Transport Demand & User Challenges of ACT

WG4: Thematic Report

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Chapter 1
Introduction

Automated and connected transport (ACT) offers increased opportunities to support new transportation services whilst having the potential to make transport more sustainable. Car sharing, ride hailing, and other emerging transport services are expected to support the Mobility-as-a-Service (MaaS) concept and practice, as well as relevant business models, promoting improved public transport and innovative last mile solutions. However, research to date has largely focused on the vehicle and infrastructure aspects of ACT. Despite these being essential ACT components, a core component of this debate missing to date is the user perspective and preferences (Shiftan et al., 2021), which can have a significant effect on ACT impact on sustainability. This WG4 Thematic Report focuses primarily on road transport and aims at contributing in this developing debate among scholars and practitioners, building on a 2017 consultation of WISE-ACT experts regarding ACT priority areas.

Therefore, this WG4 Thematic Report seeks to understand the potential impact of ACT on user mobility, and in turn on sustainability overall. If all transport users use innovative shared mobility services, then car ownership levels would be reduced, making an important contribution in meeting global sustainability objectives. Equally, if ACT led to increased individual car use and ownership levels due to potential benefits, such as reduced parking needs and ease of travel, then transport networks would come into a complete gridlock as some recent studies have already shown, increasing congestion in cities with a wide use of ride-hailing services. Eventually, the latter would have a seriously negative impact on sustainability. Therefore, this report reviews relevant academic literature, conducts a meta-analysis of stated-preference surveys, conducts a cross-country comparison based on WISE-ACT survey findings and assesses AV trials to address the following WISE-ACT MoU Tasks:

- MoU Task 9 – Identify the key economic, social, demographic, behavioural and cultural factors and barriers that determine a positive attitude of users towards AVs introduction.
- MoU Task 10 – Analyse the behaviour of AV end users by comparing their preferences and choices based on hypothetical mobility options through existing Stated-Preference experiments.
- MoU Task 11 – Propose a taxonomy of potential sites for deployment of AVs while taking into account the geographical, social, economic, environmental and transport characteristics of the areas under study.

In brief, WG4 focused on the AV acceptance by seeking to understand the key drivers for a successful integration with the existing transport system and infrastructure. The objective has been to offer insights regarding transport demand and user preferences, particularly during the transition phase.

Chapter 2
Method

This report reviews relevant academic literature to address MoU Task 9 and 10, while it is based on the WISE-ACT trials database to address MoU Task 11. Based on a consultation of WISE-ACT WG4 members, several empirical studies have been identified offering insights into the demand side of AVs, and more precisely into the acceptance of AVs (see Table 1). The majority of these empirical studies are based on surveys, sometimes with a dedicated stated preference part. A limited number of studies are based on experiments where participants can experience what it is like to travel in an AV. Task 9 reports on those empirical studies using surveys and experiments, while task 10 specifically focuses on surveys with a stated preference part. Additional studies have been reported, however Table 1 has acted as the backbone of this report and offers an overview of relevant AV studies until 2020, which aims at offering a future reference point in addition to the WISE-ACT survey.

Table 1: Empirical studies offering insights into the acceptance of AVs

Author(s)	Year of publication	Location	Data collection	Sample size
Acheampong & Cugurullo	2019	Dublin, Ireland	Online survey	507
Bansal & Kockelman	2017	USA	Online survey	2167
Bansal et al.	2016	Austin, USA	Online survey	347
Choi & Ji	2015	South Korea (?)	Online survey	552
Etzioni et al.	2020	Cyprus, Hungary, Iceland, Montenegro, Slovenia, UK	Online survey with SP part	1669
Gold et al.	2015	Munich, Germany	Driving simulator + before/after survey	69
Guo et al.	2020	Stockholm, Sweden	Online survey	505
Haboucha et al.	2017	Israel and North America	Online survey with SP part	721
Hartwich et al.	2019	Germany	Driving simulator + before/after survey	40
Hohenberger et al.	2016, 2017	Germany	Online survey	1603
König & Neumayr	2017	international	Online survey	489
Körber et al.	2018	Munich, Germany (?)	Driving simulator + before/after survey	40
Krueger et al.	2016	Australia	Online survey with SP part	435
Kyriakidis et al.	2015	International	Online survey	4886
Kyriakidis et al.	2020	Cyprus, Greece, Finland, Iceland, Italy, Montenegro, Malta, Slovenia	Online survey	1639
Lavieri et al.	2017	Puget Sound Region, USA	Online survey	1832

