp. 18–19), who incorporated it as the then latest central area of consumer research, named consumption studies, shifting the focus beyond the individual. Accordingly, an individual is characterised as a member of a tribe who considers the symbolic meaning of what they are supposed to consume, e.g., recognition by other members of the same tribe (Ostergaard & Jantzen, 2000, pp. 18–19). This concept is considered in this study to be relevant in AV consumer research where it is defined as social factors[7] that encompass different social perspectives, which lead individuals to decide to adopt a certain technology, e.g., gaining social recognition, influence of friends, family and/or others. For technologies that most people have still not had an opportunity to try out first-hand, such as AVs, social influence, including media reports and other people's opinions, plays an even more important role than for other commercially available technologies that are physically available in the marketplace for testing (Zhang et al., 2020, p. 229). According to Bansal et al. (2016, pp. 11, 13), 50% of individuals would be more likely to adopt AVs if their relatives had already done so. Similarly, C. Lee et al. (2017, p. 8) found support by peers to be a significant factor that increases interest in AVs, while Kapser and Abdelrahman (2020, p. 219) confirmed that the opinions of peers positively affect behavioural intention to adopt autonomous delivery vehicles. Moreover, Herrenkind et al. (2019, p. 15) confirmed that a social network positively influences the attitude to autonomously driven public buses, and Benleulmi and Ramdani (2022, p. 233) and Panagiotopoulos and Dimitrakopoulos (2018, p. 781) corroborated that social influence positively influences behavioural intention to use AVs. Subjective norms were shown to have a positive effect on the use of autonomous buses (Acheampong et al., 2021, p. 12), and even to be the strongest predictor of an intention to switch from private to public transport (C.-F. Chen & Chao, 2011, pp. 134–135). Important others might even be a reason explaining why people become willing to give a new technology a chance (T. Zhang et al., 2020, p. 223), and accordingly they are expected to improve their attitude towards it. Thus, T. Zhang et al. (2020, p. 228) established social influence as one of the most important factors of AV adoption. In addition, they stressed that spreading the good word can help to market AVs in the early stages. Individuals would also be more likely to adopt an AV when under the influence of social pressures and forces, and especially if they are younger (Koul & Eydgahi, 2020, pp. 138–139). Acheampong and Cugurullo (2019, p. 373) concluded that individuals are influenced by the opinions of people

[7] The definition can be found in Table 2 (page 62) and the measures used for the construct in Appendix 3.

they value while deciding to adopt an AV, but do not expect to receive much social recognition by adopting an AV. Zhu et al. (2020, p. 87) also proposed that individuals are significantly influenced by mass media and social media, with the two having different effects. Social media can participate in the formation of social norms that refer to the perspective of other people, which can influence an individual's behaviour (Zhu et al., 2020, pp. 86–87). In line with Axsen and Sovacool (2019, p. 1), AV adopters' symbolic benefit for society arises from inspiring other consumers to follow. This leads to the following hypothesis:

H5: *Positive social factors have a positive effect on the attitude to AVs.*

In the context of AVs, it is appropriate to replace perceived usefulness or performance expectancy with perceived benefits since this better reflects the content of the factor. Perceived benefits[8] represent "the degree to which using a technology will provide benefits to consumers in performing certain activities" (Venkatesh et al., 2012, p. 159); in the present case, this is the use of AV for transportation. Acheampong et al. (2021, p. 2021) and T. Zhang et al. (2019, p. 210) similarly defined perceived benefits as the extent to which a person believes that using AV will enhance their performance. Although a similar definition by Madigan et al. (2017, p. 57) – "the degree to which using an ARTS vehicle will provide benefits to consumers in their travel activities" (where ARTS stands for automated road transport systems) – actually describes performance expectancy, a match with the above definitions can be seen, suggesting that they are indeed comparable constructs. Still, benefits do not only accrue to individuals, as is considered in most definitions, but also contribute to the improvement of society's standard of living. Therefore, in this study perceived benefits are considered in a broader sense as the functional utility of an AV for users (Zhu et al., 2020, p. 85). A high level of awareness and positive perceptions of the benefits and added value brought by AVs may convince potential users to view the risks as being less of a concern (Hesse et al., 2019, p. 102). Consumers who are more aware and cognisant of the potential benefits are expected to increase their share of transport using AVs (Raj et al., 2020, p. 133). This means that the potential benefits must be communicated to the prospective end users of new (smart) services (Ismagilova et al., 2019, p. 96) and the awareness of the potential usefulness and benefits is crucial for making smart services more widely accepted (Peng et al., 2017, p. 858). Herrenkind et al. (2019, p. 15) confirmed that greater perceived usefulness related to the benefits of technology led to more positive attitudes being formed about autonomously driven public buses, whereas Nastjuk et al. (2020, p. 10) confirmed that this was the case for autonomous driving. An extensive meta-analysis by Gopinath and Narayanamurthy (2022, p. 14) that included 65 studies and a cumulative sample of more than 37,000 individuals also confirmed the positive influence of perceived usefulness/utility of AVs on attitude to AVs. Interestingly, the positive perceptions of the benefits might even be rising with rising levels of automation; thus, being the highest in the case of full automation, namely, the subject of this dissertation. A similar

[8] The definition can be found in Table 2 (page 62) and the measures used for the construct in Appendix 3.

conclusion was drawn by Jing et al. (2021, p. 9) who confirmed that parents would have more positive attitudes to the use of an AV to transport their children if they perceived it to be more useful, i.e., associated with greater benefits. Similarly, Madigan et al. (2017, p. 61) found that benefits which help people to improve the efficiency and effectiveness of their transportation were a positive predictor of behavioural intention, while Meidute-Kavaliauskiene et al. (2021, p. 13) concluded that the intention to use AVs increases when potential consumers perceive greater benefits of such use. This leads to the following hypothesis:

H6: *Higher perceived benefits regarding AVs positively influence the individual's attitude to AVs.*

A consumer with access to a favourable set of facilitating conditions would express a stronger intention to use a given technology (Venkatesh et al., 2012, p. 162). The definition for the construct facilitating conditions[9] is adopted from Madigan et al. (2017, p. 57) who defined it as consumers' perceptions of the resources and support available to use an automated road transport system, e.g., infrastructure design and implementation strategies. This is consistent with Venkatesh and Bala's (2008, p. 276) definition of it as organisational support to facilitate technology usage, except that in this study the consumer context is considered rather than the organisational context, and "organisation" refers to government and other responsible authorities. In this research, facilitating conditions examine the role of government as a facilitator in terms of incentives, road infrastructure, and legal framework. A consumer with access to a favourable set of facilitating conditions would express a stronger intention for technology use (Venkatesh et al., 2012, p. 162). Facilitating conditions were shown to exert a positive effect on the attitude to information system success, i.e., the greater the facilitating conditions, the more positive the attitude (Sabherwal et al., 2006, p. 1859). Teo (2009, p. 101) confirmed facilitating conditions' influence on attitude to computer use and Yusliza and Ramayah (2012, p. 316) confirmed the same in electronic human resource management. These two examples are more from a mandatory than a voluntary context and leave it open whether the present link also applies to AVs, as to which it has scarcely been examined. Taking account of the importance that authors attribute to incentives (e.g., Faisal et al. (2019, p. 57) and Talebian and Mishra (2018, p. 372)) and legal framework (e.g., Medina-Tapia and Robusté (2018, p. 210) and Raj et al. (2020, p. 132)), the influence of facilitating conditions to support the introduction of AVs is explored in the following hypothesis:

H7: *A positive perception of the role of government as a facilitator positively influences the attitude to AVs.*

[9] The definition can be found in Table 2 (page 62) and the measures used for the construct in Appendix 3.

3.4 Antecedents of AV adoption intention

AV adoption intention[10] represents usage or behavioural intention to adopt an AV, and originates from the well-established adoption models, e.g., TAM and UTAUT2. For AV adoption intention, this study uses the definition by Nastjuk et al. (2020, p. 22) who describe it as the "individual's motivational readiness to use or not to use autonomous driving", and propose that it is affected by three factors: perceived safety, facilitating conditions, and attitude to AVs.

Jing et al. (2020, p. 13) found safety to be the most frequently covered AV aspect in the AV literature from numerous aspects. Therefore, it is not only expected to reduce general concerns (H1), but to also directly positively affect behavioural intention (Ro & Ha, 2019, p. 57). Gopinath and Narayanamurthy (2022, p. 15) characterised the safety/security aspect as the biggest obstacle to the introduction of AVs. Gkartzonikas et al. (2022, p. 19) confirmed the positive influence of safety perceptions on behavioural intention. Moody et al. (2020, p. 643) suggested that positive perceptions of safety could be a driver of early AV adoption. Montoro et al. (2019, p. 871) established that individuals who attribute AVs with greater safety are more likely to acquire an AV in the future. Xu et al. (2018, pp. 328, 331) confirmed that perceived safety has a strong and positive influence on behavioural intention while Korkmaz et al. (2021, p. 10) and Koul and Eydgahi (2020, p. 138) even found it to have the strongest impact of all factors. This leads to the following hypothesis:

H8: *Positive perceptions of safety increase the intention to adopt an AV.*

It was hypothesised that facilitating conditions influence attitudes to AVs (H7). Further, facilitating conditions are also expected to positively influence behavioural intention. For example, this was confirmed for AV adoption intention (Park et al., 2021, p. 6), behavioural intention to accept automated road transport systems (Madigan et al., 2017, pp. 60–61), and behavioural intention to use autonomous delivery vehicles (Kapser & Abdelrahman, 2020, p. 218). While these studies looked at facilitating conditions more from the perspective of an individual (e.g., resources, knowledge), the focus here is more on the external perspective (e.g., governmental support). Further, due to the conflicting results on the effect of facilitating conditions on behavioural intention, Gopinath and Narayanamurthy (2022, p. 14) even suggest future research on this topic to clarify the actual effect. This leads to the following hypothesis:

H9: *A positive perception of the role of government as a facilitator increases the individual's intention to adopt an AV.*

Even though the best-known technology adoption models, e.g., the TAM and the UTAUT2, consider a two-stage adoption process, this is not a common practice in AV adoption research. For example, the UTAUT2 considers behavioural intention as an antecedent of use

[10] The definition can be found in Table 2 (page 62) and the measures used for the construct in Appendix 3.

behaviour (Venkatesh et al., 2012, p. 160), whereas the TAM considers attitude as an antecedent of behavioural intention and the latter as an antecedent of actual use (Davis, 1985, p. 24). The latter stance is also taken in this study where it is proposed that the more positive the attitude, the stronger the intention to adopt an AV. Since AVs are a technology that most potential adopters have not had an opportunity to try first-hand and have therefore never needed to decide whether to choose between conventional and autonomous means of transport, the inclusion of actual usage behaviour might give biased results, in turn suggesting that the behavioural intention–use behaviour relationship cannot/should not be studied. In this study, actual use is thus not considered, but the intention to use/adopt. As strong attitudes are resistant to change (Ajzen, 2001, p. 38), they are expected to be formed over a longer period of time. Moreover, the stronger the attitude, either positive or negative, the more likely that an individual will act according to their attitude (Fishbein & Ajzen, 2011, p. 260). This makes it reasonable to assume that attitudes are formed based on perceptions of other factors of the technology in question. The more positive the attitude, the more likely it is that the individual will decide to behave in a certain way (Dwivedi et al., 2019, p. 723). In the context of AVs, if the formed attitude to AVs is positive, this can hold important positive implications for AV adoption and oppositely if it is negative.

The actual behaviour of individuals is predicated by perceptions of the primary attributes, and studying their interaction can lead to the development of theory (Moore & Benbasat, 1991, p. 194). As already explained, actual behaviour regarding a technology that is not widespread available cannot be measured, while behavioural intention is significantly influenced by attitude (Dwivedi et al., 2019, pp. 726–727), and attitude is formed based on perceptions of AVs' primary attributes (e.g., benefits, safety). Haboucha et al. (2017, p. 45) found that a positive attitude to AVs is the greatest factor in the decision to use an AV, either shared or private, while Nastjuk et al. (2020, p. 10) established attitude to be the strongest predictor of usage intention of autonomous driving. Herrenkind et al. (2019, p. 15) reported that the attitude to autonomously driven public buses is the greatest predictor of intention to use. C.-F. Chen and Chao (2011, pp. 134–135) confirmed that the individual's attitude positively influences the intention to switch from private (motorcycle and car) to public transport. An extensive meta-analysis by Gopinath and Narayanamurthy (2022, p. 14) that included 65 studies and a cumulative sample of more than 37,000 individuals also confirmed the significantly positive influence of attitude to AV on behavioural intention to use AVs. Attitude was shown to significantly influence consumers' intention to adopt an AV (Ro & Ha, 2019, p. 57) and parents' intention to use an AV to take their children to school (Jing et al., 2021, p. 9). Payre et al. (2014, p. 259) and T. Zhang et al. (2019, pp. 215–216) confirmed a strong positive relationship between attitudes and intention to use a partially automated or level-3 AV, i.e., the more positive the attitudes, the stronger the intention to use. It is thus proposed that:

H10: *A positive attitude to AVs increases the intention to adopt an AV.*

3.5 The proposed model

The proposed model consists of 6 independent (exogeneous) variables and 3 dependent (endogenous) variables, all of which are latent variables since they are not directly observable. The studied variables are as follows: perceived safety, privacy concerns in the AV era, technological enthusiasm, general concerns, social factors, perceived benefits, facilitating conditions, attitude to AVs and AV adoption intention. Table 2 summarises the definitions of the variables used in the model. The independent variables/factors in particular address the aspects where AVs differ from conventional vehicles in either a positive or negative way. Authors have emphasised that both perspectives must be considered when studying adoption, as is done in the present dissertation. Moreover, the proposed model takes account of factors that are beyond the traditional adoption models (e.g., TAM, UTAUT2) and specifically address the AV context as explained in Chapter 3.1. Figure 4 visually presents the hypothesised relationships as well as their expected direction (the plus and minus signs in parentheses). The results of the proposed model will strengthen understanding of the perceptions of potential AV adopters with regard to different factors and their interplay, which is vital to make the technology more extensively adopted. Therefore, the analysis presented in the dissertation will contribute to the literature as well as provide practical implications.

Table 2: Definitions of the constructs in the model

Construct	Definition	Source
General concerns	Concerns without an objective underlying reason specific to situations that may be encountered while in an AV	Developed for the purposes of this dissertation
Perceived safety	A climate in which drivers and passengers can feel relaxed, safe and comfortable while driving in an AV	Xu et al. (2018, p. 323)
Perceived benefits	The functional utility of an AV for users	Zhu et al. (2020, p. 85)
Privacy concerns in the AV era	The individual's concerns regarding the collection and use of personally identifiable information	Le et al. (2018, p. 18), Nastjuk et al. (2020, p. 21)
Technological enthusiasm	The individual's interest in realising the potential of the technology solely due to the existence of that potential	Slotten (2014, in Kafaee, 2020, p. 970)
Social factors	Different social perspectives that lead individuals to decide to adopt a certain technology	Developed for the purposes of this dissertation
Facilitating conditions	Consumers' perceptions of the resources and support available to use an automated road transport system, e.g., infrastructure design and implementation strategies	Madigan et al. (2017, p. 57)

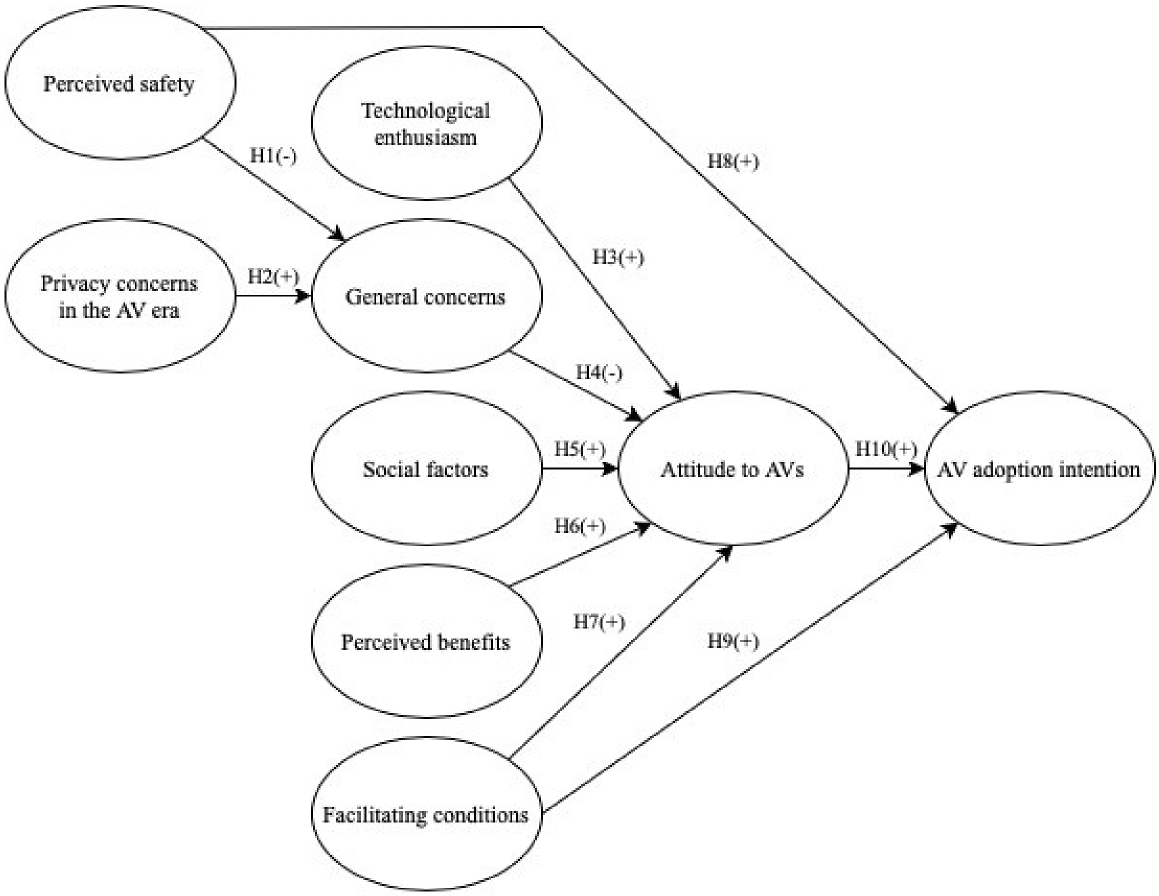
(table continues)

(continued)

Construct	Definition	Source
Attitude to AVs	Favourable or unfavourable feelings/perceptions regarding AVs	Developed for the purposes of this dissertation
AV adoption intention	The individual's motivational readiness to use (or not) autonomous driving	Nastjuk et al. (2020, p. 22)

Source: Own work.

Figure 4: Proposed model of AV adoption



Source: Own work.

4 METHODOLOGY

4.1 Methodological approach

Schreiber et al. (2006, p. 333) emphasised the importance of introducing and justifying the methodological approach taken. The focus of this chapter is thus exactly on this aspect. The study builds on a literature review and applies a survey research design with a questionnaire as the data collection method. The literature review has two purposes, the first being to introduce the main theoretical concepts and provide the theoretical underpinnings on which the research model stands (discussed in Chapter 3) since Diamantopoulos and Siguaw (2000, p. 6) and Reisinger and Turner (1999, p. 72) stressed that the conceptualisation of the model must be theory-driven. Second, the literature review was the basis for designing the questionnaire (discussed in Chapter 4.3). The questionnaire uses the stated preference approach because this is what the current level of development and availability of AV technology allows. While it is true that a revealed preference survey may have captured the perceptions of the survey participants more accurately, an effective survey of this nature would be hard to accomplish at this stage in the development of fully AVs (Daziano et al., 2017, p. 159; Wang & Zhao, 2019, p. 5), given the limited availability of AVs in the geographic area of the present research study. Although many authors have pointed out the drawbacks of only asking respondents to make hypothetical choices, e.g., Daziano et al. (2017, p. 163), on the other hand the stated preference approach was used in previous AV research (e.g., Asmussen et al. (2020, p. 4), Haboucha et al. (2017, p. 39) and Wang and Zhao (2019, pp. 11–12), and provided valuable and relevant results that were published in high-impact journals and received numerous citations. In addition, Shin et al. (2015, p. 6) considered the stated preference approach to be appropriate for evaluating vehicle- and fuel-related technologies precisely because they have little or no availability in the market. Accordingly, the stated preference approach seems to be an appropriate choice for evaluating the perception of technologies that are not yet commercially available, which is the case for fully AVs. Fully AVs are the most distant phenomenon in the field of autonomous driving, and although lower levels of automation may become commercialised before full automation is achieved, studying fully AVs throughout their development cycle could provide valuable insights for all relevant stakeholders, from car manufacturers to policymakers and investors. It is thus believed in this study that the use of stated preferences is suitable and beneficial, and have also taken all measures (e.g., participant anonymity, Harman's single-factor test, convergent and discriminant validity as well as internal consistency and model fit tests) to make the research valid within the methodological framework established herein. Finally, the limitation regarding this is nonetheless noted in Chapter 6.5.

To test the hypotheses, SEM was applied. A combination of a survey questionnaire and SEM was already proven to be credible in previous AV research (e.g., Nordhoff et al. (2020) and T. Zhang et al. (2019)). SEM is a commonly used methodology in the social sciences (Hooper et al., 2007, p. 53) and elsewhere (Reisinger & Turner, 1999, p. 72) that combines factor analysis and econometric modelling (Vieira, 2011, p. 4). It is a convenient methodology when indirectly observable variables are being researched, i.e., latent variables, and the aim is to test how constructs are linked and what is the direction of the relationship (Schreiber et al., 2006, pp. 323, 326). In the social sciences, this especially pertains to attitudes, perceptions, self-reported behaviours, and the like, which is one reason that it was used in this dissertation. The unobserved variables were operationalised with the observed variables, i.e., manifest variables, that can be measured by tests, surveys and so on

(Schumacker & Lomax, 2012, p. 3). Given that each latent variable is measured by more than one manifest variable, regression and other traditional techniques cannot be used, while SEM can be used (Vieira, 2011, p. 4). Accordingly, SEM improves on the traditional techniques by offering greater flexibility and at the same time greater complexity, which can be challenging for researchers (Chin, 1998, p. vii). It is precisely the ability of SEM to model and test the complex relationship between the manifest and latent variables that is another reason for applying SEM in the present dissertation (Reisinger & Turner, 1999, pp. 71–72; Schumacker & Lomax, 2012, p. 21). SEM can also be applied for either confirmatory or exploratory purposes (Schreiber et al., 2006, p. 325), albeit it works best for the former (Chin, 1998, p. xii). Since most of the studied relationships were previously confirmed in similar research contexts, but not in the same combination of factors that cover the many aspects of AVs, the dissertation applies it for confirmatory purposes. Specifically, the relationships between predefined constructs are modelled and tested in order to confirm the proposed relationships in the model of AV adoption.