Lee et al.	2016	?	Real-life experiment + after interview	6
Madigan et al.	2016	La Rochelle, France & Lausanne, Switzerland	Real-life experiment + after survey	349
Madigan et al.	2017	Trikala, Greece	Real-life experiment + after survey	315
Payre et al.	2014	France	Online survey	421
Xu et al.	2018	Xi'an, China	Real-life experiment + before/after survey	300 undergraduate students
Zmud et al.	2016	Austin, USA	Online survey + interviews	556 (survey), 44 (interviews)
Zmud&Sener	2017	Austin, USA	Online survey + interviews	556 (survey), 44 (interviews)
Kolarova et al.	2019	Germany	Online Survey with SP	511
Steck et al.	2018	Germany	online survey with SP	172
Kolarova and Steck	2019	Germany	online survey with SP	441
Correia et al.	2019	Netherlands	online survey with SP	252
Yap et al.	2016	Netherlands	online survey with SP	761
Ashkrof et al.	2019	Netherlands	online survey	663
Molnar et al.	2018	Michigan, US	Driving simulation + survey	72
Zhang et al.	2019	China	online survey	216
Alonso-Gonzales et al.	2020 –	Netherlands –	online survey with SP	1006
Moore et al.	2020	Dallas-Fort Worth Metropolitan Area, US	Online survey	1607
Fraedrich et al. –	2016	Germany	online survey	1000

Chapter 3
Identifying factors influencing attitudes towards AV use

This chapter addresses WISE-ACT MoU Task 9, namely to identify the key economic, social, demographic, behavioural and cultural factors as well as barriers which determine a positive attitude of users towards the introduction of AVs. Before AVs can have any impact on mobility, traffic, safety, and other aspects of passenger transport, people must be willing to use them on a large scale. A number of socio-psychological models have been developed to explain these behavioural intentions, often focusing on how a positive attitude leads to technology acceptance and use.

The most commonly used socio-psychological models on technology acceptance and use are the **Technology Acceptance Model** (TAM; Davis, 1986) and the **Unified Theory of Acceptance and Use of Technology** (UTAUT; Venkatesh et al., 2003). Originated in the socio-psychological models of the Theory of Reasoned Action (TRA; Fishbein and Ajzen, 1975) and the Theory of Planned Behaviour (TPB; Ajzen, 1991), TAM has become one of the key models in understanding the determinants of acceptance or rejection of technology (Marangunić and Granić, 2015). It considers *perceived usefulness* and *perceived ease of use* as the two main determinants of behavioural intention to use, which in turn has an influence on actual use of the technology. Whereas TRA or TPB also highlight the influence of subjective norms, TAM clearly focuses on personal attitudes only. UTAUT builds on TAM by proposing four main concepts: *performance expectancy*, *effort expectancy*, *social influence* and *facilitating conditions*. 'Performance expectancy' refers to the degree to which an individual believes that using the technology is beneficial, and thus resembles 'perceived usefulness' in TAM. 'Effort expectancy' refers to the degree of ease associated with the use of the technology, and thus resembles 'perceived ease of use' in TAM. 'Social influence' is the degree to which an individual believes that important others want him or her to use the technology, and 'facilitating conditions' is the degree to which an individual believes that the necessary infrastructure exists to support the use of the technology. A very important extension of TAM for the study of AV acceptance is the **Automation Acceptance Model** (AAM; Ghazizadeh et al., 2012). AAM stresses the importance of *trust* and *task-technology compatibility*.

Only a limited number of empirical studies have applied the full TAM or UTAUT model in relation to the acceptance of AVs (for a recent overview, see Jing et al., 2020):

- Perceived usefulness (or performance expectancy) and trust are key determinants of the intention to use AVs. There is also an interaction between both determinants: if people trust AVs, they are also more likely to perceive AVs as useful (Choi and Ji, 2015; Madigan et al., 2016, 2017).
- Social influence is also important, especially in demonstration sites where new AV-based transport services are offered to the public who are not familiar with such services yet (Madigan et al., 2016, 2017). But the influence of social norms on AV acceptance can be indirectly assessed via perceived usefulness and perceived ease of use (Acheampong and Cugurullo, 2019).
- Perceived ease of use (or effort expectancy) can be important, but often to a lesser extent than perceived usefulness and trust (Choi and Ji, 2015; Madigan et al., 2016). Also, the effect of perceived ease of use might become negligible when people can try out the new AV-based transport services themselves. Instead, hedonic motivation, or the users' enjoyment of the system, becomes a strong predictor of the intention to use AVs in the future (Madigan et al., 2017). But findings are not conclusive. For example, Xu et al. (2008) found the opposite i.e. the impact of perceived ease of use on acceptance became stronger after participants had experienced AVs themselves in a field experiment at the testing track on Chang'an University (China).