4.2 Data analyses

The data were analysed using the statistical software IBM Statistical Package for the Social Sciences version 25 (hereafter: SPSS) (IBM Corp., 2017) and the scientific software LISREL or Linear Structural Relations version 8.8 (hereafter: LISREL) (Jöreskog & Sörbom, 2006). In SPSS, the data were pre-prepared, i.e., examined, cleansed and prepared for the analysis as well as descriptively analysed. Data exploration concerned descriptive statistics to present the sample characteristics (Chapter 5.1) and identify missing values. The data were examined case by case to detect the missing data values. Hair, Black, et al. (2019, p. 631) suggest that in the case of less than 10% of observations with missing data, any approach can be taken to deal with the missing data. The share of observations with missing data in the study was 10.92%; thus, a pairwise deletion was used whereby cases that had no missing data for the variables that are relevant for the analysis were eliminated. Some variables were coded to ease the interpretation. In SPSS, the data were also tested for common method bias using Harman's single-factor test, multicollinearity by the variance inflation factor (VIF), and skewness and kurtosis. Moreover, a covariance matrix was prepared to be imported into LISREL. LISREL was chosen due to it being powerful with the numerous analyses that it is able to produce. For the analysis in LISREL, the following six stages suggested by Hair, Black, et al. (2019, p. 625) were followed:

– Defining individual constructs.
– Developing the overall measurement model.
– Designing a study to produce empirical results.
– Assessing the measurement model validity.
– Specifying the structural model.
– Assessing the structural model's validity.

In the first stage – defining individual constructs – the constructs were operationalised. Their definitions were presented in Chapter 3.5. The scale and measurement items were taken from the literature and are presented in Chapter 4.3, where the pre-testing is also explained. In the second stage – developing the overall measurement model – the constructs and corresponding measurement items were combined with the measurement model. By clearly defining the constructs and justifying the inclusion/exclusion of the constructs in Chapter 3.1 and relying on the established measurement items, the aim was to assure unidimensionality. In the third stage – designing a study to produce empirical results – decisions were made about the missing data (explained earlier in this Chapter) and sample size (explained below). Hair, Black, et al. (2019, p. 630) recommendation to choose a covariance matrix over a correlation matrix approach was followed. To avoid the situation where the software fixes the first measure of each construct by itself, the first measure of each construct was standardised to unity such that it serves as a reference variable, which also simplifies the solution of the identification problem and eases the interpretation (Diamantopoulos & Siguaw, 2000, p. 34; Lomax, 1982, p. 5). In this way, every other variable of the construct can be interpreted in relation to the reference variable (Schumacker & Lomax, 2012, p. 199). The covariance-based SEM method with the maximum likelihood estimation was applied to verify the relationship between the latent variables and their indicators as well as the proposed relationships between latent variables (Diamantopoulos & Siguaw, 2000, p. 4). In the fourth stage – assessing the measurement model's validity – the measurement items were assessed for their reliability and validity individually as well as combined, i.e., when grouped into constructs. Individual items' loadings, error variances, squared multiple correlations (R^2) and significance levels were examined (Diamantopoulos & Siguaw, 2000, pp. 89–90; Hair, Black, et al., 2019, pp. 674–675). From a construct perspective (i.e., construct validity), Cronbach's alpha, composite reliability (CR), average variance extracted (AVE), and discriminant validity were inspected (Diamantopoulos & Siguaw, 2000, pp. 90–91; Hair, Black, et al., 2019, pp. 675–677). The details of the measurement model's assessment are presented in Chapter 5.3. The fifth stage – specifying the structural model – is critical in an SEM analysis (Hair, Black, et al., 2019, p. 643). The dependent relationships were established based on the model proposed in Figure 4 and the corresponding hypotheses, and it was assured that the model is identified. In Figure 4, the single-headed arrows represent the dependent relationships and together form a structural model that was assembled into a path diagram in LISREL (Hair, Black, et al., 2019, p. 643). In the sixth stage – assessing the structural model's validity – the structural model was tested and, after the model fit was established, the hypothesised relationships were checked in terms of the parameter estimates as well as their significance. The proposed hypotheses were tested at significance levels of 0.01 and 0.001. The model tested the significance of AV adoption factors on attitude to AVs, namely, technological enthusiasm, social factors, perceived benefits, facilitating conditions, and perceived safety and privacy concerns in the AV era through general concerns. Further, the effect of attitude to AVs on AV adoption intention was tested. The details of the structural model's assessment are presented in Chapter 5.4, while Chapter 5.5 presents the results of the hypothesis testing.

4.3 Questionnaire design and measurement items

Primary data were collected using a questionnaire designed for the purposes of this analysis after a thorough literature search on the topic to find relevant measurement items. The main purpose of the questionnaire was to determine millennials' attitudes to AVs. To measure attitudes, perceptions, opinions, behaviours or other non-directly measurable phenomena, measurement items were used rather than measures as the latter can only be employed while dealing with physical quantities or measurable phenomena, and these two terms should be clearly distinguished (Hair, L.D.S. Gabriel, et al., 2019, p. 491). Since attitudes are latent constructs, they are only indirectly observable, making a questionnaire an appropriate form of data collection (Zikmund, Babin, Carr, & Griffin, in M. König & Neumayr, 2017). The verified measurement items were taken from the literature and adapted to the research context. Following the idea of Dwivedi et al. (2019, p. 728), measures from different studies were mostly combined. The questionnaire was also pre-tested, as explained below.

The questionnaire had three sections: an introduction, research-related questions, and socio-demographic questions. Completing the questionnaire containing 28 content-related questions[11] (without the socio-demographic questions) took about 15–20 minutes. The entire questionnaire relevant for the research presented in this dissertation may be found in Appendix 2. The questions were a mixture of statements with a Likert-type scale from 1 to 5, single-answer questions, multiple-choice questions, and frequency rating questions. A Likert-type scale was chosen due to it being easy to administer by the researcher and easy to understand by the respondent (Malhotra, 2006, p. 186). It is also among the methods most frequently used to measure social attitudes (Y. K. Singh, 2006, p. 207). This scale is represented by a set of statements for which participants indicate their (dis)agreement (Y. K. Singh, 2006, p. 208). A symmetric 5-point scale where the midpoint (score of 3) was clearly defined as being "neutral" was chosen in order to reduce misinterpretation by respondents, which previous authors identified as potentially problematic (e.g., Lam and Green (2019, p. 5)). The scores ranged from strongly disagree (1) to strongly agree (5) and were consistent throughout the questionnaire to avoid confusion among the participants (Malhotra, 2006, pp. 185–186).

The questionnaire was introduced as a survey that aims to explore perceptions of fully AVs. In the introduction, respondents were acquainted with the purpose of the questionnaire and assured of their anonymity. With the latter, the possibility of obtaining the most honest answers possible was increased because respondents are more inclined not to give socially desirable answers if their anonymity is guaranteed (Podsakoff et al., 2003, p. 888). The second section of the questionnaire was related to driving patterns and issues concerning AVs, and is presented in detail in the next paragraphs. Finally, the third section included the

[11] The survey formed part of a larger research project related to AVs and thus included more questions than those presented in the remainder of this Chapter.

socio-demographics questions, namely gender, age, region of residence, and residential type of settlement, to capture the respondents' characteristics. Before each section and sub-section, there was a (sub-)section title and a brief introductory description to help the respondents maintain the underlying theme.

The main part of the questionnaire was divided into 10 sub-sections[12] and the measurement items for the analysis were deduced from those questions. A total of 35 items were of interest in the analysis and, due to their low factor loadings, 2 were eliminated during the reliability and validity analyses, as explained in Chapter 5.3. The constructs (latent variables) were represented by 3 to 5 items following the recommendations of Hair, Black, et al. (2019, pp. 665–666) that 3 is the minimum to assure model identification, and that the number of items should not be higher than needed to adequately represent the construct. In the first subsection, respondents were asked about: whether they possessed a driver's licence, the frequency of them driving, the frequency of using certain transport means for particular activities, and some general questions about AVs to obtain respondents' opinion on AVs. The purpose of the first subsection was to capture the general driving patterns of the respondents and to gain the respondents' means by introducing them to the content of the questionnaire. Respondents were given an explanation of AVs and their levels with the aim to introduce the terms to avoid misinterpretation by the participants and thereby reduce potential response bias. It was also emphasised that the questions in the remainder of the questionnaire refer to the level-5 autonomy, i.e., full autonomy. The second subsection of the main questionnaire part was dedicated to general technology-related attitudes to measure the technological enthusiasm of respondents. This question was intended to measure the construct of "technological enthusiasm" for which the original four measurement items were deployed from Deb et al. (2017), Haboucha et al. (2017) and Ruggeri et al. (2018). These (and all the other constructs explained in the paragraph below) were scored on a 5-point Likert-type scale. The respondents were asked to express their agreement using the scale: 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree[13]. One item was however excluded due to its low factor loadings and thus three measurement items remained. Two items were reverse-scored.

The questionnaire continued with questions about several areas: attitudes to AVs, AV challenges, AV concerns, AV safety, AV benefits, and AV privacy. A question that measured the "attitude to AVs" construct consisted of four measurement items that were adapted from Deb et al. (2017) and Kyriakidis et al. (2015). One item was reverse-scored. A question measuring "AV adoption intention" referred to three measurement items adapted from Liu, Yang, et al. (2019b), Montoro et al. (2019), Waung et al. (2021) and Wu et al. (2019). Four measurement items for the "perceived safety" construct took account of the

[12] The survey formed part of a larger research project related to AVs and thus included more questions than those presented in the remainder of this Chapter and included in Appendix 2.

[13] The same scale applies to other questions.

measures employed by Deb et al. (2017), M. König and Neumayr (2017) and Waung et al. (2021). A question measuring the "social factors" construct initially consisted of four measurement items adapted from Acheampong et al. (2021), Deb et al. (2017), Kapser and Abdelrahman (2020), and Qu et al. (2019). These authors considered similar items and different combinations of them. After the reliability in validity tests, one measurement item was excluded due to low factor loading. A question measuring the "perceived benefits" construct consisted of five measurement items that were adopted from Bansal et al. (2016), Cunningham, Regan, Ledger, et al. (2019), M. König and Neumayr (2017), Montoro et al. (2019), and Qu et al. (2019). As current literature points to many benefits of AV, more than five items were initially included, but some were excluded due to low item loadings in two iterations of the pilot survey in two consecutive years before the actual survey was conducted (the pilot survey is further elaborated on below). Four measurement items for the "general concerns" construct were adopted from Cunningham, Regan, Ledger, et al. (2019), M. König and Neumayr (2017), and Qu et al. (2019). These items were reverse-scored. Four measurement items for the "privacy concerns in the AV era" construct were adopted from Kyriakidis et al. (2015) and Waung et al. (2021). A question measuring the "facilitating conditions" construct consisted of three measurement items taken from Jain et al. (2022), Kapser and Abdelrahman (2020) and Venkatesh et al. (2012). These items were also reverse-scored. To ensure transparency and enable researchers to develop measurement items in subsequent studies, Appendix 3 summarises the measurement items by constructs with supporting sources as recommended by Hair, L.D.S. Gabriel, et al. (2019, pp. 492–493).

As the questionnaire builds on measurement items from the literature, which are mostly in English, the questionnaire was originally prepared in English. The questionnaire was then translated into Slovenian to reduce the participants' possible misinterpretation, which Malhotra (2006, p. 188) listed as a potential cause of bias. By doing so, the aim was to tackle the issue of designing and translating the questions as researchers, rather than leaving it to the participants. Due to the topic's specificity and the limited knowledge about the research area, the intention was to provide the participants with the most understandable questionnaire possible; hence, in the Slovenian language as the mother tongue of the Slovenian sample. Once the English version of the questionnaire was prepared, it was translated into Slovenian and back-translated into English, helping to improve the initial questionnaire's shortcomings. Technical terms were either further explained or replaced with colloquial words to reduce potential method bias (Hair, L.D.S. Gabriel, et al., 2019, p. 494; Podsakoff et al., 2003, p. 888). Certain reverse-scored statements were also included to maintain the respondents' focus. Prior to conducting the large-scale survey, two pilot surveys were run to identify any misunderstandings or difficulties while completing the questionnaire, as recommended by Saunders et al. (2009, p. 394). The pilot surveys were performed in two consecutive years prior to the main survey, i.e., 2018 and 2019. The pilot survey participants were earlier generations of university students than those who would complete the actual survey questionnaire, and had similar characteristics as the participants in the main survey. The pilot respondents were native speakers of Slovenian who did not then participate in the main survey. With the pilot survey, the aim was to detect errors and check the clarity of the questionnaire and questions, and measure how much time was needed to complete the questionnaire. Based on that, the questionnaire was revised.

The questionnaire was administered online via the open-source application 1KA (hereafter: 1KA) (1KA, 2017). An online questionnaire was selected for the following reasons. First, the aim was to bring the survey closer to millennials, who are adept at digital technologies and consider filling out the questionnaire online as the primary way of completing it. Second, the self-administered form reduces potential bias due to the presence of the interviewer who is absent when a questionnaire is administered online. Third, the online form reduces the associated costs and time burden. In addition, it was the most reasonable choice in 2020 due to the considerable risk of infection during the COVID-19 pandemic. On the other hand, an online questionnaire is not without its disadvantages, namely, it can lead to self-selection bias, with this limitation being acknowledged in Chapter 6.5. Still, it must be considered that each method has both advantages and disadvantages, where the choice of a self-administered online questionnaire was found to be appropriate for the reasons explained above.

4.4 Sample selection and data collection

The target population for testing the research hypotheses in this study was millennials in Slovenia. Slovenia is a Central European country with around 2.1 million inhabitants, who were almost equally divided between the genders (50.21% male and 49.79% female) at the time the questionnaire was distributed in 2020 (Statistical Office of the Republic of Slovenia, 2022a). The target sample was university students from a business school that is one of the most recognised business schools in the geographic region and heavily involved in international activities. University students represent a subset of the millennials generation and share generational characteristics that make them similar and lead them to develop similar perceptions. Even though the use of a student sample is debatable, the appropriateness of the sample selection was justified and followed the recommendations of Compeau et al. (2012, pp. 1004–1007) to address topics that could be of concern accordingly. The data collection via the open-source application 1KA took place between June and September 2020. An online survey was disseminated among students who were compensated with bonus points in their course. They were invited to complete the questionnaire via a URL. Representativeness was ensured by considering various criteria (gender, region of residence, possession of a driver's licence) and is presented in Chapter 5.1.1.

As regards the student sample, the following actions were taken to justify the appropriateness of the sample selection procedure. Compeau et al. (2012, pp. 1004–1005) recommended explicitly stating the goal of the research and defining the target population for which the results will be generalised. The goal was to generalise the findings to the millennials generation rather than the entire population, and university students are a subset of millennials. Therefore, the findings are intended to be generalised to a target population of millennials. Next, a rationale was provided for the sample selection (Compeau et al., 2012, p. 1105). Given that university students are a subset of millennials and the fact that members of the same generation share common generational characteristics that make them similar to each other justifies the sample selection. In addition, because millennials tend to have higher levels of education than previous generations, it is very likely that they are also students. Zhu et al. (2020, p. 86) recruited university students in a similar context and justified the sample selection by noting that younger generations are a critical group of early adopters. The next action taken was a discussion of the sample choice in the context of limitations (Compeau et al., 2012, p. 1106). Although evidence was provided to justify the sample selection, it is mentioned under the limitations because the possibility that the sample selection influenced the results cannot be ruled out. Consistency between the research goals and the implications discussed was additionally ensured (Compeau et al., 2012, p. 1007), i.e., the findings in Chapter 6 are discussed in the context of millennials.

With respect to sample size, there are no "one sample size fits all cases"; rather, sample size depends on the case under study, as Wolf et al. (2013, pp. 10–11) concluded based on an analysis of different confirmatory factor analyses and SEM studies. According to their study, the sample size should be between 30 and 460 observations (Wolf et al., 2013, p. 11), which is more than the recommendations of other authors who refer to a general rule of thumb of 10 participants per estimated parameter, which usually results in a sample size of between 40 and 240 observations (e.g., Schreiber et al. (2006, p. 326)). The more complex the model, the larger the sample must be. Further, the larger the sample, the lower the variability and the greater the stability of the results (Hair, Black, et al., 2019, p. 632). Considering that the research model has 33 measurement items, the sample should consist of at least 330 individuals, which also meets the criteria proposed by Wolf et al. (2013, p. 11).

5 RESULTS

5.1 The participants

5.1.1 Socio-demographic characteristics and sample representativeness

The hypotheses were tested on a sample of millennials who ultimately provided 359 valid responses, which satisfies the criteria listed in Chapter 4.4 (between 30 and 460). Age was a screening variable used to filter out the responses. Only respondents meeting the criterion of being a millennial, i.e., born between 1981 and 2000, were considered for the analysis. The total surveyed number of respondents was 562 individuals, although only 403 respondents properly completed it according to 1KA. The questionnaire was fully completed by 373 respondents (a 66.37% completion rate). After cleansing the data, some units were excluded due to an incomplete survey response or an inappropriate age group, leading to a final sample of 359 millennials. The respondents' basic socio-demographic characteristics and their driving frequency are shown in Table 3, while the following paragraphs demonstrate the representativeness of the sample and elaborate on the characteristics of the respondents in terms of their preferences for transportation modes and vision of future autonomous driving. The millennials surveyed were aged between 20 and 39 years, which corresponds to the age range of millennials in 2020. Being born between 1981 and 2000, they were exactly between 20 and 39 years old. The fact that most Bachelor's and Master's degree students are below 30 means that it is not surprising the majority of the sample falls into the 20–29 category.

Table 3: Profile of the respondents (N = 359)

		Percent
Age	20–29 years	98.61
	30–39 years	1.39
Gender	Male	48.47
	Female	51.53
Type of settlement	Large urban settlement	50.14
	Suburban settlement	20.06
	A smaller compact settlement	23.68
	Scattered or secluded houses	6.13
Region	Western	43.73
	Eastern	56.26
Valid driver's licence	No driver's licence	9.20
	Driver's licence	90.80
Frequency of driving a car	Never	8.08
	Less than once a week	4.18
	Once to twice a week	15.88
	Three to four times a week	38.16
	Daily	33.70

Source: Own work.

The sample was almost split in half by gender, which corresponds to the population characteristics of both Slovenian inhabitants and EU-28 inhabitants. The total Slovenian population[14] in the second half of 2020 (when the survey was conducted) was 50.23% female and 49.77% male (Statistical Office of the Republic of Slovenia, 2022c), while the European distribution among male/female millennials was 50.83%:49.17% (Statistical Office of the European Communities (Eurostat), 2022). The distribution of respondents was also approximately representative of the distribution of the inhabitants of the regions in Slovenia, which is almost divided into two halves with 52.48% inhabitants in Western Slovenia and 47.52% inhabitants in Eastern Slovenia (Statistical Office of the Republic of Slovenia, n.d.). When only millennials are considered, the distribution is 51.07% for Western Slovenia and

[14] Due to data unavailability, it was not possible to calculate the distribution for millennials only.

48.93% for Eastern Slovenia (Statistical Office of the Republic of Slovenia, n.d.), which reflects the sample even better.

Nearly all respondents held a driver's licence (90.80%), which might roughly correspond to the position of the population of Slovenian millennials, although the exact number of them could not be determined due to the lack of available data. According to data from 2016 concerning the number of valid driver's licences, there were 1,343,642 of such licences (Javna agencija RS za varnost prometa, 2017, p. 1), while more recent data are not available. The data on driver's licences would not enable a precise determination of how many holders of them are millennials as the year of birth is not given, only the age category. According to approximate calculations, 552,992 people had a driver's licence in the age categories 18–20 years, 21–24 years, 25–30 years, and 31–40 years at that time (Javna agencija RS za varnost prometa, 2017, p. 1). One may assume that the millennials were born between 1981 and 2000, and were between 16 and 35 years old in 2016, which partially corresponds to the age categories mentioned above given that in that year there were 630,126 people in the age categories 15–19 years, 20–24 years, 25–29 years, 30–34 years and 35–39 years (a similar age range as above was used to obtain an approximation for millennials) in Slovenia (Statistical Office of the Republic of Slovenia, 2022b). These would make up 83% of valid driver's licences for these categories that approximate millennials (denoted in quotation marks in the following sentences). Since the age categories listed for the number of "millennials" are somewhat broader than those of "millennials" with a driver's licence, it may be assumed that the percentage of millennials holding a driver's licence would in fact be slightly higher, e.g., 85%–90%, which corresponds to the share of driver's licences in the study presented in this dissertation. Other studies also report similar proportions of survey respondents with a driver's licence, e.g., 87% (Hohenberger et al., 2016, p. 384), 89% (C. Lee et al., 2017, p. 8) and 93% (Liljamo et al., 2018, p. 28).

5.1.2 Driving patterns and views on AVs

The most popular mode of transportation among the respondents was a car, either as a driver or passenger. About one-third of the respondents (34%) reported driving a car daily, and slightly more than one-third (37%) reported driving one three to four times per week. About 11% of respondents were daily car passengers and 45% were car passengers three to four times a week. Over one-third of respondents (38%) walked at least once a week and 41% walked three or four times a week. Further, 65% of respondents used public transport at least once a week, among whom only 10% were daily users; 52% of respondents rode a bicycle at least once a week, among whom only 7% rode daily. The biggest share of respondents used one less than once a week. The two least frequently used transport means were taxis and car sharing. Taxis were generally used less than once a week (62%), while car sharing was mostly never used (66%). Detailed results are summarised in Table 4.

Table 4: Frequency of mode of transportation usage (in %)

	Never	Less than once per week	Once or twice per week	Three or four times per week	Daily
Driving a car	8.91	4.18	15.60	37.33	33.98
Passenger in a car	0.28	6.96	36.77	45.40	10.58
Car sharing	66.30	18.66	8.36	3.34	3.34
Taxi	25.07	62.12	10.86	1.67	0.28
Public transport	7.80	27.30	26.46	28.97	9.47
Bicycle	19.78	28.69	27.02	17.27	7.24
Walking	1.39	5.57	13.93	40.95	38.16

Source: Own work.

Respondents were additionally asked what mode of transport they most often used for their daily errands, i.e., shopping, drive to work, travel for work, trips for leisure, visits to friends and relatives, taking children or other family members around, and other local trips. The car was used the most often by at least one-third of respondents, regardless of the type of errand. Table 5 summarises respondents' preferences regarding mode of transport used for specific daily tasks.

Table 5: Mode of transport used for daily tasks (in %)

	Car	Motor bike	Bus	Train	Taxi	Bicycle	Walk	Other	N/A
Shopping	78.83	0.28	5.29	0.56	0.56	2.23	11.42	0.28	0.56
Travel to work	45.68	1.11	17.55	1.67	0.00	5.85	8.36	0.56	19.22
Travel while at work	35.65	1.39	3.06	0.84	0.56	1.67	6.41	0.28	50.14
Local leisure travel	66.85	2.79	8.36	1.11	0.84	11.14	6.69	0.56	1.67
Visiting friends and relatives locally	77.99	1.95	3.90	0.84	0.84	6.13	7.80	0.00	0.56
Taking children to school or nursery	36.49	0.00	1.95	0.00	0.00	0.00	0.84	1.11	59.61

(table continues)

(continued)

	Car	Motor bike	Bus	Train	Taxi	Bicycle	Walk	Other	N/A
Driving other family members	85.52	0.00	0.28	0.00	0.28	0.28	0.56	0.56	12.53
Other local travel	37.33	1.67	26.18	5.29	1.67	7.24	5.85	0.84	13.93

Note: N/A means that the respondents did not participate in this task.

Source: Own work.

Most respondents had read about AVs or seen information concerning AVs (57%), but were not overly familiar with the idea of autonomous driving (56%) and were more likely to be ignorant of it (50%) than not ignorant (27%). Table 6 details these results.

Table 6: Opinions about AVs (in %)

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I am quite familiar with the idea of driverless vehicles.	4.74	23.68	15.60	44.29	11.70
I have not read or seen much information about AVs.	14.21	42.90	12.81	26.46	3.62
I am mostly ignorant about AVs.	10.03	39.83	23.12	22.56	4.46

Source: Own work.

They expressed a slightly more positive than negative view of AVs. They found them fascinating and were excited about fully AVs being present in their area of residence. Almost half the respondents (45%) were fascinated with AVs (scores of 4 or 5 on a 1–5 Likert-type scale) and around one-third of respondents (34%) were neutral, amounting to a mean of 3.14. Respondents were also more positively inclined about seeing AVs in their area with more people scoring 4 or 5 than 1 or 2; however, over one-third of the respondents (42%) were neutral in this respect (mean value = 3.27). On the other hand, the mean for being against the dispersion of AVs was 2.16, indicating a larger share of respondents having a negative stance. Almost two-thirds of the respondents (65%) scored negatively in this respect. The negative stance might stem from worries about AVs due to unfamiliarity with the technology, as was expressed by more than half the respondents (53%; mean value = 2.66). Only one-quarter of the respondents was less worried than more worried. As concerns trust in AVs, slightly more respondents were trustworthy of AVs than not trustworthy, with approximately one-quarter being neutral (mean value = 3.10). Results are summarised in Table 7.

Table 7: Outlook for the future with an AV (in %, except the mean)

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Mean
I look forward to the widespread use of AVs.	5.85	16.99	41.78	27.86	7.52	3.14
I look forward to using AVs.	5.29	16.43	33.70	35.10	9.47	3.27
I am completely against buying an AV.	31.48	33.43	26.18	5.29	3.62	2.16
I am worried about AV technology because I am not familiar with it.	9.19	43.45	22.56	21.73	3.06	2.66
I do not like AVs because I have less control over the steering of the vehicle.	5.85	28.69	27.86	25.07	12.53	3.10

Source: Own work.

Over three-quarters of the respondents (77%) found the task of driving to be fun (mean value = 4.01). Transferring the driving to an AV would mean the loss of driving pleasure for almost half the respondents (46%; mean value = 3.25) while almost two-thirds (59%) would miss the pleasure of driving a conventional vehicle (mean value = 3.50) as can be seen from Table 8.

Table 8: Fun and pleasure of driving (in %, except the mean)

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Mean
AVs would take away the pleasure of driving.	6.13	20.06	27.86	34.82	11.14	4.01
Driving is particularly fun for me.	1.95	5.01	16.43	43.73	32.87	3.25
I would miss the pleasure of driving a conventional vehicle.	5.57	16.99	18.66	39.83	18.94	3.50

Source: Own work.

Respondents were more inclined to own vehicles with higher levels of automation than vehicles with lower levels, and also considered them to be safer as automation increased. However, the safest vehicle in the respondents' eyes was a level-3 autonomous vehicle, which they would also be most likely to own if their budget were unlimited. Respondents were further asked about their vision of AVs on public roads. These questions were not mandatory because they were a primary interest of the study and thus two respondents (less than 1%) did not answer all of them fully, although the results are presented here anyway to outline how respondents envision AVs on our roads in the future. Respondents thought it more likely that semi-AVs would be prevalent in the marketplace in 10 years than fully AVs; 74% of respondents did not believe that fully AVs would be widespread in the market within 10 years or were neutral. In terms of areas other than private mobility, 45%–50% of respondents indicated that autonomous taxis, autonomous public transport, and autonomous freight transport will be widespread on the roads within 10 years.

The respondents would feel more safe than not safe while using an AV (mean value = 3.24), with 43% of the respondents expressing a positive view here and 21% a negative view. They would however feel safer while driving a semi-automated vehicle rather than a fully AV (mean value = 3.92). Almost all the respondents (91%) were either neutral or more positive regarding a semi- than a fully AV. Also consistent with this is the result that respondents would trust AVs less than conventional vehicles. Specifically, 28% of the respondents would trust an AV more than a human-operated vehicle and 39% of the respondents would trust one less. The respondents also believed that AVs can perform better than human drivers in foreseeable circumstances, while a human would react better in unforeseeable circumstances. Nearly two-thirds of the respondents (60%) agreed that AVs will perform better than human drivers in foreseeable circumstances (mean value = 3.64). Opinions on whether humans will react better than an AV in unforeseeable circumstances were more balanced, with 33% of respondents agreeing, 37% being neutral, and 30% disagreeing. Table 9 summarises the described results.

Table 9: Perceptions of AV safety (in %, except the mean)

	Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**	**Mean**
I would feel safe while using an AV.	3.62	17.83	35.38	37.05	6.13	3.24
I would feel safer while driving in semi-automated vehicle than in a fully automated vehicle.	1.67	7.24	19.22	41.23	30.64	3.92
I would trust an AV more than a human-driven vehicle.	8.64	30.36	32.87	22.56	5.57	2.86
In the foreseeable circumstances, AVs will perform better than humans.	1.39	10.86	27.30	43.73	16.71	3.64
In unforeseen circumstances, a human would have better reactions than an AV.	4.74	24.79	37.33	26.46	6.69	3.06

Source: Own work.

The most prominent benefits perceived by the respondents were better compliance with traffic signals and the road traffic rules (mean value = 4.09), an improved emergency response to traffic accidents (mean value = 4.01) and fewer traffic accidents (mean value = 3.99). Conversely, the weakest belief was attached to a lower insurance rate (mean value = 3.22), a reduced need to take a driving test (mean value = 2.87) and a reduced need to have multiple cars in a single household (mean value = 2.60). The respondents believed that most of the benefits are more likely than unlikely to be realised since most mean values were above 3 (on a 1–5 Likert-type scale), e.g., increased road safety, increased fuel efficiency, lower vehicle emissions, no need to look for a parking space, and ability to be productive while commuting. In terms of concerns, the respondents attributed the greatest concerns to fear of system intrusion and vehicle theft (mean value = 3.79), the high cost (mean value = 3.78), and safety consequences due to equipment or system failure (mean value = 3.68). The respondents were the least concerned about driving in a vehicle with no driver controls available (mean value = 2.79), an AV moving by itself from one location to another while unoccupied (mean value = 2.82), and an AV becoming confused in unexpected situations (mean value = 2.29). No concern attracted a score higher than 4, suggesting that the concerns are not very high, but medium high.

The respondents also indicated concerns regarding the privacy perspective. They would be worried about data misuse (mean value = 3.99), feel uncomfortable about their driving route being tracked (mean value = 3.66), and be bothered if companies were to use their personal information (mean value = 3.62). They would be less willing than unwilling to share data with different companies and authorities, but among them, they would be most willing to share data with AV developers for the purpose of vehicle improvement (mean value = 3.55), the police, or other security providers (mean value = 3.04), and insurance companies (mean value = 2.62). Nevertheless, the mean values are more on the neutral-to-negative side. Next, the respondents agreed that policymakers and governments would have a role to play in modifying the regulatory framework (mean value = 4.05) and road infrastructure (mean value = 3.94), as well as in providing incentives for buying AVs (mean value = 3.74).

5.2 Data inspection

The data were tested for common method variance and multicollinearity. A widely used method for testing common method variance is Harman's single-factor test in which all factors are loaded onto a single construct (Podsakoff et al., 2003, p. 889). Harman's single-factor test was used to check if the common measurement source significantly affected the correlation among variables. The test assumes that the variance explained by a single factor should not account for the majority of the variance (Podsakoff et al., 2003, p. 889). The test was conducted in SPSS and the results of the test on 33 variables revealed 31% to be the largest initial eigenvalue, suggesting that common method bias is not a problem.

Despite carrying out detailed reliability and validity testing (discussed in Chapter 5.3), Kock and Lynn (2012, p. 561) proposed that a collinearity test should be conducted alongside the reliability and validity tests. Multicollinearity was tested through the VIF in SPSS. The VIF is the most commonly used measure of multicollinearity and an acceptable level is when VIF values do not exceed 3.3 or in some cases 5 or 10, which indicate no multicollinearity (Kock & Lynn, 2012, p. 552). The VIF values were obtained for all combinations of model variables as well as for each construct separately. The results showed that most VIF values were below 3, while the values that exceeded 3 were still below 3.3. Accordingly, there is no multicollinearity problem in the data used here.

To test for normality, skewness and kurtosis tests that are suitable for a larger rather than a smaller sample size (above 300) were applied (Mishra et al., 2019, p. 70). The results confirmed that the data under study are moderately normally distributed since the skewness values are in the range of between +/-1 and the kurtosis values are in the range of between +/-1.5 (Hau & Marsh, 2004, p. 331). Nevertheless, a major problem caused by the moderate non-normality in the data analysis is not seen considering that Hau and Marsh (2004, pp. 343–344) reported little effect on the solution in case of using the maximum likelihood estimator.

5.3 Testing the measurement model

Evaluation of the measurement items in the measurement model is, along with evaluation of the model fit and testing of the structural model, one of the aspects that must be considered in the SEM framework. Even though some authors advocate a two-stage approach to assessing models, starting with a measurement model and only then assessing a structural model, Fornell (1985, p. 40) justifiably explained that the two assessments should be performed together because measurement validity is not isolated from the theoretical context. The measurement model shows the manifest variables used to measure the constructs at hand (Diamantopoulos & Siguaw, 2000, p. 4) and its evaluation is necessary due to operationalisation of the constructs with measurement items where information loss and errors can occur (Trommsdorff, 2004, in Günthner & Proff, 2021, p. 595). The measurement items should be reliable and valid. Reliable measurement items will provide consistent results when replicating the measurement scale, while valid measurement items will actually measure what they are intended to measure (Hair, L.D.S. Gabriel, et al., 2019, p. 505; Schumacker & Lomax, 2012, p. 182). These must be tested to avoid incorrect inferences arising from flawed measurement items (Davis, 1985, p. 73). The measurement model in this study was evaluated for its reliability and validity using different criteria since each has its own weaknesses/strengths (Nunnally, 1975, p. 11).

Internal consistency reliability was assessed by Cronbach's alpha and CR, which Richter et al. (2016, p. 388) suggested complement each other. Cronbach's alpha was chosen because it is the most often referred to (Streiner, 2003, p. 99; Trizano-Hermosilla & Alvarado, 2016,

p. 1). It should be calculated by constructs rather than for the full scale (Hair et al., 2019, p. 502). While Cronbach's alpha weights the indicators equally, CR as its alternative assigns various weights to different indicators (Hair et al., 2019, p. 502). Therefore, it was considered necessary to evaluate both. According to these two measures, internal consistency is sufficient when Cronbach's alpha exceeds 0.70 (Nunnally, 1975, p. 10) but is not above 0.90, as this could reflect redundancy in the measurement items (Streiner, 2003, p. 5), and/or when the values of CR exceed 0.60 (Bagozzi & Yi, 1988, in Diamantopoulos & Siguaw, 2000, p. 91). Next, convergent validity tests whether all measurement items measure the underlying construct (Davis, 1985, p. 327). According to Fornell and Larcker (1981, p. 46) and Diamantopoulos and Siguaw (2000, p. 91), AVE as a measure of convergent validity should not be lower than 0.50 to show that the variance captured by the underlying latent variable is larger than the measurement error. Discriminant validity is a measure of divergent validity and tests whether measurement items of different constructs that should not be highly correlated are in fact not highly correlated (Davis, 1989, p. 327). It was assessed by the Fornell-Larcker criterion, according to which square root AVE values are compared against the correlation between each pair of latent variables. To satisfy the criterion of discriminant validity, square rooted AVE values should be higher than the correlations for each pair of variables (Fornell & Larcker, 1981, p. 46).

The measurement items were also independently evaluated for their loadings. Anderson and Gerbing (1988, p. 416) advised that a loading should be twice as high as its standard error and significant. Hair, Black, et al. (2019, p. 674) stated that a factor loading should ideally be 0.70 or higher, but at least 0.50. Similarly, MacCallum et al. (1999, p. 96) advised loadings above 0.60, not varying over a wide range, and with a mean of at least 0.70, which was considered here. Two factors were thus excluded due to their low factor loadings, namely one for the "technological enthusiasm" and one for the "social factors" constructs (explained in Chapter 4.3). Still, at least three indicators per construct were retained, as is typically recommended, e.g., Falk and Miller (1992, p. 79). All factor loadings were significant and all measurement items had R^2 above 0.20 (Hooper et al., 2007, p. 56). The measurement items were evaluated for their communalities and total variance explained and met the criteria proposed by Hair, L.D.S. Gabriel, et al. (2019, pp. 499–500). All communalities were above the recommended value of 0.50 with the lowest being 0.55 and the highest 0.79. Next, at 66%, the total variance explained exceeded 60%. The results shown in Table 10 and Table 11 confirm that the measurement model is adequate. For all constructs, Cronbach's alpha values are above 0.70, CR values are above 0.60, and AVE values are above 0.50. Moreover, the squared root AVE values are lower than the correlations between the constructs. Once a measurement model has been proven to be adequate, i.e., valid and reliable, one is justified in proceeding with the analysis (Richter et al., 2016, pp. 387–388).

Table 10: Descriptive statistics, validity and reliability test results by items and constructs

Constructs	Items	Mean	Standard deviation	T-value	Completely standardised loadings	CR	AVE	Cronbach's α
Technological enthusiasm (TECent)	TECent1	2.72	1.06		0.79	0.77	0.52	0.72
	TECent2[a]	3.40	1.01	11.42	0.66			
	TECent3[a]	3.41	1.03	12.85	0.77			
Attitude to AVs (attAV)	attAV1	3.14	0.98		0.86	0.88	0.64	0.87
	attAV2	3.27	1.02	20.49	0.87			
	attAV3[a]	2.90	1.13	15.68	0.72			
	attAV4[a]	3.84	1.04	15.87	0.73			
Perceived safety (SAF)	SAF1	3.60	0.94		0.71	0.85	0.59	0.85
	SAF2	3.24	0.94	15.16	0.85			
	SAF3	2.86	1.04	13.83	0.77			
	SAF4	3.34	0.85	13.23	0.74			
Social factors (socFAC)	socFAC1	3.03	1.01		0.72	0.78	0.55	0.72
	socFAC2	3.35	0.99	8.19	0.90			
	socFAC3	3.59	1.04	8.64	0.68			
Perceived benefits (BEN)	BEN1	3.94	0.88		0.83	0.80	0.56	0.87
	BEN2	3.99	0.85	18.29	0.85			
	BEN3	3.82	0.91	14.77	0.72			
	BEN4	4.01	0.83	13.57	0.67			
	BEN5	4.09	0.86	13.71	0.68			
General concerns (CON)	CON1[a]	3.21	1.23		0.78	0.81	0.51	0.82
	CON2[a]	3.18	1.33	13.58	0.73			
	CON3[a]	3.71	1.28	12.21	0.66			
	CON4[a]	2.95	1.29	12.88	0.69			

(table continues)

(continued)

Constructs	Items	Mean	Standard deviation	T-value	Completely standardised loadings	CR	AVE	Cronbach's α
Privacy in the AV era (PRI)	PRI1[a]	3.99	0.93		0.72	0.86	0.61	0.85
	PRI2[a]	3.66	1.05	11.67	0.80			
	PRI3[a]	3.83	1.05	12.22	0.87			
	PRI4[a]	3.76	1.04	11.63	0.79			
AV adoption intention (AVado)	AVado1	3.42	0.97		0.77	0.83	0.62	0.71
	AVado2	2.73	1.16	7.84	0.69			
	AVado3	3.28	0.99	8.26	0.81			
Facilitating conditions (facCON)	facCON1	3.74	1.03		0.79	0.79	0.55	0.78
	facCON2	3.20	1.19	11.42	0.66			
	facCON3	3.55	0.96	12.85	0.77			

Note: [a] = reverse-scored; There are no t-values for the first factor of each construct because it was used as a reference variable to scale the construct (see Chapter 4.2).

Source: Own work.

Table 11: Discriminant validity test results

Latent variable	attAV	CON	AVado	tecENT	socFAC	BEN	SAF	PRI	facCON
attAV	*0.80*								
CON	-0.67	*0.72*							
AVado	0.76	-0.68	*0.79*						
tecENT	0.53	-0.46	0.46	*0.72*					
socFAC	0.34	-0.17	0.26	-0.03	*0.74*				
BEN	0.66	-0.59	0.66	0.47	0.19	*0.75*			
SAF	0.69	-0.63	0.59	0.53	0.21	0.72	*0.77*		
PRI	-0.36	0.51	-0.37	-0.35	-0.09	-0.28	-0.46	*0.78*	
facCON	0.56	-0.41	0.62	0.24	0.28	0.54	0.50	-0.19	*0.74*

Note: Numbers in italics on the diagonal represent the squared AVE values. The numbers below the diagonal are the correlations between latent variables.

Source: Own work.

5.4 Assessment of the model fit

Model fit assessment is a key aspect of SEM (Yuan, 2005, p. 115), but nevertheless should not displace the focus on the theoretical aspects of proposed model (Hooper et al., 2007, p. 57). By assessing the model fit, the fit between the overall model and the empirical data is checked, which should complement the assessments of the measurement model and the structural model (Diamantopoulos & Siguaw, 2000, p. 82). Following the recommendations of Schumacker and Lomax (2012, p. 76), the model fit assessment was evaluated using the following indices: chi-square test (hereafter: χ^2) per degree of freedom, goodness-of-fit index (hereafter: GFI), adjusted goodness-of-fit index (hereafter: AGFI), root-mean-square residual (hereafter: RMR), standardised root-mean-square residual (hereafter: SRMR), root-mean-square error of approximation (hereafter: RMSEA), normed fit index (hereafter: NFI), parsimony normed fit index (hereafter: PNFI), and Akaike information criterion (hereafter: AIC). Hooper et al. (2007, pp. 53–56) classified these indices in the following groups: absolute fit indices (χ^2, RMSEA, GFI, AGFI, RMR, SRMR), incremental fit indices (NFI, comparative fit index (hereafter: CFI)), parsimony fit indices (parsimony goodness-of-fit index (hereafter: PGFI), PNFI), consistent Akaike information criterion (hereafter: CAIC), AIC). Hair, Black, et al. (2019, pp. 641–642) are more liberal in terms of which indices to report, stating that reporting too many indices can be redundant. They state that at least χ^2 and degrees of freedom, one absolute index, one incremental fit index, one goodness-of-fit index, and one badness-of-fit index should be reported (Hair, Black, et al., 2019, p. 647). The results for this study are summarised in Table 12. The reference values take account of work summarised by Hooper et al. (2007, p. 10), Hu and Bentler (1999, p. 27), Schreiber et al. (2006, p. 330) and Schumacker and Lomax (2012, p. 76), as shown in Table 12. Since there is neither agreement with regard to the indices to report nor on their acceptable values, different values from more to less restrictive values are presented. The results show that all of the model fit indices are close to or within the most restrictive recommendations. Moreover, in each of the afore-mentioned groups there are at least some indices that correspond to the most restrictive values, indicating that the model meets the criteria in terms of absolute, incremental and parsimonious aspects. Since Diamantopoulos and Siguaw (2000, p. 88) stated that it is necessary to rely on multiple indices, because none is the ideal one, it was important that at least each group satisfy some indices if not each index individually. In addition, the two indexes found at the lower boundaries, i.e., GFI and AGFI, can be affected by the model's complexity and thus be misleading (Baumgartner & Homburg, 1996, p. 153); it was thus believed that deviance from the reference values is not critical. Considering the results, the model fit may be assessed as acceptable.