Most empirical studies are, however, organized on an ad-hoc basis and are only loosely based on a theoretical framework, if any. Some recurring themes are how to increase trust, general attitudes and personality, as well as differences across population groups.

1. Trust

As mentioned before, trust is believed to be an important determinant of behavioural intention to use AVs in the future. Although people might perceive AVs as a useful advancement in transport service provision, they can also be concerned of their wider impact or even afraid of driverless vehicles. Uncertainty regarding liability in the event of an accident with an AV is one of the reasons why people do not feel comfortable using AVs (Bansal and Kockelman, 2017; Haboucha et al., 2017; Lavieri et al., 2017; Zmud and Sener, 2017; König and Neumayr, 2017). Other barriers to trust are privacy concerns e.g. about the disclosure of trip data (Costantini et al., 2020), cybersecurity and hacking issues (Gkartzonikas and Gkritza, 2019). Trust in AVs can therefore be limited. Several studies have therefore examined how trust can be increased.

Experience is often believed to increase trust. As AVs are not widely deployed yet, most people gain experience with AVs in experimental driving simulators (e.g., Gold et al., 2015; Hartwich et al., 2019), demonstration sites or in testbeds (e.g., Lee et al., 2016; Xu et al., 2018). However, often the participants in these experiments still do not fully trust AVs after having experienced it. They often mention distrust factors related to the process (i.e., lack of information, unpredictability, machine-like), performance (i.e., functional incompetence, lack of control, lack of confidence) and purpose (i.e., liability, value incongruence, disloyalty).

Offering targeted **information** is one of the possibilities to overcome distrust. Körber et al. (2018) presented trust promoting information to one group and trust lowering information to another group of participants in an AV experiment. Trust was measured at the beginning, after an introductory drive and at the end of the experiment. Initially significant differences in trust existed between both groups, indicating the importance of the type of information presented. But these differences disappeared after gaining more experience in the experimental drives.

2. Personal attitudes and personality

Attitudes can be defined as evaluation of ideas, events, objects, or people. Every attitude has three components: affective, behavioural, and cognitive component. The **affective** component refers to the emotional reaction someone has towards an attitude object (e.g., people are scared of AVs, or think it is fun to travel on a fully automated car). The **behavioural** component refers to the way someone behaves when exposed to an attitude object (e.g., pedestrians stop walking when an AV is approaching, passengers of an AV relax and start gazing out the window). The **cognitive** component refers to the thoughts and beliefs someone has about the attitude object (e.g., AVs are believed to have a positive impact on traffic safety).

Not surprisingly, many studies found a strong and positive effect of a **pro-AV attitude** on the willingness to use AVs (Payre et al., 2014; Haboucha et al., 2017). The affective component of attitudes can also have a moderating effect on the influence of the cognitive component (Hohenberger et al., 2016, 2017). For example, while a positive evaluation of benefits (= cognitive component) directly increases the willingness to use AVs, this effect diminishes with increasing levels of anxiety (= affective component). Some studies also include **other attitude objects** than AVs such as attitudes towards technology, environment, driving and public transport (Bansal et al., 2016; Zmud et al., 2016; Haboucha et al., 2017; Lavieri et al., 2017; Zmud and Sener, 2017). Especially an interest in technology and environmental concerns seem to increase the willingness to use AVs. People with a green lifestyle are more likely to be early adopters of AVs, and favour a sharing-based model over private ownership.

A limited number of studies also investigated the role of **personality**, similarly to the WISE-ACT survey (Kyriakidis et al., 2020), but generally found a very small effect (Choi and Ji, 2015; Kyriakidis et al., 2015). However, the influence of personality might be indirect through personal attitudes. For example, the negative effect of feelings of anxiety on the willingness to use AVs decreases with increasing levels of self-enhancement (Hohenberger et al., 2017).