Table 12: Results of testing the model fit

Fit index	Index value	Reference value	Source
χ^2/degree of freedom	1.75	below 2.00 or 3.00	Schreiber et al. (2016, p. 330)
GFI	0.88	close to 0.90 or 0.95	Schreiber et al. (2016, p. 330); Schumacker and Lomax (2012, p. 76)
AGFI	0.85	close to 0.90 or 0.95	Schreiber et al. (2016, p. 330); Schumacker and Lomax (2012, p. 76)
RMR	0.05	as close to 0 as possible	Schreiber et al. (2016, p. 330); Schumacker and Lomax (2012, p. 76)
SRMR	0.05	below 0.05 or 0.08	Hu and Bentler (1999, p. 27); Schreiber et al. (2016, p. 330); Schumacker and Lomax (2012, p. 76)
RMSEA	0.05	below 0.05-0.08	Hu and Bentler (1999, p. 27); Schreiber et al. (2016, p. 330); Schumacker and Lomax (2012, p. 76)
NFI	0.96	close to 0.90 or 0.95	Schreiber et al. (2016, p. 330); Schumacker and Lomax (2012, p. 76)
CFI	0.98	above 0.95	Hooper et al. (2007, p. 10); Hu and Bentler (1999, p. 27); Schreiber et al. (2016, p. 330)
AIC	1,002.27	the smaller the better	Schreiber et al. (2016, p. 330)

Source: Own work.

5.5 Hypotheses testing

After ensuring that the measurement items applied were adequate, the structural model was examined (Schumacker & Lomax, 2012, p. 192). A structural model represents the relationships between the latent variables and indicates the amount of variance explained (Diamantopoulos & Siguaw, 2000, p. 4). The relationships under study were stated in the form of 10 hypotheses, and the examination of the structural model tested whether the data support the proposed relationships (Vieira, 2011, p. 73). The sign of the relationships, its magnitude and significance, and the variance explained (R^2) were of interest (Diamantopoulos & Siguaw, 2000, p. 92; Vieira, 2011, pp. 73–74). The significance was tested at the p-value of 0.01, even though all but one hypothesis was also significant at the p-value of 0.001. Table 13 summarises the path coefficients, t-values, and the results of the hypothesis testing, which confirms all 10 hypotheses. The highest path coefficient was observed between perceived safety and general concerns, indicating that more positive perceptions of safety can significantly reduce the perceptions of general concerns, while the path coefficient from privacy concerns in the AV era to general concerns is lower. Considering the path coefficients from different factors to attitude to AVs, the latter is most strongly influenced by negatively general concerns and positively by technological enthusiasm. Finally, attitude to AVs positively influences AV adoption intention. The results are discussed in detail in Chapter 6.1.

Table 13: Results of the structural model

Hypothesis	Relationship	Path Coefficient	t-value	Result
H1	Perceived safety → General concerns	-0.83**	-10.75	Supported
H2	Privacy concerns in the AV era → General concerns	0.20*	3.06	Supported
H3	Technological enthusiasm → Attitude to AVs	0.35**	4.16	Supported
H4	General concerns → Attitude to AVs	-0.35**	-5.21	Supported
H5	Social factors → Attitude to AVs	0.34**	4.17	Supported
H6	Perceived benefits → Attitude to AVs	0.22**	3.24	Supported
H7	Facilitating conditions → Attitude to AVs	0.22**	3.59	Supported
H8	Perceived safety → AV adoption intention	0.30**	5.15	Supported
H9	Facilitating conditions → AV adoption intention	0.12**	3.13	Supported

(table continues)

(continued)

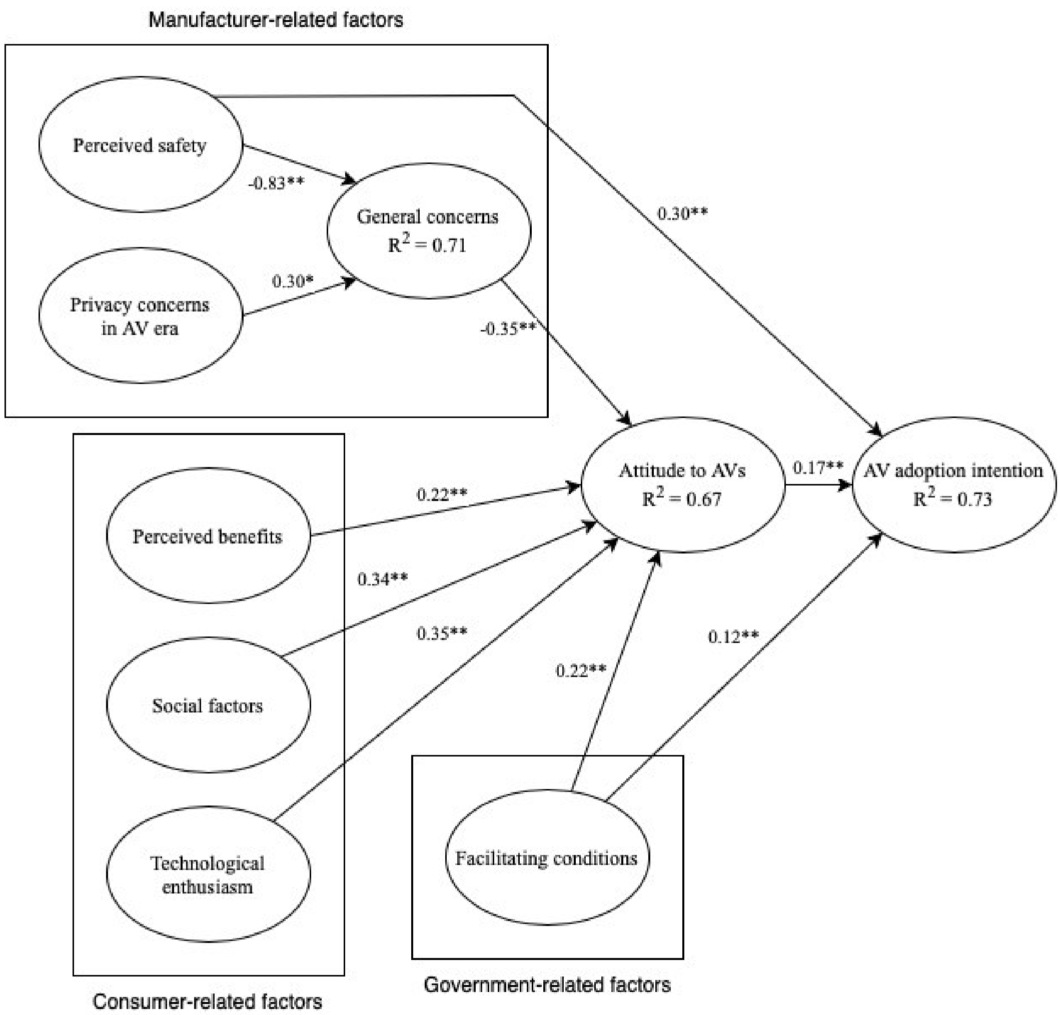
Hypothesis	Relationship	Path Coefficient	t-value	Result
H10	Attitude to AVs → AV adoption intention	0.17**	3.89	Supported

*Note: ** = p ≤ 0.001, * = p ≤ 0.01.*

Source: Own work.

Figure 5 also graphically presents the estimated structural model and provides the R^2 values of the endogenous variables, as recommended by Hair, Black, et al. (2019, p. 711). The R^2 of the endogenous variables are as follows: 0.71 for the general concerns, 0.67 for the attitude to AVs, and 0.73 for the AV adoption intention. Variables are also grouped into two categories of factors, namely, the consumer-related factors, manufacturer-related factors and government-related factors, as further explained in Chapter 6.1.

Figure 5: Graphical representation of the results of the structural model



*Note: ** = p ≤ 0.001, * = p ≤ 0.01.*

Source: Own work.

6 DISCUSSION

6.1 Interpretation

The objective of this dissertation was to examine the factors affecting millennials' adoption of fully AVs based on the TAM and UTAUT2 models and a literature review from which the relevant adoption factors were deduced and tested by an online questionnaire. The hypotheses were formulated and justified based on the findings of prior studies, while new findings were obtained from an original survey with a sample of 359 Slovenian millennials. The study shows that technological enthusiasm (H3), social factors (H5), perceived benefits (H6) and facilitating conditions (H7) have a positive direct effect on attitude to AVs. On the other hand, the effect of general concerns on attitude to AVs (H4) is negative, and general concerns are positively influenced by perceived safety (H1)[15] and negatively by privacy concerns in the AV era (H2)[16]. Perceived safety (H8) and facilitating conditions (H9) also have a positive effect on intention to adopt an AV. The effect of attitude to AVs on intention to adopt an AV is positive (H10).

The first two hypotheses studied the effect of perceived safety and privacy concerns in the AV era, respectively, on general concerns. It was shown that perceived safety significantly negatively influences general concerns (path coefficient = -0.83). Since general concerns were reverse-scored, a negative path coefficient indicates a positive relationship. When perceived safety increases in the eyes of potential adopters, general concerns are reduced. Conversely, low perceptions of safety would lead to higher general concerns. Privacy concerns in the AV era significantly negatively influence general concerns (path coefficient = 0.20). As both constructs were reverse-scored, a positive path coefficient indicates a negative relationship where one factor reinforces the other one in the same direction. When privacy concerns are on a higher level, general concerns increase. Oppositely, lower privacy concerns would lead to lower general concerns for potential adopters. Hypotheses 3–7 studied the effect of different adoption factors on attitude to AVs, where all relationships but one were positive. The effect of technological enthusiasm was positively significant (path coefficient = 0.35). If an individual is more technologically enthusiastic, i.e., interested in technology, they will be more likely to form a positive attitude to AVs. The effect of general concerns was significantly negative (path coefficient = -0.35), indicating that higher general concerns would lead to forming a more negative attitude to AVs. Social factors significantly positively influence the attitude to AVs (path coefficient = 0.34). When individuals are influenced by people who are close to them (e.g., family and friends) or expect to acquire social recognition by adopting an AV, they will form a more positive attitude to AVs. Perceived benefits significantly positively influence attitude to AVs (path coefficient = 0.22). When individuals perceive the benefits arising from AVs to be higher, they will form

[15] A negative path coefficient indicates fewer concerns.
[16] A positive path coefficient indicates that stronger privacy concerns stimulate stronger general concerns.

a more positive attitude to AVs. The effect of facilitating conditions on attitude to AVs is significantly positive (path coefficient = 0.22). If AV adoption is facilitated by the government (e.g., by providing incentives and setting the legal framework), individuals will form a more positive attitude to AVs. Finally, three hypotheses studied the effect on AV adoption intention and all relationships were positive. Perceived safety significantly positively influences AV adoption intention (path coefficient = 0.30), meaning that individuals will more likely have an intention to adopt an AV if they perceived AVs to be safe. Facilitating conditions significantly positively influence AV adoption intention (path coefficient = 0.12). The influence of attitude to AVs was shown to be significantly positive (path coefficient = 0.17), indicating that potential adopters would have a stronger adoption intention if they formed a more positive attitude to AVs.

Perceived safety remains among the most important AV adoption factors because it can significantly reduce the general concerns that are perceived as well as directly influence the intention to adopt an AV. It seems that perceived safety appears at the very beginning of the chain of influencing factors and can shape perceptions about other aspects featuring later down the chain. Accordingly, safety perceptions can be critical for the success or failure of AV technology among end users. Neither the benefits of AVs nor the vehicles' desirability are meaningful unless the perceptions of safety are positive (Othman, 2021, p. 358); conversely, more negative perceptions of safety may lead to lower perceived benefits. Still, this is not surprising because AVs are unlike manually-driven vehicles and require a high level of trust that the promised safety features will actually work. On one hand, automation shows the potential to improve safety while, on the other, technology in general is prone to error, which calls the safety aspect into question (Daziano et al., 2017, p. 153). The many negative announcements made in the media about accidents involving AVs just add to this, make people less trustworthy of them, and indicate that safety is justifiably so important. Given that people lack experience with AVs, negative media coverage can be all the more destructive by creating a negative attitude to autonomous vehicles and reducing the likelihood of them being adopted. To mitigate negativity arising from the media and the environment, manufacturers should clearly communicate that their paramount focus is on safety and quality, while telling potential users which measures have been taken to protect passengers in an AV. Further, they should in fact completely avoid using negative wording in their public communications since even a minor negative connotation can produce a negative effect on people, also in a positive context (Anania et al., 2018, p. 223). It was even suggested that manufacturers should tell potential users which measures an AV takes to protect passengers (T. Zhang et al., 2019, p. 217), while Liljamo et al. (2018, p. 36) stressed that safety is a major concern of people that must be placed first. A survey by Kyriakidis et al. (2015, p. 895) determined that about one-quarter of respondents would trust the technology as soon as safety is assured by the authorities, while about one-third of respondents would need to try it out beforehand, which together amounts to almost two-thirds relying on safety as a factor that must be assured prior to adoption. Participants in interviews conducted by Zmud et al. (2016b, p. 8) also became more confident about AVs when they were assured of safety. Even though manufacturers have slightly shifted their focus to the more visual characteristics of vehicles, they should continue prioritising safety, present their actual safety features, and potentially demonstrate through tests to confirm that AVs are equal to, if not better than, human-operated vehicles.

Approaches to demonstrating safety for a technology that is unknown should focus on making the technology more familiar and understood among potential adopters. By drawing parallels with known and widely used technologies, the understanding and acceptance of AVs might increase, especially among millennials who are particularly open to new technologies. Analyses of road accidents comparing the number of accidents today compared to a decade ago, when not many automated driving systems/features were available in cars, could be conducted. Reasons for accidents should be studied in detail to determine the extent to which automated features have potentially contributed to this aspect since these features could not contribute to avoiding/reducing accidents for all types of reasons. This real-life data might be valuable/persuasive for potential adopters to really see/believe in the contribution AVs make to safety. Car manufacturers might also prefer to retain a steering wheel in the vehicle or focus on developing and implementing level-4 vehicles rather level-5 vehicles, at least in the medium-term, noting that Rezaei and Caulfield (2021, p. 486) reported that half of their survey respondents would have higher confidence and trust in terms of AV safety if the vehicle had a steering wheel, even though it would drive by itself.

In terms of safety, car manufacturers should also give top priority to sensors and their detection because one study reported the highest technical concerns in relation to incorrect detection of surrounding objects and subjects (Rezaei & Caulfield, 2021, p. 485) while another study pointed out that roads will never be without humans because of cyclists and pedestrians (Mueller et al., 2020, p. 313) , which further underlines the importance of sensor detection. If the aim is to have a 100% autonomous fleet, additional attention will need to be paid to road participants that are non-autonomous. Clear communication by an AV to the external environment should be put forward. Deb et al. (2018, p. 144) concluded that pedestrians would prefer a textual warning (e.g., “braking”) and a walking silhouette for crossing the street in the presence of an AV. In addition, a verbal message might be useful for braking when around distracted pedestrians (e.g., those mid text messaging) and visually impaired. By focusing on features related to pedestrians, car manufacturers would more comprehensively cover all participants in transport and add to the chance of success of the new mobility system. These findings indicate how important sensors installed in AVs are for accurately detecting their surroundings. Accordingly, the effective operation of sensors will play a crucial role in a world that is simultaneously autonomous and non-autonomous, an aspect car manufacturers should not neglect. Moreover, car manufacturers should clearly present and demonstrate which sensors, why and how are installed in AVs for detection. Since an AV is a complex technology, displaying the functionality of the entire vehicle at the same time might overburden individuals with information. Thus, car manufacturers could group similar features together and present them at once to make potential adopters feel that they understand the individual parts of the whole. Further, because AVs still function as a single entity and no single sensor or safety feature will be sufficient for all situations and road conditions, a useful approach could entail presenting how the features complement each other such that potential adopters obtain the impression that all aspects/situations have been covered. Another finding in favour of focusing on communicating separate features is the following. According to Kalra and Paddock (2016, p. 191) , there could not be enough testing to prove AVs' 100% reliability in terms of fatalities and injuries in the foreseeable future, indicating that additional testing is not the most appropriate strategy for building trust and confidence. On the other hand, if potential adopters could become acquainted with AV features that add to safety, this could positively affect their safety perceptions, and build trust and confidence. Car manufacturers could also link AV features with some already existing features and communicate them in this way. Potential adopters might easier imagine features they already know from other similar technologies.

While features with which vehicle users are already familiar can be more easily presented by linking them with the current vehicle's safety features, novel features should not be neglected, yet it is exactly these that would require greater effort to communicate and present as clearly as possible. One example of such a feature would be autonomous lane changing that not many vehicles on the market are presently using (Van Brummelen et al., 2018, p. 389). It would also be valuable to focus on features that support driving in risky and complex conditions, e.g., poor lighting or poor weather conditions. In order to further identify which features should be promoted more and how, it would make sense to conduct a separate study to specifically investigate different features and individuals' perceptions of them. A study of this nature should combine a survey questionnaire and a demonstration drive, which would show the participants first-hand how the features work. Another contribution to building trust and confidence would be by lowering speed limits and AV driving speeds, which would make several contributions, namely the severity of potential accidents could be reduced and pedestrians might feel safer when seeing an AV approaching at a lower speed. Potential adopters might also feel that AVs are more controllable if they are driving slower, thereby increasing their trust and confidence. Future research could accordingly dive deeper into comparing acceptable speeds for AVs with a view to providing implications for programming AVs in line with expectations.

However, the safety aspect is not the sole factor that leads to concerns being formed with respect to AVs. Privacy is another important factor, albeit it is much less important according to the results of the presented study, while the experts participating in the interviews conducted by Whittle et al. (2019, p. 309) also decided that privacy is less important than other safety- and security-related aspects. There are several reasons explaining why this could be the case, as discussed below. First, the issue of privacy is already present in several modern technologies widely found in the market, e.g., smartphones and mobile banking, which may make the issue better understood by people. They might also feel protected by the General Data Protection Regulation (GDPR) established in 2018, which reduces potential concerns. Another explanation could emerge by drawing a parallel to what Moody et al. (2020, p. 642) suggest relative to road safety, namely that individuals compare the safety of an AV with the existing level of road safety and perceive it by comparing it to that. Similarly, if an individual compares privacy with current privacy levels and finds no discrepancy (the same level) and feels that it is well taken care of, this could be satisfactory for them and thus mean it is not a cause for concern. Next, since privacy concerns are more under the control of the individual than those related to safety, they are not directly observed and often neglected. Barth and de Jong (2017, pp. 1050–1051) investigated the discrepancy between expressed privacy concerns and the data privacy measures actually taken (the 'privacy paradox') in online media activities in previous studies on the topic to highlight the problems faced nowadays, while Barth et al. (2019, p. 64) experimentally confirmed that even among more technologically-savvy individuals, functionality and design were ranked as more important than potential data misuse when downloading an app.

Many people in fact do not realise the true extent of what they are already sharing today with the outside world, especially millennials as digital natives whose use of applications and other personal data-related resources is unrestrained. For example, navigation systems record the current location, driving speed, and destination. In Slovenia, one insurance company has an application through which users collect discounts for taking out car insurance. There is a strong motivation to use the app because use can significantly reduce the insurance premium, yet at the same time the app tracks the location, movements, driving speed, acceleration rate etc., which could be defined as personal data, that also gives important information to the insurance company about the driver and the way they drive, and thus the risk, which could be the basis for determining insurance premiums in the future. People might only become concerned when confronted with these facts, like in the present research study where potential privacy problems were pointed out, while in everyday life they do not think about it often enough. Consumers should be made more aware of what awaits them and be potentially involved in the development of solutions. In any case, privacy concerns is an important factor in AV adoption and manufacturers' assurance of privacy could drive adoption. To compensate for consumers' ignorance/unawareness, governments and/or the EU should be responsible for creating laws in favour of consumers' privacy that manufacturers and service providers would have to comply with so that they do not exploit personal data for their own benefit. Considering that the main responsibility regarding data privacy is on manufacturers (Kenesei et al., 2022, p. 389), they would be bound to respect what is legally stipulated.

Perceived safety and privacy concerns in the AV era nonetheless explain a significant share of variance in general concerns that further form the attitude to AVs. Negative perceptions of safety and greater privacy concerns add to general concerns, and elevated general concerns negatively influence the attitude to AVs. Noting that people with strong attitudes are not easily persuaded to the contrary (Ajzen, 2001, p. 37), it is difficult to change a negative attitude into a positive one. Accordingly, car manufacturers should work on forming a positive attitude from the beginning, rather than subsequently looking for ways to change it for the better. Authors have emphasised the importance of addressing the concerns held by potential users about AVs (e.g., Kenesei et al. (2022, p. 389)), which takes on additional importance when one realises that general concerns significantly influence attitude formation. The relationship is among the strongest, which is not surprising given that relinquishing control to an external system, i.e., an AV, can put one's life and the lives of other road participants at risk, particularly if the new technology has not been adequately tested. People may have difficulty engaging with vehicles driving themselves from place to place, especially in adverse and unpredictable weather conditions. To mitigate these types of concerns, potential adopters should be more involved in developing use cases in collaboration with various stakeholders, with each contributing from their point of view, experience, and knowledge. This would increase the likelihood that some issues would not be overlooked and would be considered in the pre-programming of AVs. The behaviour of AVs in different weather conditions could be demonstrated through demonstration drives, e.g., on icy surfaces and in heavy rain. The proper media channel for reducing AV-related concerns would be social media, while the mass media could enhance them since the latter allows for more detailed reporting and greater information allows individuals to make more detailed judgments (Zhu et al., 2020, pp. 88–89).

Next, the presented study shows that social factors can strongly shape millennials' attitude to AVs. In different technology development stages, various social aspects might come to the fore. For example, individuals might initially be influenced by media reporting and the posts of car manufacturers, but once they internalise the benefits that new technology offers, they would start prioritising the gaining of social recognition and/or image by adopting a novel technology. Further, they would start spreading the good word among relatives to influence them to follow. In the initial stages, a useful strategy for car manufacturers for spreading the good word about AVs is through social influence, i.e., 'influencers'/'social influencers', as confirmed in the study and also other studies (e.g., Nordhoff et al. (2020, pp. 291–292)) as an influential factor. In the digital era and era of widely dispersed social media as well as communication via them for marketing purposes, especially among millennials, influencers could act as 'change agents' and 'opinion leaders' that car manufacturers would rely on. If millennials are indeed early adopters of AVs and early adopters are highly respected by their peers, as suggested by Rogers (2003, p. 283), they should be targeted by car manufacturers and governments to push adoption forward and reach a critical mass of adopters, especially by providing incentives and rewards for the first adopters to facilitate their adoption process. Highly-respected individuals might have a strong enough influence that others will follow them. Through influential others, individuals can hear of a positive experience and may therefore be more willing to give a new technology a chance, even though they have themselves not yet tested it. Exactly because of the little testing available, demonstrations could help individuals evaluate the new technology. For example, Rogers

(2003, p. 389) attributed considerable importance to demonstrations that would bring an initial experience to people with a technology in conditions akin to real-life ones, e.g., when others are using the technology in question. This could help them picture themselves in a similar situation and form a positive image of the new technology. For the case of artificial intelligence-based intelligent products, Sohn and Kwon (2020, p. 12) noted that a positive image of new technologies should be built, especially in early adoption stages, and could be promoted through experienced users, while Mogaji et al. (2021, p. 10) showed the importance of social influence for the adoption of banking chatbots, including promotions, family and friends. Thorpe and Motwani (2017, p. 11) believe that pressuring individuals with statements that they are missing out in comparison to their peers who are already using AVs would arouse interest in them. This could create a sense of regret and encourage the adoption so as to join the 'AV adopter family' as soon as possible. Further, adopting a particular product is closely linked to expressing an individual's identity, reputation and status through what they use/own (Arbore et al., 2014, p. 103). Accordingly, if AVs were promoted as something luxury and as a potential source of higher status, while being differentiated from conventional vehicles in positive terms, potential adopters who find social status important might be more motivated to adopt AVs.

The target group of influential others should specifically be more technologically enthusiastic individuals given that the study found that technological enthusiasm positively affects attitudes to AVs to a similar extent as social factors. Previous studies found that the share of enthusiasts is more than double the share of indifferent individuals and almost eight times higher than the share of sceptics regarding how likely they believe in the increased safety brought by AVs (Nielsen & Haustein, 2018, p. 52). Moreover, individuals with a more favourable attitude to technology would hold more positive perceptions of the benefits (Acheampong & Cugurullo, 2019, p. 360; Nastjuk et al., 2020, pp. 10–11), and thus having enthusiasts among early adopters could mean that they would influence and persuade more sceptical groups to adopt. More enthusiastic millennials would also search earlier for additional information about AVs than less enthusiastic millennials due to their general interest in new technology and hence their awareness of both the positive and negative aspects of AVs would increase and could be shared with their relatives. Car manufacturers and other responsible authorities must thus be careful about what they post so as not to create a negative attitude or cause misinterpretation about what is being shared. The enthusiasts should be targeted by suitable marketing approaches considering the preferences held by the target population of millennials. Millennials as digital natives would prefer electronic sources of marketing communication. The information should be clearly and concisely presented on car manufacturers' websites with an emphasis on safety aspects, the corresponding benefits, and measures taken to assure privacy and safety while travelling in an AV. It may seem that it would make sense to increase the technological enthusiasm of individuals, as a bigger share of them would contribute to the greater adoption of technology at the beginning, yet Asmussen et al. (2020, p. 18) concluded that increasing individuals' tech-savviness would be a less efficient strategy for convincing them to adopt AVs than promoting the safety and benefits aspects.

In addition, this study confirmed that perceived benefits improve the attitude to AVs. Therefore, the benefits should, along with the safety and quality features of AVs, be communicated to potential AV adopters. Car manufacturers could offer test drives and demonstrations that would additionally help showcase the benefits and safety to make the technology more appealing. Further, it would enable potential adopters to obtain a first-hand impression and evaluate the new technology. Yuen, Wong, et al. (2020, p. 8) confirmed that public participation in trials and demonstrations can positively influence the perceived value of AVs, and Günthner and Proff (2021, p. 601) stated that once people get in touch with a technology, they will be able to attribute a higher value to AVs. Demonstration campaigns should be accompanied by verbal and visual presentations that include 'did you know' type questions describing use cases and potential AV benefits, which has been suggested as an efficient approach to stimulate individuals' interest and heighten their senses of what a positive AV implementation has to offer to individuals as well as to society as a whole. Benefits would be disseminated more efficiently via the mass media than via social media because the former reinforces perceived benefits while the latter has no impact on people (Zhu et al., 2020, p. 88). Statements, including the "did you know" wording mentioned above, which contrast a positive effect of AVs with a negative effect without AVs (i.e., with the current transport alternatives) could be an effective way of information sharing and communication (Thorpe & Motwani, 2017, p. 11). The presented study also showed that perceived benefits were slightly less important for forming the attitude to AVs than general concerns, even though other studies have revealed that perceived benefits is a stronger predictor than perceived concerns/risks. For example, perceived benefits was a stronger predictor of AV acceptance than perceived risk in a study by Liu, Yang, et al. (2019b, p. 336), where it in fact proved to have the strongest effect among all predictors. In the study, the path coefficient of perceived benefits (0.22) was lower than the path coefficient of general concerns (-0.35) in absolute terms. This suggests that the benefits might be unable to outweigh the concerns and highlights the importance of addressing potential users' concerns about AVs, and is similar to the finding by Herrenkind et al. (2019, p. 18) who questioned the success of approaches that solely promote benefits to achieve the desired adoption intention effect among young people. Yet, the benefits and features of AVs should nevertheless be communicated as they could increase the value of AVs in the eyes of potential consumers, while educating about the benefits could raise the likelihood of AVs becoming more widely adopted. It is advised that governments and/or car manufacturers invest greater resources to explain the benefits to people, demonstrating the 'fun' of AVs, and thereby create a positive perception of the benefits that they may not yet be aware of and leading to a positive attitude. Policies should also aim to encourage people to spread their positive views among those close to them, in turn creating a more positive perception among them as well.

Facilitating conditions is another variable in the study that affects the attitude to AVs and AV adoption intention, with the former being greater (path coefficients = 0.22 and 0.12, respectively). It is worth noting that Hair, Black, et al. (2019, p. 711) stated that a path coefficient below 0.10 in absolute terms might be meaningless. The path coefficient in this study between facilitating conditions and AV adoption intention is close to this value and thus the results should be interpreted with caution. Even though the significant relationship suggests the presence of an effect, subsequent studies should look for answers for the low path coefficient as well as a deeper understanding of the role played by facilitating conditions. In the areas of facilitating AV adoption, the government is chiefly responsible and could facilitate adoption by creating an enabling environment for the adoption of AVs with appropriate incentives and regulatory frameworks. The primary focus should be on the tangible barriers, e.g., standards, regulations and certifications, due to their direct and indirect effect on AV acceptance by consumers (Raj et al., 2020, p. 132). The approach with incentives was already taken to promote the dispersion of electric vehicles, which are also known for being relatively more expensive than conventional vehicles. X. Zhang et al. (2014, p. 8066) divided possible incentives for electric vehicles into four categories depending on who is to benefit from them, i.e., consumers or manufacturers, and to which type of vehicle they apply, i.e., CO_2 emitting or not CO_2 emitting. The potential incentives are, but not limited to, the following: tax credits, tax exemptions, subsidies for purchase, subsidies for production and sales, parking privileges, high fuel (oil or gas) prices etc. (X. Zhang et al., 2014, pp. 8066–8067), and some of these could also apply to AVs. However, not all incentives are equally efficient. This means it is advisable to dedicate a study specifically to incentive schemes for AVs in order to discover what potential adopters want, what they expect, and what would bring the greatest benefits. In fact, AVs are different from both electric and conventional vehicles in many respects, and due to other concerns the effectiveness of the incentives may also be worse or non-existent. Once incentives are chosen, they must be clearly presented to the public to ensure they know what is available to take advantage of.

A supporting/facilitating mechanism would also be an appropriate legislative framework. Policies should mainly aim to address potential controversial and ethically problematic situations on the roads in the case of autonomous driving. Moreover, policy design should be aligned with broader national or global policies/strategies, particularly to support the United Nations' SDGs to make cities sustainable and to combat climate change. A novel approach to car design offers the opportunity to improve material use and production processes for greater sustainability, and the government could be a key player here. While these aspects lie beyond the scope of this study, they are an interesting area for future research. These findings suggest that there are at least three relevant groups of stakeholders in the context of AVs: consumers (users/adopters), manufacturers, and governments. Since each plays a distinct role, it is important to identify them and outline their responsibilities as the interests of consumers can only be pursued if all stakeholders are clear about how they can support adoption. Further studies may prove valuable for gaining more insights into these roles.

The proposed factors discussed above explain a moderately high proportion (67%) of the variance in attitude to AVs. All factors but general concerns positively contribute to forming the attitude to AVs. Technology enthusiasm has the greatest influence, closely followed by social factors, with perceived benefits and facilitated conditions contributing equally. It is important to note that strong attitudes are resistant to change and thus once an attitude has been formed it is difficult to change it. This makes it worthwhile to work on building a positive attitude among potential users as this is more likely to lead to a positive intention to adopt an AV. Similar remarks were made by Herrenkind et al. (2019, pp. 18–19) and Sanbonmatsu et al. (2018, p. 120). Herrenkind et al. (2019, pp. 18–19) advised that policymakers should work on forming positive attitudes among young people, while Sanbonmatsu et al. (2018, p. 120) pointed out that negative views of AVs are hardly persuaded to the contrary which indicates the importance of forming a positive attitude from the outset. Noting that the attitude to AVs depends on a wider range of factors, there are several aspects via which its formation can be influenced as explained above, e.g., by promoting benefits, demonstrating safety, engaging influential others.

The factors that influence attitude to AVs could be grouped into three categories as shown in Figure 5 in Chapter 5.5. Technological enthusiasm, social factors and perceived benefits primarily refer to a consumer – what drives/motivates them to adopt an AV. Perceived safety, privacy concerns in the AV era, and general concerns generally refer to a manufacturer – what it is expected to work on to assure safe and carefree autonomous driving on public roads. Facilitating conditions chiefly refer to the government that is responsible for establishing the legal framework, road infrastructure as well as incentives to facilitate adoption. This is how factors can be divided according to their primary link, yet because they are interlinked it does not mean that they do not to some extent also fall into another category. Although the factors in fact should not be looked at separately, the proposed division can nevertheless help guide future research to increase the contribution to theory and practice.

Finally, the presented study also supports the positive effect of attitude to AVs on AV adoption intention. The more positive the attitude, the stronger an intention to adopt an AV. Noting the studies by Nastjuk et al. (2020, p. 10), Payre et al. (2014, p. 259) and T. Zhang et al. (2019, p. 215), a strong positive relationship was expected. Nastjuk et al. (2020, p. 10) reported a path coefficient of 0.52, Payre et al. (2014, p. 259) a path coefficient of 0.62, and T. Zhang et al. (2019, p. 215) a path coefficient of 0.53, which is notably higher than the path coefficient of 0.17 determined in this study. On the other hand, a look at the variance explaining AV adoption intention shows a high proportion (73%) being explained in the proposed model. A comparison of this result with previous adoption models reveals a range of values that the conclusions made here are in harmony with. However, not all models actually reported R^2 values. Among those that did, for example, the model by Korkmaz et al. (2021, p. 8) explains a high proportion in behavioural intention, although most of the proposed relationships were found not to be significant. The following factors were confirmed to influence behavioural intention to use an autonomous public transport system: performance expectancy, social influence, habit, trust, and safety. J. Lee et al. (2019, p. 419) also failed to confirm all the relationships they proposed and their model explained 52% of the variance in intention to use an AV. Liu, Yang, et al. (2019b, p. 335) examined the effect of social trust, perceived benefit and perceived risk on three dependent variables: general acceptance, willingness to pay, and behavioural intention. The authors found 41% of the variance in behavioural intention to adopt an AV was explained by the explanatory variables, while 36% and 14% of the variance was explained in general acceptance and willingness to pay, respectively. In a study by Madigan et al. (2017, pp. 60–61), all factors except effort expectancy were significant, and 59% of the variance was explained by the model. The factors used in a study by Manfreda et al. (2021, p. 5) largely overlap with the factors in this dissertation because the earlier model was refined by considering the significant factors and adding other relevant factors. The model explained 78% of the variance and confirmed the factors of technological mindedness, perceived safety, personal and societal benefits, and perceived technological and legal concerns as significant factors for the adoption of AVs. A model by Panagiotopoulos and Dimitrakopoulos (2018, p. 781) reported that 44% of the variance in behavioural intention to use or have AVs was explained by four explanatory variables, while Park et al. (2021, p. 6) explained a bigger share, i.e., 61%, in a similarly composed model, yet failed to confirm the role of perceived ease of use in explaining intention to use AVs. Xu et al. (2018) examined both behavioural intention and willingness to ride again in level-3 AVs. Trust, perceived usefulness, perceived ease of use, and perceived safety explained 55% and 40% of the variance in behavioural intention and willingness to ride again, respectively. Yuen, Chua, et al. (2020, p. 12) and Yuen, Wong, et al. (2020, p. 9) took a significantly different approach, and the factors in their models have little in common with the model considered in this study. Nevertheless, it is interesting to mention them here because they explain a higher proportion of the variance than most other models and mentioning them here for the sake of completeness may encourage future research to also consider relevant adoption factors that are less covered in the literature. Their two studies explained 74% and 69% of the variance in public acceptance of AVs, respectively. Further, T. Zhang et al. (2019, p. 215) could not confirm the influence of perceived privacy risk on any of the variables, while other proposed factors influenced at least one of the variables, explaining a total of 61% of the variance in behavioural intention to use level-3 AVs. T. Zhang et al. (2020, p. 228) took a similar approach with some distinguishing features in the model and explained 54% of the variance in behavioural intention to use level-3 AVs. Zhu et al. (2020, p. 87) reported that their model explained 54% of the variance in AVs in general and 34% in public AVs.

Given the results, the proposed model with 73% of variance explained performs at the upper end of the various models proposed. Table 14 summarises the relevant factors according to the proposed model and with corresponding R^2 values. The factors in the mentioned model overlap with the currently proposed models to some extent. Even though it does not consider all possible influential factors, the model proposed in this study takes account of what was pointed out in the literature as being critical, overlooked or scarcely covered. This is where the contribution of the dissertation stems from. Chapters 6.3 and 6.4 are dedicated specifically to a summary of the main contributions of the dissertation.

Table 14: Comparison of influential factors and variance explained in different AV adoption models

Authors	Factors in the model	Variance explained (%)
Korkmaz et al. (2021)	Performance expectancy, **perceived usefulness**, effort expectancy, **social influence**, **facilitating conditions**, hedonic motivation, price value, habit, trust and safety, **perceived risk**	72
J. Lee et al. (2019)	Self-efficacy, relative advantage, psychological ownership, **perceived risk**, perceived ease of use, **perceived usefulness**	52
Liu, Yang, et al. (2019b)	Social trust, **perceived benefit**, **perceived risk**	41
Madigan et al. (2017)	**Performance expectancy**, effort expectancy, **social influence**, **facilitating conditions**, hedonic motivation	59
Manfreda et al. (2021)	**Technological mindedness**, **perceived safety**, **personal and societal benefits**, **perceived technological and legal concerns**, perceived security, perceived mobility-related efficiencies	78
Panagiotopoulos and Dimitrakopoulos (2018)	**Perceived usefulness**, perceived ease to use, perceived trust, **social influence**	44
Park et al. (2021)	**Perceived usefulness**, perceived ease to use, **facilitating condition**, **social influence**	61
Xu et al. (2018)	Trust, **perceived usefulness**, perceived ease of use, **perceived safety**	55
Yuen, Chua, et al. (2020)	Relative advantage, compatibility, complexity, hedonic motivation, behavioural control, **attitude towards AVs**, **subjective norms**	74
Yuen, Wong, et al. (2020)	Relative advantage, compatibility, complexity, trialability, observability, perceived value of AVs, trust in AVs	69
T. Zhang et al. (2019)	Perceived ease of use, **perceived usefulness**, **perceived safety risk**, **perceived privacy risk**, initial trust, **attitude toward using**	61
T. Zhang et al. (2020)	Perceived ease of use, **perceived usefulness**, trust, **social influence**, personality traits, sensation seeking	54

(table continues)

(continued)

Authors	Factors in the model	Variance explained (%)
Zhu et al. (2020, p. 88)	Mass media, social media, self-efficacy of AVs, **subjective norms**, **perceived usefulness**, **perceived risks**	54

Note: Factors in bold are the same, similar, or overlap somewhat with the factors in the presented study.

Source: Own work.

6.2 Discussing the research questions

This dissertation sought answers to three research questions. The first question (RQ1: Which factors affect millennials' willingness to adopt an AV?) was answered in the article entitled "Autonomous vehicles in the smart city era: An empirical study of adoption factors important for millennials" that was published in the "International Journal of Information Management" co-authored by Anton Manfreda, Klara Ljubi and Aleš Groznik (Manfreda et al., 2021). The study results provided an answer to RQ1 by confirming technological mindedness, perceived safety, technological and legal concerns, and mobility-related efficiencies as factors that affect millennials' willingness to adopt an AV. To complement the first research article on RQ1, the initially proposed model was refined by excluding non-significant relationships, introducing additional adoption factors, and testing them to more comprehensively answer the research question. The results were published in a second article entitled "Role played by social factors and privacy concerns in autonomous vehicle adoption" which was published in the "Transport Policy" journal and co-authored by Klara Ljubi and Aleš Groznik (Ljubi & Groznik, 2023). Only the results of the research conducted for the second article are presented in this dissertation as it builds upon the findings of the first article. According to the results, RQ1 may be answered by listing the following AV adoption factors as those relevant to millennials when weighing up whether to adopt an AV: perceived safety, privacy concerns in the AV era, technological enthusiasm, general concerns, social factors, perceived benefits, and facilitating conditions. Based on these, the attitude to AVs is formed that further influences the intention to adopt an AV. The second research question (RQ2: Do social factors and privacy concerns in the AV era affect millennials' willingness to adopt an AV?) aimed at specifically testing two adoption factors that were more scarcely covered in the literature at the time of preparing the proposed model and performing the research. As regards RQ2, it was confirmed that social factors and privacy concerns in the AV era affect willingness to adopt AV among millennials; however, these two were not among the strongest factors. Privacy concerns in the AV era negatively affect general concerns, while social factors positively affect attitude to AVs. The interest of the third research question (RQ3: What is the effect of technological enthusiasm in millennials' adoption of AVs?) concerned the effect of technological enthusiasm in AV adoption. It was confirmed that technological enthusiasm is one of the AV adoption factors that positively influences the attitude to AVs. The strength of this effect comes right after the perceived safety effect and is similar to the general concerns and social factors effects. Although it was originally planned to test technological enthusiasm as a mediator by indirectly influencing AV adoption through other adoption factors, since in some cases it could be considered as a mediator, RQ1 confirmed technological enthusiasm as a separate factor equal to any other adoption factor that affects AV adoption intention through attitude to AVs. It then became less relevant to test it as a mediator through all the other factors. Technological enthusiasm was accordingly confirmed as an individual adoption factor and it was not tested as initially planned.

6.3 Scientific contributions

Several theoretical contributions arise from the current study. First, the study confirms the influence of technological enthusiasm, general concerns, social factors, perceived benefits, and facilitating conditions on attitude to AVs, together with the effect of perceived safety and privacy concerns in the AV era effect through general concerns. A more welcoming attitude to AVs is further reflected in a stronger intention to adopt an AV, and the latter is also directly influenced by perceived safety and facilitating conditions. The proposed relationships were also empirically confirmed. The evidence supported the idea of people being affected by 'influencers'/'social influencers'. Especially in relation to novel controversial technologies that are altering established patterns of living and doing business, individuals are swayed by the opinions of others and this can shape their view on them and their willingness to adopt them. Despite the emphasis on safety given by car manufacturers, it remains one of the primary concerns in the adoption of AVs because it can either reduce concerns with AVs or directly play a role in adoption to determine the success or failure of AVs. Alongside car manufacturers, the government can facilitate the adoption of AVs by creating a supportive environment.

Second, the empirically supported relationships contribute to theory being tested on a specific segment of the population, namely the millennials generation, which is known to be one of the first to adopt smart and digital technologies, unlike previous research that typically looked at entire populations rather than just segments of them. Indeed, Asmussen et al. (2020, p. 19) emphasised the importance of distinguishing the various groups of AV adopters as they have different characteristics and therefore the approaches to bring AVs closer to them must vary. Millennials as one of the generational groups has demonstrably different characteristics and therefore understanding this specific market segment is the first step to making the technology more widely adopted. T. Zhang et al. (2020, p. 230) even suggested that marketing approaches should be tailored in consideration of distinct personality traits, and generations can in fact be distinguished by personality traits. Thus, the contribution made by this dissertation lies in more closely understanding one of the segments that will represent a significant share of AV adopters in the coming decades. In addition, the proposed model as well as methodological approach can be applied to other contexts and population segments.

The third contribution of this study is in distinguishing the different types of concerns and introducing attitude as a successor to other adoption factors, which is rare in the literature. Not many research papers separate the different types of concerns. This approach is similar to that of T. Zhang et al. (2019, p. 211), yet their model is not as extensive overall because they considered a narrower range of factors and the model also holds less explanatory power. From the early adoption models proposed (e.g., the TAM (Davis, 1985), the Theory of Reasoned Action (Fishbein & Ajzen, 1975), the Theory of Planned Behaviour (Azjen, 1980)), the research did not overly rely on the inclusion of attitude, even though Rondan-Cataluña et al. (2015, p. 798) reported that it can importantly affect the R^2 value of the model. It is therefore believed that the renewed attention to attitude is an important contribution that future research should keep in mind.

Fourth, the study highlights the importance of context-specific factors in adoption studies to achieve greater explanatory power of the model. The factors included cover both positive and negative aspects of AV adoption, and the proposed model is firmly established on previous technology adoption models. Fifth, the presented results show the need to distinguish between at least three types of stakeholders: consumers/potential adopters, government and similar authorities, and car manufacturers. Each of them plays their own role and it is necessary that they do not work in isolation but collaboratively. The sixth contribution of the dissertation is the focus on the most controversial level of AVs, i.e., level 5, which has been less extensively addressed according to the literature review by Nastjuk et al. (2020). Even though level-5 automation belongs to the more distant future, the findings of this dissertation can be incorporated into today's early-stage development such that in a few years there will be AVs that meet the desires and expectations of potential uses.

6.4 Practical contributions

At the same time, practical contributions include the examination of the factors of AV adoption in the population and by providing valuable information to car manufacturers, policymakers and investors alike concerning the perceptions and preferences of millennials. These stakeholders can apply the findings to identify and subsequently address problem areas that require further development to reduce the barriers to adoption and to help users feel safe and find the technology adoptable. The right approach should selectively focus on prioritised areas to help potential adopters shift their focus over to the positive aspects instead of the negative ones. Stakeholders should aim to capitalise on the positive attitude in the eyes of potential users, which can be formed through various adoption factors, as this will lead to a stronger adoption intention. Further, what is expected by certain stakeholders should not be overlooked. For example, governments are critical for providing the supporting infrastructure, as already demonstrated for electric vehicles, while car manufacturers are responsible for ensuring that the vehicles they bring to market adequately address potential adopters' concerns, especially safety ones. Even though privacy concerns were not as strong as safety perceptions, they are present among millennials and this means that car manufacturers must assure that personal data will not be used for purposes other than for what it is primary collected, e.g., vehicle coordination.

The cooperation of stakeholders could lead to greater success in ensuing that individuals' visions are realised, while harmonised legislation could establish the grounds for better communication between different stakeholders. Practitioners should also be aware of the importance of technological enthusiasm and social factors. The finding that more technologically enthusiastic individuals view the AV technology more positively clarifies who to target in the early-adoption stage. Technologically enthusiastic individuals could be a target group for marketers and become 'influencers'/'social influencers' for the further promotion of AV technology. In a world of social media, the effects of influential others should not be ignored since millennials, and younger people, increasingly rely on external opinions and try to imitate the behaviour they admire. Marketers must adjust their marketing activities accordingly. They could potentially get in touch with a few millennials they deem suitable for the role of an influencer and cooperatively design the approaches to attract others to follow the adoption process. It would make sense for future research to especially concentrate on the marketing aspects of AVs and determine who the influential others are in this case (e.g., family members, relatives, friends, social media influencers, local or global celebrities) and which marketing approach is the most effective (e.g., social media, word-of-mouth).

6.5 Limitations and further research

Finally, it is worth noting some other circumstances that could have affected the presented study. The COVID-19 pandemic only made it possible to conduct an online survey. While the latter offers many advantages over other data collection methods, it can introduce self-selection bias into the research process, which is acknowledged as a methodological limitation of the study. To mitigate this problem, future studies using a questionnaire should consider simple, systematic, stratified or cluster random sampling techniques. Respondents in surveys also tend to seek socially desirable answers. Despite all the precautions taken (e.g., ensuring anonymity, testing for common method bias), it still cannot be assured that the respondents answered the questions honestly and did not choose socially desirable answers or answers they believed that people in general would choose. Rather than addressing social desirability retrospectively, research could already be designed that minimises the possibility of socially desirable responses occurring. For example, Podsakoff and Organ (1986, pp. 537–538) suggest including social desirability measures in a questionnaire and examining the relationships between these measures and those of interest in the research. They also suggest that data could be collected in a combination of ways, e.g., in terms of time, location or media (Podsakoff & Organ, 1986, pp. 539–540), and in AV research this could be combining a survey questionnaire and experimental design.

The fact the study did not did not analyse a specific ownership situation may also be described as a limitation of this study. Since this was not clearly specified in the questionnaire, the respondents imagined the situation that was closest to them, which means that not all respondents necessarily held the same view, which could skew the results. However, once questions like for what purpose will AVs be used and what type of AV business models will permeate in society become clearer, future research will be able to focus on AV adoption from the perspective of different business models. As the entire research procedure and measurement items were reported, replication of the study is possible by considering different scenarios (e.g., private-shared AVs, AVs in public transport). It would be advisable that future research clearly specify the ownership scenario and make assumptions accordingly because different scenarios might bring different associations to respondents that may influence perceptions of the studied areas. Especially nowadays given the numerous initiatives on national levels and on the EU level to promote public transport, people's perceptions might be changing in response.

Further, the aim of the study was not to specifically address the before and during pandemic circumstances, but the timing of the pandemic's escalation and the period in which this study was conducted overlap somewhat. The pandemic began in early 2020 and peaked at different times in various countries, while the study was carried out in mid 2020, which could indirectly affect perceptions of AVs. Inter- and post-pandemic circumstances may have raised additional concerns regarding the affordability and ownership of AVs, with some equating AVs with shared AVs, others with private AVs, and thus their perceptions may have changed accordingly. At the same time, we must take the post-pandemic circumstances as a given and, as is often described, a 'new reality'. This means it is irrelevant to consider which kinds of responses may have been obtained had COVID-19 not emerged since it did happen, and even though the results may have been affected, it is indeed important to determine what kind of responses and perceptions potential adopters have today after the pandemic because it the current time that is the basis for decisions made for tomorrow.

Another limitation of the study is that it is based on a stated preference approach because of limited availability of fully AVs, but as soon as technology allows this will have to be upgraded to revealed preferences. For a similar reason, the model proposed in this dissertation only measured AV adoption intention but not actual adoption behaviour. Despite behavioural intention being commonly used as a predictor of actual behaviour, gaps still exist and this might limit the results of this study when drawing conclusions about actual behaviour. When sufficient resources are available in the future, research participants could be placed in a decision situation to choose between an autonomous and a conventional vehicle (e.g., an autonomous bus in public transport) in an actual environment (e.g., at a bus station). Data collection could take place in three phases. First, it could start with a questionnaire in which respondents would self-report their perceptions about the constructs studied in the present study, which could be gathered using the same measurement items applied herein. Second, a real drive in an AV on a racing track could be offered to gather data about actual behaviour. Even though this would not yield exactly the same results as in an open environment, the stage of technology development today will not allow AVs to be driven on public roads. The experiment would collect data on actual behaviour in order to test the relationship between behavioural intention, collected in the first phase, and actual behaviour, observed in the second phase. Third, participants should be asked immediately after the drive about their feelings during the journey. Finally, participants would reflect on the journey in a second questionnaire that would gather similar data as the first one, just at a different point in time in order to compare whether the perceptions changed after the drive and in which ways. Researchers should partner with car manufacturers whose cars are close to level-5 vehicles in order to confront the participants in the experiment with the highest level of autonomy. While the sample would probably be skewed to more technologically enthusiastic participants who would be unafraid to ride in an AV, but will be excited by the adventure of driving without a driver, the contribution would still be invaluable for both science and industry. So as to attract the attention of potential participants and lower their concerns to boost the likelihood of participation, AVs could be presented to them by drawing a parallel with autonomous solutions in public transport that are already seeing mass use. For example, Nürnberg was the first German city to introduce an automatic metro line already in 2008 (Railway Technology, 2008). Similarly, Hamburg launched the first autonomously-driven train that can perform all tasks itself in 2021, but the driver remained present in the driver's cabin for safety reasons during the introduction phase (Euronews, 2021). In both cases, it was Siemens that provided the means of transport (Euronews, 2021; Railway Technology, 2008). A similar initiative was also taken on roads when in Scotland an autonomous bus was introduced in 2023. The bus operates using sensors and artificial intelligence and is the first full-sized autonomous bus in the world (Frangoul, 2023). If individuals were made aware of solutions that already exist, yet may not have heard of, they would be more likely to agree to participate in the study.

As regards the sample in the present study, the literature led to the choice of millennials as early adopters. Still, the literature on this topic is not consistent in its conclusions and thus future research should engage different age groups and determine whether differences exist and in what direction they point. Moreover, despite assuring the representativeness of the sample, the latter was drawn from business school university students. All remedies suggested in the literature were used to mitigate this problem, although it could still have biased the results to some extent. It also important to note that drawing a sample from fields other than a business school could show different patterns and perceptions since students from other fields would possess different knowledge, experience and backgrounds, revealing a different perspective from which respondents would look at AVs. For example, in business schools AVs would be viewed mainly from the perspective of creating new business models, while more technical subjects (e.g., engineering) would tend to cover the technological aspects. The latter might have already learned about the safety features of AVs and perceive

AV safety accordingly – either positively or negatively, albeit differently than business school students. Further, business students might be more concerned with status gains than science students. Due to the different knowledge of students from other disciplines, the questionnaire might also need to be adjusted with emphases placed elsewhere in the questionnaire. Useful advice while compiling questionnaires for level-5 vehicles in the future is to look for parallels with existing technologies in the market when explaining the circumstances and questions, which could help respondents imagine a technology that is not yet fully developed and tangible when comparing it to something known. For example, the infrastructure aspect could be linked to the importance of establishing infrastructure for public transport or cycling routes in cities for well-functioning transport in the city, while incentive schemes could be explained through those established for electric vehicles.

Even though all of the proposed relationships in the model were statistically significant, a low path coefficient close to what Hair, Black, et al. (2019, p. 711) denoted as meaningless was found for the effect of facilitating conditions on AV adoption intention. Even though a significant relationship suggests the presence of an effect, future studies should look for answers for the low path coefficient as well as a deeper understanding of the role of facilitating conditions, especially the role of government as a facilitator. Another surprising result was the lower path coefficient between attitude to AVs and AV adoption intention compared to previous research, which should be tested in subsequent studies. An additional worthwhile direction for future research is a more person-to-person examination of privacy perceptions, e.g., focus groups, in order to discover more profound explanations of what makes privacy important.

Influences from an individual's surrounding social network might vary in different technology development stages, which offers opportunities for additional research. The development stages could be determined for the AV lifecycle and how social influences change over time from low to higher AV adoption rates could be investigated. Venkatesh and Davis (2000, p. 199) indeed established that the effect of social information fades over time, but the effect of social status remains. Since few people have a direct experience with AVs, it would also be expected that social recognition/status will become more relevant in later stages of adoption once people acquire more experience. This question warrants further investigation. Moreover, because social factors in the study is a fairly broad construct, it is suggested that future studies specifically focus on different nuances of the social factors and provide more in-depth implications for each. In addition, electric autonomous mobility can hold significant implications for the environment and the achievement of the environmental targets set by the EU and hence future research should study the perceptions of individuals with regard to the environmental consequences of AVs and determine how to present/market them in the most appealing way possible to attract additional adopters. Next, the role of AV manufacturers in sustainability measures could be explored along with how they can encourage potential users to develop a positive attitude to AVs, and facilitate AV adoption among them.

It is also necessary to point out the selection of the country for the study. It is believed that targeting Slovenia in the sample is not a limitation in itself. An EU-based study may even fill the gap in terms of the geographic coverage of research that is currently prevalent in the USA. On the other hand, while focusing on a single-country case study may be a limitation, the remainder of the paragraph justifies why this is of little concern. Moody et al. (2020, p. 640) found only small differences in perceptions of AV safety in a sample of 51 countries that could be attributed to the country level, with most of the differences attributable to individual characteristics. The presented study also offers the transferability of the methods as well as the proposed model. The latter could be tested and validated in other country settings to enable a comparison in terms of what cultural differences and differences in the level of development of countries mean for perceptions regarding AVs. Future studies could also replicate the proposed model in other specific market segments, i.e., by using a sample other than millennials. As the current literature mainly concentrates on the general population and does not separate different population groups, the study does this and the proposed model could be applied, for instance, to a sample of elderly people facing a decline in their cognitive/functional abilities, likely representing another group that may consider AVs as a mobility option to stay mobile. Future studies could also transfer the applied methodological approach combining a questionnaire and SEM to studies investigating other digital technologies in future smart cities or in the transportation industry to investigate perceptions and attitudes.

A single-country case study may be considered a limitation which reduces the generalisability of the results. Still, although the main focus of this dissertation was not on addressing the national and cultural differences it might be relevant to note these to put forward some avenues for future research. In recent years, AV adoption research has flourished, but has not spread very geographically. It has been observed that the biggest share of the literature is oriented to the US market and other major countries, e.g., larger European nations and China. On the other hand, smaller countries are studied less often even though they might face different difficulties implementing AVs on a wide scale. They are less densely populated, have smaller budgets to be dedicated to infrastructure development and providing incentives, and have higher rates of private vehicle ownership. For example, Slovenia has a growing number of privately owned vehicles and is above the EU average in this respect. A worthwhile direction for future research would be identifying the differences between variously-sized and differently-developed countries, especially European ones, in order to determine the challenges they are facing in the different stages. The findings would benefit the EU as it develops policies that will help countries progress in the field of autonomous driving.

On top of the presented ideas for future research, there are some future research directions that arise from observations of what the current literature lacks. The literature lacks studies taking account of the price value and affordability of AVs and willingness to pay for them. Liu, Guo, et al. (2019, p. 315) found that willingness to pay for an AV would be positively influenced by perceived benefits and trust in AVs, and negatively by perceived risk and perceived dread, while Rahimi et al. (2020, p. 16) found that willingness to pay for an AV would be positively influenced by pro-technology attitude and some socio-economic/demographic characteristics. Another study forecasted AV adoption based on different price reduction levels (Dubey et al., 2022, p. 16). Contrary to these, it would be interesting to look at the affordability issues from another perspective by considering price value as an independent variable and examining its effect on behavioural intention. It would also be valuable to consider each individual adoption factor alone and to examine it more closely. Another important contribution would come from clearly defining the relevant constructs under study as current studies examine constructs with similar names that vary in content, e.g., there is considerable confusion around the distinction between security, privacy and safety. Researchers are asked to clearly define the constructs they are examining at the beginning of their study and to consistently follow these definitions in their study. Establishing common ground is an important step in clarifying what we are talking about and for broadening the field. This could bring extra benefits in terms of understanding the aspects of prospective adopters and thereby contribute to further AV development. The factors studied, especially perceived safety as the most important factor, could benefit from a comprehensive literature review or meta-analysis to present the state of the art to understand how safety is evaluated by potential adopters.

It would further make sense to focus on different stakeholders separately and determine their role in supporting potential users and AV adoption in the market. One possible approach to exploring the roles of different stakeholders would be focus groups as they allow for different types of participants, each contributing their part. Namely, authors have emphasised the importance of different stakeholders cooperating to develop an effective legal regulatory framework, find the most effective incentive systems, redesign and build the necessary road infrastructure to name just a few, which indicates the value of a collaborative approach. Government is one relevant group that can be further subdivided into governmental authorities on the EU, national and municipal levels. For car manufacturers, we must distinguish between developers, designers, producers and testers, all of which may or may not be the same entity/company. Finally, end users/adopters are a group whose preferences and needs must be respected and should therefore also be part of the role determination. The roles of these stakeholders can only be identified specifically enough if this is done with all groups simultaneously rather than concurrently. At this point in time, they might see their roles contradictorily, transferring rather than accepting responsibilities and thus not fully covering the issues that need to be discussed and resolved. By conducting a focus group, participants would have a discussion in real time and it would be possible to detect where understanding between different groups is not on the same level and to reach a consensus on the topics being studied. Since a focus group also has a moderator, the latter can moderate the discussion so that no issues are overlooked/neglected. For a successful focus group, a clear goal should be defined, which in this case would be to clarify the roles of stakeholders, and the right participants selected. Participants should be representative of the group they are standing in for and motivated to reach a common conclusion. Among end users, it would make sense to select people who are technologically enthusiastic about the topic and are interested in driving the development forward. Nevertheless, a representative from the group who is less open to AVs should be selected as their contribution could be valuable for understanding what is holding them back from being more open to AVs and they might accordingly also view the stakeholder role differently. From the car manufacturers group, companies that are leaders and have a strong vision should be selected and, in terms of personnel in these companies, it is necessary to select individuals who have the power to make decisions so that they can disseminate ideas and make them a reality. Similarly, the government group should include visionary and influential individuals. Two to three participants per group should be engaged.

Research should also distinguish between drivers and passengers and gather a diverse sample age-wise to enable the direct comparison of results of two extreme groups, e.g., generation Z as the youngest people and elders as the oldest people to hold a driver's licence, to discover the actual existence/absence of differences. Here, it should be noted that older people require different research methods to ensure quality data. For example, they are less skilled at filling in an online questionnaire and might have less knowledge of AVs and would thus need additional explanations which could be visual (e.g., a video) or practical (e.g., a demonstration drive). Another related direction for further research would be to delve deeper into experiencing AVs first-hand in terms of experiments and to explore the post-pandemic circumstances to identify which perceptions of AVs may have changed due to the pandemic. Future studies should also apply more in-depth, open-ended methods in order to identify areas that recent research may have overlooked but could be helpful in closing the gap between potential adopters and the actual introduction of fully AVs on our roads. Next, it is advisable to dedicate a study specifically to incentive schemes for AVs with a view to discovering what potential adopters want, what they expect, and what would bring them the greatest benefits. Finally, it has been observed that the literature is relatively more modest when it comes to the use of AVs for delivering goods than personal transport, which could be deepened by future research. Private vehicles generally spend most of their time idle and if AVs are privately owned, this will also be the case with them. Alternatively, private AVs could be used for, but limited to, autonomous goods delivery or as a delivery solution for delivering necessities to the elderly. Possibilities and perceptions concerning this should be researched in greater depth, where the general constructs from this study could be used as a basis.

All in all, it was shown that AV adoption research has significantly progressed. Many adoption models have been proposed that looked at adoption from different perspectives and incorporated a wide range of adoption factors. The field in the future would benefit the most by shifting to more specific adoption areas and several ideas concerning this were given. The focus of the study was primarily on the consumer perspective, but a worthwhile direction for future research would be to clearly identify the role of each stakeholder group to ensure they are playing their part. Based on the results, the AV adoption factors were divided into three groups of stakeholders. While much research focuses on the consumer perspective, the roles of government and manufacturers are less extensively addressed. Although they should cooperate, each stakeholder still has a distinct role that would have to be clearly identified in order to determine the responsibilities that will enable a more comprehensive approach to the development of all relevant areas.

CONCLUSION

The focus of this dissertation was on empirically testing AV adoption factors among millennials. It first shed light on the emerging AV technology by presenting its development, benefits and challenges. Even though the technology is highly developed, its testing is limited and acceptance levels uncertain. Further, a bigger share of research is focused on the technological aspects instead of the consumer aspects. The contribution made by this dissertation concerns exactly the latter – understanding the perceptions of and attitudes to AVs held by potential consumers/adopters. A specific market segment, i.e., millennials, was focussed on, as it has been characterised as open to technology and presumably among early AV adopters. A sample of 359 millennials was drawn from business school university students and the data were collected with a questionnaire through the open-source application 1KA between June and September 2020. A questionnaire was developed for the purpose of analysis and its measurement items were adapted from the literature. The aim was to collect data in order to empirically test the proposed AV adoption model containing the following AV adoption factors: perceived safety, privacy concerns in the AV era, general concerns, technological enthusiasm, perceived benefits, social factors, and facilitating conditions, that affect one of the three dependent variables: the general concerns, attitude to AVs and/or AV adoption intention. After assessing the measurement model and the model fit, all 10 hypotheses were confirmed, thereby providing an important contribution to science as well as implications for car manufacturers, policymakers and investors. The proposed model explained 67% of variance in attitude to AVs and 73% in AV adoption intention, which is at the upper end compared to other adoption models. Moreover, the adoption factors included cover both encouraging as well as discouraging adoption factors, and the factors could be further divided into groups by stakeholder, i.e., consumers/potential adopters, government and similar authorities, and car manufacturers, where each has their own role but in any event must mutually cooperate rather than work in isolation.

The importance of safety still trumps other factors in its ability to reduce general concerns and directly influence AV adoption. There are also privacy concerns, that are less worrisome than safety ones, but also affect general concerns. This means car manufacturers should continue to prioritise safety, present their actual safety features, and through tests potentially demonstrate them to confirm that AVs are equal to, if not better than, human-operated vehicles. Further, they should avoid negative wording in their public communications. As regards privacy, millennials might feel protected by the GDPR or be completely unaware of what they are sharing. It would accordingly make sense to increase the awareness about privacy among users, not only AVs but in general services/products that in any way touch on privacy. Further research about how privacy concerns are formed and what raises them would also be beneficial. General concerns, technological enthusiasm and social factors affect attitude to AVs to a similar extent. It was confirmed that social factors and technological enthusiasm positively affect attitude to AVs, in turn suggesting who the initial target market of marketers should be – technologically enthusiastic highly-respected/influential millennials. Since millennials are digital natives, they should be primarily targeted via electronic sources, e.g., social media. Perceived benefits were slightly less important for contributing to a positive attitude to AVs. To increase the awareness of benefits and showcase measures taken to assure safe driving and reduce concerns, car manufacturers should offer test and demonstration drives, especially in risky weather conditions, e.g., icy surfaces or heavy rain. A more positive attitude to AVs might also be formed by an appropriate supportive environment considering that facilitating conditions were positively significant. A similar approach with incentives as for electric vehicles could be taken. Future research should specifically study the incentive schemes in the AV field. Next, governments are chiefly responsible for regulatory frameworks where they should cooperate with different stakeholders. According to the presented results, attitude to AVs depends on a wider range of factors and considering that a negative attitude is not easily persuaded to the contrary, car manufacturers should work on forming a positive attitude from the beginning. Finally, a stronger AV adoption intention will be realised in the case of a positive attitude to AVs, better facilitating conditions, and a higher perception of safety.

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APPENDICES

Appendix 1: Summary in Slovenian language / Daljši povzetek disertacije v slovenskem jeziku

ANALIZA DEJAVNIKOV PRIVZEMANJA AVTONOMNIH VOZIL MED MILENIJCI

Raziskovalni problem in raziskovalno področje

Avtonomna prihodnost naj bi bila neizogibna; ni pa še jasno, v kakšni obliki, kdaj in kako se bo uresničila. V zadnjih letih se v pogovorih o transportni industriji in v povezavi z mobilnostjo večkrat srečamo s tematiko avtonomne vožnje, ki obljublja revolucijo, primerljivo s prehodom od konjskih vpreg do vozil na motor z notranjim izgorevanjem na začetku 20. stoletja. Hitrost tehnološkega napredka že omogoča popolnoma avtonomno vožnjo, preden pa bodo avtonomna vozila (v nadaljevanju: AV) množično prisotna na naših cestah, morajo biti rešene številne dileme, med katerimi je tudi razumevanje končnih uporabnikov/posvojiteljev AV. AV so vozila, ki imajo določeno stopnjo avtomatizacije in ta, ali nadomešča človeka ali mu pomaga med vožnjo (Narayanan in drugi, 2020, str. 1). AV bodo bistveno spremenila tako transportno industrijo kot vsakdanje življenje (Shabanpour in drugi, 2018, str. 463–464) in so definirani na 6. ravneh od stopnje 0, kjer avtomatizacije ni, do stopnje 5, ki pomeni popolnoma avtonomno vožnjo, kjer AV lahko opravlja vse vozne funkcije, ki bi jih primarno opravljal voznik. Slednji postane sopotnik, ali pa sploh ni prisoten v vozilu (SAE International, 2018, str. 4, 33). Vmesne ravni avtonomije med 0 in 5 vključujejo tehnologije, ki vozniku pomagajo pri vožnji, ali pa aktivnost prevzamejo od njega, s tem da mora biti voznik prisoten in pripravljen prevzeti nadzor v določenih situacijah (Payre in drugi, 2014, str. 253). Nekatere tehnologije so dandanes že v uporabi. Uveljavljeni proizvajalci avtomobilov in podjetja, ki v panogo vstopajo na novo, se poskušajo pozicionirati na trgu AV (International Transport Forum, 2015, str. 13; Skeete, 2018, str. 28) in čeprav delujejo predvsem kot konkurenti, bi lahko veliko koristi in sinergij prinesla sodelovanje in partnerstva (Heineke in drugi, 2017, str. 8). Predmet te disertacije so AV 5. stopnje po SAE International (National Highway Traffic Safety Administration, 2016, str. 9), kar je najbolj oddaljen in kontroverzen pojav, ki pri večini ljudi sproža največ pomislekov, zato je treba temeljito preučiti in razumeti dejavnike, ki vplivajo na privzemanje AV med potencialnimi uporabniki, saj je od tega lahko odvisna uspešnost razširitve AV na trgu (Nastjuk in drugi, 2020, str. 2; Payre in drugi, 2014, str. 253). Howard in Dai (2014, str. 8) sta leta 2014 navajala, da ni jasno, kako se bodo AV razvila, in tudi danes še ni jasno, kateri tipi poslovnih modelov vozil bodo preplavili trg, npr. lastniška, javna, deljena, zato ta disertacija zavzema podobno stališče kot Nastjuk in drugi (2020, str. 2) z osredotočenjem na splošno sprejemanje AV in ne na določen scenarij lastništva, da bi najprej razumeli osnovne dejavnike vplivanja, ki jih je nato mogoče uporabiti za specifične scenarije.

Debate okrog AV se predvsem dotikajo področja potencialnih koristi, ena izmed njih je varnost (Deb in drugi, 2017, str. 179; Xu in drugi, 2018, str. 321). Čeprav literatura kaže na obe smeri, tj. povečanje ali zmanjšanje varnosti na cestah, so Nascimente in drugi (2019, str.

4931) v nedavnem pregledu literature ugotovili, da je 81 % člankov, vključenih v pregled, poročalo o povečani varnosti zaradi umetne inteligence, implementirane v AV. Zmanjšanje konfliktov na cestah bi lahko znašalo od 12 % do skoraj popolne odprave, odvisno od deleža AV na cestah (Papadoulis in drugi, 2019, str. 19; Virdi in drugi, 2019, str. 107). Obljubljena in prikazana varnost pa ni nujno enaka zaznani varnosti, ki jo oblikujejo potencialni uporabniki v svojih mislih. Ugotovljeno je bilo na primer, da bi posamezniki potrebovali vsaj dve leti od uvedbe AV, da bi začeli razmišljati o njihovi uporabi (Othman, 2021, str. 357) in zagotovitev od štiri- do petkrat manjšega tveganja v AV, da bi jih sprejeli v podobnem obsegu kot obstoječa vozila, ki jih upravlja človek (Liu, Yang in drugi, 2019a, str. 320–321). Skladno s tem lahko varnost spodbuja ali zavira sprejemanje AV. Druge prednosti, ki bi lahko prepričale potencialne posvojitelje za privzemanje, so: manjša gneča in potreba po parkiriščih, manjši vpliv na okolje, učinkovitejša uporaba časa v vozilu, večja mobilnost starejših in otrok ter krajši potovalni časi (Ercan in drugi, 2022, str. 14; Y.-C. Lee in Mirman, 2018, str. 416; Stager in drugi, 2018, str. 134; Wadud in drugi, 2016, str. 5; Yang in Coughlin, 2014, str. 333). Po drugi strani pa pomisleki potencialnih posvojiteljev izhajajo iz pravnih vprašanj, hekerskih napadov, vprašljive varnosti, nepričakovanih prometnih situacij, vprašljive odgovornosti v primeru nesreč, okvare opreme ali sistema ter povečane odvisnosti od tehnologije in strojev (Bansal in drugi, 2016, str. 3; Hulse in drugi, 2018, str. 9; M. König & Neumayr, 2017, str. 43, 48; Kyriakidis in drugi, 2015, str. 136). Nezanemarljivi so tudi pomisleki glede zasebnosti, saj se z izmenjavo podatkov, ki je potrebna za komunikacijo in koordinacijo vozil, deli veliko osebnih podatkov, zato je treba zagotoviti, da se podatki ne uporabljajo na nepooblaščen način, proti uporabnikom ali s strani hekerjev (Jadaan in drugi, 2017, str. 642–643; Le in drugi, 2018, str. 18; T. Zhang in drugi, 2019, str. 211).

Podobno kot varnost imata tudi zakonodaja in infrastruktura lahko pozitiven ali negativen vpliv na potencialne posvojitelje. Če je varnost zagotovljena/prisotna, bo to podporni mehanizem za posvojitev, v primeru njene odsotnosti pa bo sprejemanje postavljeno pod vprašaj. Za več jasnosti je ključnega pomena ustrezen, popoln in podporen zakonodajni okvir, ki bo omogočil uvedbo AV ter omejevanje negativnih stranskih učinkov uvedbe, npr. povišanje prevoženih kilometrov (Duranton, 2016, str. 194; S. H. Kim in drugi, 2020, str. 1; Wadud in drugi, 2016, str. 12). Vseeno pa regulativne spremembe nenehno zaostajajo za tehnološkim napredkom (Juhasz, 2018, str. 47–48), opazna pa je tudi razlika med Združenimi državami Amerike in Evropo, pri čemer je Evropa izrazito zadaj (Punev, 2020, str. 96). Pri oblikovanju zakonodaje se je treba odločiti tudi glede standardizacije in enotnosti politik, o ponujanju spodbud in o drugih primerljivih vprašanjih. Ni jasno niti, ali naj zakonodajo AV ločujemo od tiste ali združujemo s tisto, ki se nanaša na vozila s človeškim voznikom (International Transport Forum, 2015, str. 26–27; Medina-Tapia & Robusté, 2018, str. 210; Skeete, 2018, str. 28). V povezavi z infrastrukturo obstaja potreba po preoblikovanju obstoječe cestne infrastrukture, da se omogoči udeležba v cestnem prometu vsem uporabnikom cest, vključno s kolesarji in pešci (Narayanan in drugi, 2020, str. 26; Rouse in drugi, 2018, str. 14). Ključno bo tudi določiti odgovornosti v primeru nesreč, kar odpira problematična etična vprašanja glede tega, čigavo življenje rešiti v primerih, ko je ogroženo več kot eno živo bitje (Fleetwood, 2017, str. 534; Hulse in drugi, 2018, str. 2).

Zaznana varnost je eden najpomembnejših dejavnikov, ki jih posamezniki tehtajo, ko se odločajo za uporabo AV ali proti njej (Osswald in drugi, 2012, str. 55). Pozitivno dojemanje varnosti je lahko gonilo sprejetja AV (Montoro in drugi, 2019, str. 869; Moody in drugi, 2020, str. 643), po drugi strani pa bi zaznava višjega tveganja negativno vplivala na namero za sprejetje AV (Meidute-Kavaliauskiene in drugi, 2021, str. 14). Nižji, vendar še vedno prisotni, so pomisleki v zvezi z zasebnostjo (Kyriakidis in drugi, 2015, str. 133), odsotnost zasebnosti in varnosti pa lahko privede do nižjega sprejemanja AV pri potrošnikih (Raj in drugi, 2020, str. 132; Waung in drugi, 2021, str. 336). Med dejavniki, ki vplivajo na sprejemanje, so avtorji raziskovali tudi tehnološko navdušenje. Prejšnje raziskave so pokazale, da bodo bolj tehnično podkovani/navdušeni posamezniki prej dali priložnost AV (Asmussen in drugi, 2020, str. 7; Tennant in drugi, 2019, str. 108). Posamezniki so lahko tudi navdušeni nad potencialnimi koristmi, ki jih prinašajo AV, kar bo pozitivno vplivalo na njihov odnos do AV in namero za privzem AV (Herrenkind in drugi, 2019, str. 15; Nastjuk in drugi, 2020, str. 10). Nadalje bi odnos do AV lahko obrnili na pozitivnejšega, če bi bili posamezniki pod vplivom oseb, ki so jim pomembne, npr. družine ali prijateljev (T. Zhang in drugi, 2020, str. 223). Herrenkind in drugi (2019, str. 15) so potrdili, da na odnos do avtonomno vodenih javnih avtobusov pozitivno vplivajo tudi socialna omrežja, zato bi lahko med »pomembne druge« šteli še vplivneže s socialnih omrežij. To je le nekaj možnih vplivov, ko posamezniki tehtajo, ali so AV bolj naklonjeni ali so proti. Dejavniki privzemanja v literaturi niso enotno razumljeni, vendar pa je to glavna nejasnost, ki jo je treba rešiti, preden se lahko AV široko uveljavijo na trgu. Razumevanje sprejemanja končnih uporabnikov in njihovega dojemanja o različnih vidikih AV je ključnega pomena za iskanje načinov, kako jim približati AV, k čemur prispeva ta disertacija.

Pomen in cilji raziskave

Zgodnje AV raziskave so se večinoma osredotočale na tehnološki vidik. Pregled literature, ki sta ga opravila Rosenzweig in Bartl (2015, str. 9), je ugotovil, da se več kot 90 % člankov osredotoča na tehnološki vidik AV, medtem ko se le zanemarljivih 1,3 % osredotoča na vidik privzemanja in vedenja potencialnih uporabnikov. V zadnjih letih se je zavedanje glede pomena slednjega izboljšalo in vse več raziskav preučuje vedenjske vidike in vidike, ki so osredotočeni na potrošnika, da bi poglobili razumevanje potrošniškega dojemanja AV. Če potencialni uporabniki namreč niso naklonjeni uporabi razpoložljive tehnologije, bodo stopnje privzemanja nizke, koristi, ki se ponujajo kot rezultat uvedbe AV, pa ne bo mogoče uresničiti, vsaj ne v polni meri (Asmussen in drugi, 2020, str. 2). To nakazuje, da je treba preučiti odnos in stališče potencialnih posvojiteljev do privzemanja AV (Ruggeri in drugi, 2018, str. 40), da bomo razumeli, kaj vpliva na sprejemanje, kako se boriti proti pomislekom in kam vlagati za nadaljnji razvoj (Haboucha in drugi, 2017, str. 38; Osswald in drugi, 2012, str. 57). Globlje kot bo razumevanje, lažje bodo dotični deležniki sodelovali pri uresničevanju vizij množice, da se razvoj premika v smeri, ki jo prihodnji uporabniki želijo. Predhodni avtorji (npr. Asmussen in drugi, 2020, str. 19) so nadalje poudarili, da je raziskovanje nujno po različnih demografskih skupinah, npr. starosti, saj se njihovi vzorci vožnje in potrošnje razlikujejo. Prispevek disertacije je na obeh omenjenih področjih, in sicer, da s preučevanjem dejavnikov privzemanja AV prispeva k razumevanju specifične demografske skupine, tj. milenijcev, ki so ena izmed skupin na trgu, ki bo v prihodnje privzemala AV. Milenijci se pogosto pojmujejo kot zgodnji posvojitelji novih tehnologij, prav tako pa trenutno predstavljajo največji delež delovno aktivnega prebivalstva. Predstavljajo generacijo, rojeno med letoma 1981 in 2000, ki je bolj seznanjena s sodobnimi tehnologijami kot katera koli prejšnja generacija, odprta za spremembe in usmerjena v sledenje najnovejšim trendom (Bolton in drugi, 2013, str. 246; Brosdahl & Carpenter, 2011, str. 549; Ordun, 2015, str. 42, 44). Milenijce so že prepoznali med zgodnjimi uporabniki storitev skupne mobilnosti (Azimi in drugi, 2021, str. 2), kar upravičuje izbor raziskovalnega vzorca.

Cilj te disertacije je identificirati pomembne dejavnike sprejemanja AV pri milenijcih in jih vključiti v model sprejemanja AV ter odgovoriti na naslednja tri raziskovalna vprašanja:

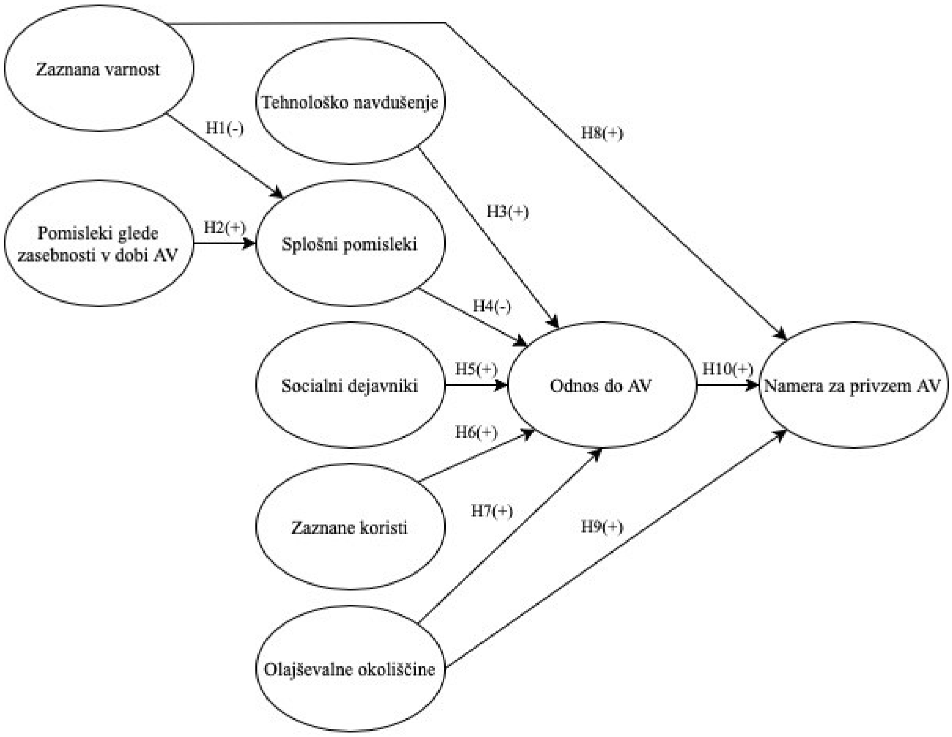
- RV1. Kateri dejavniki vplivajo na pripravljenost milenijcev za privzemanje AV?
- RV2. Ali družbeni dejavniki in pomisleki glede zasebnosti v dobi avtonomnosti vplivajo na pripravljenost na privzemanje AV med milenijci?
- RV3. Kakšen je učinek tehnološkega navdušenja pri privzemanju AV med milenijci?

Prvo raziskovalno vprašanje (RV1) izhaja iz potrebe po opredelitvi dejavnikov privzemanja tehnologije AV, saj so jo mnogi raziskovalci izpostavili kot ključno za uspeh na trgu in spremembo transportne industrije ter mobilnosti (Liu, Guo, in drugi, 2019, str. 306–307; Nastjuk in drugi, 2020, str. 2). Prvi korak raziskave bo raziskovalne narave, da identificiramo vplivne dejavnike privzemanja AV iz literature in empirično testiramo predlagane povezave. Glede na to, da je razvoj modela privzemanja tehnologije ponavljajoč se proces (Osswald in drugi, 2012, str. 58), bomo v drugem koraku model nadgradili s spremembo začetnega modela. Odstranili bomo statistično neznačilne dejavnike in vključili dodatne dejavnike, in sicer dejavnike, specifične za preučevano raziskovalno področje AV, in dejavnike, ki izvirajo iz široko uveljavljenih modelov sprejemanja, tj. modela sprejemanja tehnologije (v nadaljevanju: TAM) in enotne teorije sprejemanja in uporabe tehnologije 2 (v nadaljevanju: UTAUT2). Od dejavnikov bomo vključili podporne okoliščine, pomisleke glede zasebnosti v dobi AV in družbene dejavnike. Ti so se izkazali za pomembne v literaturi po testiranju modela v prvem koraku raziskave. Glede na izpopolnjen model, ki bo predlagani model privzemanja AV te disertacije, bo drugo (RV2) in tretje raziskovalno vprašanje (RV3) iskalo odgovor na to, kakšna je vloga naslednjih treh specifičnih dejavnikov: tehnološkega navdušenja, družbenih dejavnikov in pomislekov glede zasebnosti v dobi AV, v procesu sprejemanja AV. Rezultati disertacije bodo pripomogli k razumevanju dojemanja milenijcev in njihovega odnosa do AV, kar bo prineslo pomembne ugotovitve za proizvajalce avtomobilov, oblikovalce politik in vlagatelje v njihovih razmišljanjih in prizadevanjih glede prihodnosti AV.

Metodologija in analize

V disertaciji sta bili uporabljeni dve primarni raziskovalni metodi, in sicer pregled literature ter anketni vprašalnik. Pregled literature smo uporabili za pridobitev vpogleda v preučevano področje, kar je omogočilo razvoj modela privzemanja AV in pripravo vprašalnika. Dejavnike privzemanja, ki smo jih vključili v model, smo izpeljali iz obstoječe literature in zajemajo tako spodbudne kot odvračajoče vidike preučevanega področja, kot priporočajo avtorji (Davis, 1985, str. 133; Huang & Qian, 2021, str. 684). Predlagani model smo zastavili na trdno uveljavljenih modelih sprejemanja, tj. TAM in UTAUT2, iz katerih smo upoštevali naslednje konstrukte/dejavnike: zaznana uporabnost/pričakovana izvedba, odnos do uporabe, podporne okoliščine, družbeni vpliv in vedenjske namere, prilagojene AV kontekstu, saj so avtorji poudarili pomen upoštevanja kontekstualnih dejavnikov obravnavane tehnologije, ko se preučuje privzemanje slednje (Dwivedi in drugi, 2019, str. 719; Kapser & Abdelrahman, 2020, str. 220). Poleg tega smo v model dodali specifične dejavnike, ki so pomembni le za AV-je, in sicer zaznano varnost, pomisleke glede zasebnosti v dobi AV, splošne pomisleke in tehnološko navdušenje. Postavili smo 10 hipotez, ki smo jih empirično testirali z uporabo modeliranja strukturnih enačb. Predlagani model je skupaj s povezavami med dejavniki (hipotezami) predstavljen na sliki 1.

Slika 1: Predlagani model privzemanja AV



Vir: Lastno delo.

Vprašalnik smo pripravili posebej za raziskovalni namen in je temeljil na merskih lestvicah iz obstoječe literature. Poleg demografskih vprašanj in vprašanj za pridobivanje vpogleda v splošno mnenje glede AV so se glavna področja vprašalnika nanašala na odnos do tehnologij, izzive v povezavi z AV, skrbi glede AV, varnost AV, prednosti AV in zasebnost v AV. Anketirancem smo zagotovili anonimnost in vključili tudi definicijo AV ter pojasnilo glede stopenj avtonomnosti, da bi se izognili napačni razlagi vsebine in vprašanj s strani udeležencev. Raziskavo smo izpeljali med junijem in septembrom 2020 ter v vzorec zajeli 359 milenijcev na univerzitetni poslovni šoli. V statističnem orodju IBM SPSS – različica 25 (IBM Corp., 2017) smo zbrane podatke pregledali, prečistili in opisno analizirali. Izvedli smo test multikolinearnosti, test normalnosti in test variance skupne metode. Vrednosti faktorjev inflacije variance za vse kombinacije spremenljivk po konstruktih in za model kot celoto so bile pod 3,3, kar nakazuje na odsotnost multikolinearnosti (Kock & Lynn, 2012, p. 552). Test normalnosti je pokazal zmerno nenormalno porazdelitev z vrednostmi asimetričnosti med -1 in +1 ter vrednostmi sploščenosti med -1,5 in +1,5 (Hau & Marsh, 2004, str. 331), česar nismo videli kot problematično, saj sta Hau in Marsh (2004, str. 343–344) ugotovila, da v primeru uporabe metode največjega verjetja to ne vpliva bistveno na rezultate. Harmanov enofaktorski test je potrdil odsotnost variance skupne metode, saj je pri uvedbi novega skupnega faktorja, na katerega smo vezali vseh 33 spremenljivk, faktor pojasnil zgolj 31 % variance, problematična meja pa je 50 % (Podsakoff in drugi, 2003, str. 889). V programskem orodju LISREL – različica 8.8 (Jöreskog & Sörbom, 2006) smo ocenili merski model in prileganje modela z analizo fit indeksov, nato pa testirali strukturni model z uporabo metode modeliranja strukturnih enačb. Rezultati merskega modela so pokazali, da so naši merski elementi ustrezni, tj. zanesljivi in veljavni. Upoštevali smo nasvet Nunnallyja (1975, str. 11), ki pravi, da moramo za ustreznejšo oceno uporabiti različne kriterije. Vrednosti koeficientov Cronbach's alpha za vse konstrukte so bile med 0,70 in 0,90 (Nunnally, 1975, str. 10; Streiner, 2003, str. 5). Vrednosti kompozitne zanesljivosti vseh konstruktov so bile nad 0,60 (Bagozzi & Yi, v Diamantopoulos & Siguaw, 2000, str. 91). Vrednosti povprečno izračunanih varianc vseh konstruktov so bile nad 0,50, kar pomeni, da je delež pojasnjene variabilnosti v preučevanem konstruktu višji kot njegova merska napaka (Diamantopoulos & Siguaw, 2000, str. 91; Fornell & Larcker, 1981, str. 46). Faktorske uteži vseh razen dveh merskih elementov so bile nad 0,60 in se ena od druge po konstruktih niso preveč razlikovale (MacCallum in drugi, 1999, str. 96), pri faktorjih tehnološko navdušenje in socialni dejavniki pa smo po en merski element izločili. Diskriminantno veljavnost smo potrdili s kriterijem Fornell-Larcker, ki pravi, da morajo biti verjetnosti korenjene povprečno izračunane variance višje od korelacij za vsak par spremenljivk. Analiza fit indeksov je pokazala, da je večina indeksov modela blizu ali znotraj postavljenih restriktivnih mej. Vrednosti indeksov so bile naslednje (v oklepaju je zapisana restriktivna meja, upoštevajoč avtorje Hooper in drugi (2007, str. 10), Hu in Bentler (1999, str. 27), Schreiber in drugi (2006, str. 330) in Schumacker in Lomax (2012, str. 76)): χ^2/stopinje prostosti = 1,75 (pod 2,00 ali 3,00); GFI = 0,88 (blizu 0,90 ali 0,95); AGFI = 0,85 (blizu 0,90 ali 0,95); RMR = 0,05 (čim bližje 0); SRMR = 0,05 (pod 0,05 ali 0,08); RMSEA = 0,05 (pod 0,05-0,08); NFI = 0,96 (blizu 0,90 ali 0,95); CFI = 0,98 (nad 0,95); AIC = 1.002,27 (čim nižja vrednost). Pri testiranju strukturnega modela smo vseh 10 predhodno postavljenih hipotez potrdili, rezultate interpretirali in na njihovi osnovi podali priporočila ključnim deležnikom transportne industrije, kar je predstavljeno v naslednjem razdelku.

Glavne ugotovitve

Ugotovili smo, da pomen varnosti še vedno prevlada nad drugimi dejavniki v njeni zmožnosti zmanjšanja splošnih skrbi in neposrednega vpliva na pripravljenost na privzem AV. Zaznati je tudi pomisleke glede zasebnosti, ki so manj zaskrbljujoči kot varnost, a prav tako vplivajo na splošne skrbi. Proizvajalci avtomobilov bi morali še naprej dajati prednost varnosti, predstavljati implementirane varnostne funkcije in s testi potrditi, da so AV enaki, če ne boljši od vozil s človekom za volanom. Kar zadeva zasebnost, se milenijci morda počutijo zaščitene z GDPR, ali pa se premalo zavedajo, kaj ob uporabi AV (ali drugih digitalnih tehnologij in pri udejstvovanju v spletnih aktivnostih) delijo, zato bi bilo koristno povečati zavedanje o zasebnosti med uporabniki, ne samo AV, temveč v splošnih storitvah/izdelkih, ki se kakor koli dotikajo zasebnosti. Koristne bi bile nadaljnje raziskave o vidiku zasebnosti – zakaj je manj pomemben, kakšen je mentalni proces tvorjenja skrbi glede zasebnosti ter kaj jih povzroča. Splošne skrbi, tehnološko navdušenje in družbeni dejavniki v podobni meri vplivajo na odnos do AV. Potrdili smo, da družbeni dejavniki in tehnološko navdušenje pozitivno vplivata na odnos do AV, kar lahko pomaga identificirati ciljni trg tržnikov v zgodnjih fazah – to so tehnološko navdušeni visoko cenjeni/vplivni milenijci. Zaznane koristi imajo nekoliko manjši pomen za pozitiven odnos do AV. Da bi povečali ozaveščenost o prednostih in uporabljenih ukrepih za zagotavljanje varnosti ter zmanjšanje skrbi, bi morali proizvajalci avtomobilov ponuditi testne in predstavitvene vožnje, zlasti v tveganih vremenskih razmerah, npr. ledeno cestišče ali močan dež. Bolj pozitiven odnos do AV lahko oblikuje tudi ustrezno podporno/olajševalno okolje, zato bi lahko bil za povečanje privzemanja AV uporabljen podoben pristop s (finančnimi) spodbudami kot za električna vozila. Vlade morajo znaten delež svoje vloge odigrati tudi pri prizadevanjih za razvoj regulativnih okvirov, kjer bi morale sodelovati z različnimi deležniki. Rezultati so pokazali, da je odnos do AV odvisen od širšega nabora dejavnikov in upoštevajoč dejstvo, da negativnega odnosa ni enostavno spreobrniti v nasprotno, bi si morali proizvajalci avtomobilov že od samega začetka prizadevati za ustvarjanje pozitivnega odnosa v miselnosti milenijcev, saj ta poleg boljših olajševalnih pogojev in višje zaznane varnosti vpliva na namero za privzem AV.

Znanstveni in praktični prispevek

Prispevek disertacije znanosti je na več področjih. Prvič, disertacija potrjuje vpliv tehnološkega navdušenja, splošnih pomislekov, družbenih dejavnikov, zaznanih koristi in olajševalnih okoliščin na odnos do AV, skupaj z učinkom zaznane varnosti in pomislekov glede zasebnosti prek splošnih pomislekov. Bolj pozitiven odnos do AV se nadalje odraža v večji nameri za privzem AV, na slednjega pa neposredno vplivajo tudi zaznana varnost in olajševalne okoliščine. Predlagane povezave so bile empirično potrjene in rezultati podpirajo idejo, da na ljudi vplivajo "vplivneži/družbeni vplivneži". Ljudje se lahko zanašajo na mnenja drugih, še posebej pri novih kontroverznih tehnologijah, ki spreminjajo ustaljene vzorce življenja in poslovanja, zato lahko mnenja drugih ljudi prispevajo k spreminjanju posameznikovega pogleda na AV in s tem na njegovo pripravljenost, da jih sprejmejo. Kljub poudarku varnosti, ki ga dajejo proizvajalci avtomobilov, ta ostaja- ena izmed glavnih skrbi pri uvajanju AV, saj lahko bodisi zmanjša pomisleke glede AV bodisi igra neposredno vlogo pri milenijcih, ko se odločajo o privzemanju AV. Od tega bo odvisen tudi uspeh ali neuspeh množične razširjenosti AV. Poleg proizvajalcev avtomobilov lahko k izboljšanju sprejemanja AV pripomore tudi vlada, in sicer z ustreznim podpornim okoljem, npr. zakonodajni okvir in/ali spodbude.

Drugič, empirično podprte povezave med dejavniki (hipotezami) imajo teoretičen prispevek, testiran na specifičnem segmentu populacije, tj. na generaciji milenijcev, za katero je znano, da je ena prvih, ki sprejema pametne in digitalne tehnologije. To je dodana vrednost glede na predhodne raziskave, ki običajno obravnavajo celotno populacijo namesto njenih segmentov. Asmussen in drugi (2020, str. 19) so poudarili, da je ločevanje med različnimi skupinami posvojiteljev AV ključno, da izberemo ustrezne pristope, kako vsaki izmed njih približati AV. Milenijci imajo kot ena izmed generacijskih skupin očitno drugačne značilnosti, zato je razumevanje tega specifičnega tržnega segmenta prvi korak k širši uporabi tehnologije, prispevek te disertacije pa je v natančnejšem razumevanju enega od segmentov, ki bo v naslednjih desetletjih predstavljal pomemben delež uporabnikov AV. Poleg tega sta predlagani model in metodološki pristop uporabna tudi v drugih kontekstih in segmentih prebivalstva in upoštevajoč, da smo v disertaciji natančno poročali o procesu in načinu izvedbe raziskave, je mogoče raziskavo ponoviti še npr. med starejšimi, ki se srečujejo z upadom kognitivno in/funkcionalnih sposobnosti in bi AV lahko uporabljali za ohranjanje svoje mobilnosti.

Tretji prispevek te disertacije je v razlikovanju med različnimi vrstami pomislekov in vključitvi odnosa do AV kot rezultantskega dejavnika drugih dejavnikov privzemanja, kar je v literaturi redkost. Malo raziskovalnih člankov razlikuje med različnimi vrstami skrbi (npr. varnost, zasebnost, splošne skrbi) in primerljiva raziskava je članek avtorjev T. Zhang in drugi (2019, str. 211), a njihov model na splošno upošteva vsebinsko ožji nabor dejavnikov, model pa ima tudi manjšo pojasnjevalno moč (R^2). Starejši modeli sprejemanja tehnologij (npr. TAM (Davis, 1985), Teorija razumne akcije (Fishbein & Ajzen, 1975), Teorija načrtovanega vedenja (Azjen, 1980)) so odnos do nove tehnologije upoštevali kot pomemben dejavnik, nedavne raziskave pa slednjega niso pogosto vključevale, čeprav rezultati analize Rondan-Cataluña in drugih (2015, str. 798), ki je preučevala razvoj modelov sprejemanja tehnologij, poročajo, da lahko pomembno vpliva na vrednost vrednosti R^2. Skladno s tem verjamemo, da je vrnitev k upoštevanju odnosa do tehnologij/AV in prikaz pomena slednje pomemben prispevek, ki ga morajo prihodnje raziskave upoštevati.

Četrtič, disertacija poudarja pomen kontekstno specifičnih dejavnikov za doseganje večje pojasnjevalne moči modela pri raziskovanju privzemanja novih tehnologij. Predlagani dejavniki vključujejo tako pozitivne kot tudi negativne vidike privzemanja AV, predlagani model pa temelji na uveljavljenih modelih sprejemanja tehnologije. Petič, naši rezultati kažejo na potrebo po razlikovanju med vsaj tremi vrstami deležnikov: potrošniki/potencialni posvojitelji, vlada in podobni organi ter proizvajalci avtomobilov. Vsak od njih igra svojo vlogo in pri njihovem delovanju je nujno, da delujejo sodelovalno in ne ločevalno. Šesti prispevek disertacije je preučevanje najbolj kontroverzne stopnje AV, to je na stopnji 5, ki je bila po pregledu literature Nastjuka in drugih (2020) do zdaj v literaturi najmanj pokrita. Čeprav je razširitev avtomatizacije 5. stopnje najbolj odmaknjena v prihodnost, je mogoče trenutne ugotovitve vključiti v današnjo zgodnjo fazo razvoja AV. Z upoštevanjem trenutnih rezultatov se bodo AV, ki bodo čez nekaj let obstajala, lahko razvijala v smeri želja in pričakovanj potencialnih uporabnikov.

Appendix 2: Survey questionnaire

Dear participant,

Please take about 20 minutes and by clicking on "Next Page" start the survey about autonomous vehicles. The research seeks to evaluate the attitudes of participants related to several aspects of autonomous vehicle adoption. The questionnaire is divided into sections that have headings and contain an introductory paragraph. Additional explanations are added wherever necessary to ensure clarity and unambiguity.

Participation is voluntary and you can terminate your participation at any time. When processing the data, we will adhere to all rules related to ensuring the anonymity of the respondents and the confidentiality of the data obtained through the survey. The collected data will thus only be used in aggregate form and not be displayed individually anywhere.

Do not hesitate to contact us if you require any additional information or have comments or concerns.

Thank you very much in advance for your cooperation.

SECTION 1: DRIVING EXPERIENCE AND PATTERNS

This section reviews your driving status, everyday driving patterns in terms of either public or private means of transport, the reasons for your choices and your attitudes to vehicle ownership.

Q1 – Do you have a driver's licence?

- Yes, I do.
- No, I do not.

Q2 – Please indicate how often you use the following means of transport (1 = never, 2 = a few times per year, 3 = a few times per month, 4 = a few times per week, 5 = always):

- Driving a car
- Passenger in a car
- Car sharing
- Taxi
- Public transport
- Bicycle
- Walking
- Other: _____________

Q3 – Please indicate the main means of transport you most frequently use for the following activities. Please only tick one box per activity related to daily or weekly travel. If an activity does not apply to you, please tick "N/A" (1 = car, 2 = motorbike, 3 = bus, 4 = train, 5 = taxi, 6 = bicycle, 7 = walk, 8 = other, 9 = N/A).

- Shopping
- Travel to work
- Travel while at work

- Local leisure travel
- Visiting friends and relatives locally
- Taking children to school or nursery
- Driving other family members
- Other local travel

SECTION 2: INTEREST IN TECHNOLOGY

This section reviews your general interest in technology.

Q4 – Please indicate the extent to which you agree or disagree with the following statements related to interest in technology (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree):[17]

- New technologies contribute to a higher standard of living.
- I am among the first to use new technologies and experiment with them soon after they become available.
- I am hesitant to use new technologies.
- I am waiting until new technology use becomes unavoidable and is accepted by the general public.

SECTION 3: ATTITUDES TO AUTONOMOUS VEHICLES

This section reviews your attitudes to autonomous vehicles from several perspectives. Autonomous vehicles or self-driving vehicles are vehicles that do not require direct driver input to control the steering, acceleration and braking. Autonomous vehicles are defined on six levels from 0 to 5, as follows (SAE International, 2018, p. 19):

- Level 0: There is no automation and a human driver performs all tasks at hand.
- Level 1: A human is responsible for driving; however, the technology can help with some features, e.g., Adaptive cruise control, Parking assistant.
- Level 2: This means partial automation where a human driver is helped by automated features, e.g., Lane assist, but is still responsible for driving, checking and observing the environment.
- Level 3: The AV takes on the role of observing the environment, e.g., Traffic jam assistant, yet a human driver is still needed.
- Level 4: This means a high level of automation where the majority of the driving is performed by the AV while the human only takes control in specific, pre-defined circumstances.
- Level 5: It means complete automation where AV can operate on its own in any circumstances.

Levels 1–4 are semi-automated, whereas level 5 is fully autonomous. The remainder of the questionnaire refers to fully AVs or level-5 vehicles for which the abbreviation AV/AVs is consistently used.

Now, try to put yourself in the situation where all vehicles are moving autonomously, without drivers. Those vehicles communicate with each other, the driver becomes a

[17] Question used to measure the construct of Technological enthusiasm.

passenger and the only input provided to the AV by the passenger is the address. Answer the questions below with this in mind.

Q5 – Please express your agreement about the general idea of AVs (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree):

- I am quite familiar with the idea of driverless vehicles.
- I have not read or seen much information about AVs.
- I am mostly ignorant about AVs.

Q6 – Please express your agreement with the following statements about the future with AVs (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree):

- I look forward to the widespread use of AVs.
- I look forward to using an AV.
- I am completely against buying an AV.
- I am worried about AV technology because I am not familiar with it.
- I do not like AVs because I have less control over the steering of the vehicle.

Q7 – Please express your agreement about the following statements related to the fun and pleasure of driving (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree):

- AVs would take away the pleasure of driving.
- Driving is particularly fun for me.
- I would miss the pleasure of driving a conventional vehicle.

Q8 – Please indicate the extent to which you agree or disagree with the following statements related to attitudes to AVs (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree):[18]

- I would be excited to see AVs in my area.
- The idea of fully automated driving is fascinating.
- I do not trust AVs. (reverse-scored)
- I am completely against the spread of AVs.

Q9 – Please indicate the extent to which you agree or disagree how AVs could affect safety on the roads (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree):[19]

- AVs will be safer than human drivers.
- I would feel safe while using an AV.
- I would feel safer while driving in semi-automated vehicle than in a fully automated vehicle.
- In the foreseeable circumstances, AVs will perform better than humans.
- In unforeseen circumstances, a human would have better reactions than an AV.
- I would trust an AV more than a human-driven vehicle.

[18] Question used to measure the construct of Attitude to AVs.
[19] Question used to measure the construct of Perceived safety.

– AVs have enough safeguards to make me feel safe while using them.

Q10 – Please indicate the extent to which you agree or disagree with the following statements related to AV use influenced by the opinions of others (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree):[20]

– I would proudly show an AV to the people who are close to me.
– Possessing an AV would give me social recognition.
– I would be more eager to use an AV if my friends and family were using one.
– I would feel more confident in using an AV if they were commonly used by others.

Q11 – Please indicate the extent to which you agree or disagree with the benefits that AVs could bring (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree):[21]

– AVs will bring increased road safety.
– Fewer traffic accidents.
– Less traffic congestion.
– A reduced environmental impact due to lower emissions.
– Better compliance with traffic signals and road traffic rules.

Q12 – Please indicate the extent to which you agree or disagree with what concerns you regarding AVs (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree):[22]

– I am concerned about riding in a vehicle with no driver controls available.
– I am concerned about AVs moving by themselves from one location to another while unoccupied.
– I am concerned about AVs becoming confused by unexpected situations.
– I am concerned about AVs not driving as well as human drivers generally.

Q13 – Please indicate the extent to which you agree or disagree with the following statements related to data- and location-sharing (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree):[23]

– I would be worried about misuse of my data.
– I would feel uncomfortable if the management system tracked my route.
– The idea that someone has access to my location details scares me.
– The idea that someone holds data about my habits scares me.

Q14 – Please indicate the extent to which you agree or disagree with the following statements related to governmental support (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree):[24]

– Government should provide incentives, e.g., lower the taxes on the purchase of an AV.
– Government should allow AV owners to pay lower tolls for road maintenance.

[20] Question used to measure the construct of Social factors.
[21] Question used to measure the construct of Perceived benefits.
[22] Question used to measure the construct of General concerns.
[23] Question used to measure the construct of Privacy concerns in the AV era.
[24] Question used to measure the construct of Facilitating conditions.

– The legal framework should support the presence of more AVs on the road.

Q15 – Please indicate the extent to which you agree or disagree with the following statements related to your AV adoption intentions (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree):[25]

– If an AV became available to me, I would ride in it.
– I plan to buy an AV in the coming years if I have enough money to do so.
– I would be willing to transport my children or parents in an AV.

SECTION 5: DEMOGRAPHICS

Q16 – Gender:

– Male
– Female

Q17 – What is your current status?

– High school student
– Student
– Employed person
– Self-employed person
– Unemployed
– Retired

Q18 – To which age group do you belong?

– Up to 20
– 21–30
– 31–40
– 41–50
– 51–60
– Above 60

Q19 – What is your highest level of formal education?

– Primary school
– High school
– Undergraduate programme/university
– Graduate programme (2 years)
– Doctoral programme (PhD)

Q20 – In which region do you live?

– Pomurska
– Podravska
– Koroška

[25] Question used to measure the construct of AV adoption intention.

- Savinjska
- Zasavska
- Spodnjeposavska
- Jugovzhodna
- Osrednjeslovenska
- Gorenjska
- Notranjsko-kraška
- Goriška
- Obalno-kraška

Q21 – Type of settlement in which you reside:

- City
- Suburban settlement
- A smaller compact settlement
- Scattered houses or secluded houses

Appendix 3: Questionnaire items and references

Technological enthusiasm (TECent)

References: Deb et al. (2017), Haboucha et al. (2017), and Ruggeri et al. (2018)

- TECent1: I am among the first to use new technologies and experiment with them soon after they become available.
- TECent2: I am hesitant to use new technologies. (reverse-scored)
- TECent3: I am waiting until new technology use becomes unavoidable and is accepted by the general public. (reverse-scored)

Attitude to AVs (attAV)

References: Deb et al. (2017) and Kyriakidis et al. (2015)

- attAV1: I would be excited to see AVs in my area.
- attAV2: The idea of fully automated driving is fascinating.
- attAV3: I do not trust AVs. (reverse-scored)
- attAV4: I am completely against the spread of AVs. (reverse-scored)

AV adoption intention (AVado)

References: Liu, Yang, et al. (2019b), Montoro et al. (2019), Waung et al. (2021) and Wu et al. (2019)

- AVado1: If an AV became available to me, I would ride in it.
- AVado2: I plan to buy an AV in the coming years if I have enough money to do so.
- AVado3: I would be willing to transport my children or parents in an AV.

Perceived safety (SAF)

References: Cunningham, Regan, Ledger, et al. (2019), Deb et al. (2017), M. König and Neumayr (2017) and Waung et al. (2021)

- SAF1: AVs will be safer than human drivers.
- SAF2: I would feel safe while using an AV.
- SAF3: I would trust an AV more than a human-driven vehicle.
- SAF4: AVs have enough safeguards to make me feel safe while using them.

Social factors (socFAC)

References: Acheampong et al. (2021), Deb et al. (2017), Kapser and Abdelrahman (2020) and Qu et al. (2019)

- socFAC1: Possessing an AV would give me social recognition.
- socFAC2: I would be more eager to use an AV if my friends and family were using one.
- socFAC3: I would feel more confident in using an AV if they were commonly used by others.

Perceived benefits (BEN)

References: Bansal et al. (2016), Cunningham, Regan, Horberry, et al. (2019), M. König and Neumayr (2017), Montoro et al. (2019) and Qu et al. (2019)

– BEN1: AVs will bring increased road safety.
– BEN2: Fewer traffic accidents.
– BEN3: Less traffic congestion.
– BEN4: A reduced environmental impact due to lower emissions.
– BEN5: Better compliance with traffic signals and road traffic rules.

General concerns (CON)
References: Cunningham, Regan, Horberry, et al. (2019), M. König and Neumayr (2017) and Qu et al. (2019)
– CON1: I am concerned about riding in a vehicle with no driver controls available. (reverse-scored)
– CON2: I am concerned about AVs moving by themselves from one location to another while unoccupied. (reverse-scored)
– CON3: I am concerned about AVs becoming confused by unexpected situations. (reverse-scored)
– CON4: I am concerned about AVs not driving as well as human drivers generally. (reverse-scored)

Privacy concerns in the AV era (PRI)
References: Kyriakidis et al. (2015) and Waung et al. (2021)
– PRI1: I would be worried about misuse of my data. (reverse-scored)
– PRI2: I would feel uncomfortable if the management system tracked my route. (reverse-scored)
– PRI3: The idea that someone has access to my location details scares me. (reverse-scored)
– PRI4: The idea that someone holds data about my habits scares me. (reverse-scored)

Facilitating conditions (facCON)
References: Kapser and Abdelrahman (2020), Venkatesh et al. (2012) and Jain et al. (2022)
– facCON1: Government should provide incentives, e.g., lower the taxes on the purchase of an AV.
– facCON2: Government should allow AV owners to pay lower tolls for road maintenance.
– facCON3: The legal framework should support the presence of more AVs on the road.