3. Trip characteristics

Furthermore, AV acceptance might also depend on specific trip characteristics. For example, Kyriakidis et al. (2020) discussed the role of human operators in safety perceptions of AVs. Through the online WISE-ACT survey distributed in several European countries, different hypothetical situations were presented to the respondents. The willingness to travel in an AV yourself or to allow your children to travel in an AV appears to be higher in the presence of a human operator inside the vehicle. Respondents appeared much more skeptical without a human operator or when this operator would only have remote control of the vehicle. The presence of onboard operators appears to have a positive impact on how respondents perceive safety of AVs (Guo et al., 2020).

AV acceptance studies tend to focus on commuting trips. The importance of AVs for non-commuting trips is less studied. Nevertheless, Thomopoulos et al. (2021) point out how the interest of the public in AVs for leisure trips appears to exceed that for commuting trips, although such non-commuting trips might require a lower level of automation compared to commuting. Furthermore, a shared model of AVs seems less appropriate for leisure trips. Equally, a stated preference survey conducted by Kolarova et al. (2019a) found that AV seem to be a more attractive option on commuting trips than on leisure or shopping trips since a reduction in the value of time was found for commuting trips, but not for leisure one. Also, another stated preference survey found that AVs are perceived as an attractive option on long-distance trips (Kolarova and Steck, 2019, Ashkrof et al., 2019).

4. Differences across population groups

Results of the aforementioned studies are generally controlled for socio-economic and demographic differences. Most studies showed that men, young people, those with higher level of educational degrees, and higher income groups are more open to AV technology (e.g., Kyriakidis et al., 2015; Bansal et al., 2016; Haboucha et al., 2017; König and Neumayr, 2017; Lavieri et al., 2017; Kyriakidis et al., 2020). However, it is important to note that most surveys are not representative and skewed towards a male and younger population. In terms of **gender**, Haboucha et al. (2017) as well as Polydoropoulou et al. (2021) noted that the difference between privately owned AV (PAV) and shared AV (SAV) is important to women. Women are more likely to choose the privately owned model over the shared one. This might be due to concerns about personal safety when sharing rides with somebody else. Krueger et al. (2016) specifically focused on the interest in different types of SAV (i.e., with or without dynamic ride sharing), but found no significant differences between men and women.

Safety concerns might also explain why women are less open towards travelling in an AV without the supervision of a human operator, and why they are less positive towards allowing children to travel in an AV without human supervision (Kyriakidis et al., 2020).

In terms of **age**, Bansal et al. (2016) found a negative effect of age on the willingness to pay for automation, but no significant effect when age was regressed on the adoption time relatively to the one of friends. This raises a broader question whether older people are simply not technology-focused or rather wait to use a new technology only after a critical mass is using such a technology. Most studies only analyze the direct effect of these socioeconomic and demographic variables, but studies like Hohenberger et al. (2016) also studied the moderating effect of age and gender on the influence of attitudes. They found that women in general are less likely to drive an AV. But women are also more anxious about using an AV and have less pleasure compared to men, resulting in an even lower likelihood to drive an AV. But this difference in feelings about AVs becomes smaller when they get older.

Some studies (e.g. WISE-ACT survey) also control their results for respondents' current mobility behaviour, but results remain mixed to date. For example, **car mileage** is often found to increase an interest in AV (e.g., Kyriakidis et al., 2015; Haboucha et al., 2017). But others like Bansal et al. (2016) found no significant effect of car mileage on the willingness to pay for automation. Similar results have been obtained about **car sharing experience** (positive effect in Krueger et al., 2016; no significant effect in Bansal et al., 2016). Findings with respect to other aspects of mobility behaviour, like **past crash incidents** and **car ownership**, seem to be more conclusive. People who do not own a car at the moment tend to have a more positive attitude towards AV (König and Neumayr, 2017) and are also more likely to choose PAV or a combined SAV/PAV (Lavieri et al., 2017). Also, people who already own a car with some level of automation are more open to AV (König and Neumayr, 2017).

Finally, results are sometimes also controlled for residential differences. Most studies agree that especially *urbanites* are more positive towards AV (König & Neumayr, 2017), are more likely to be early adopters (Lavieri et al., 2017) even when friends do not yet use AVs (Bansal et al., 2016), and are willing to pay for adding connectivity to an existing vehicle (Bansal et al., 2016).

Chapter 4
Comparing user preferences about AVs based on stated preference surveys

This chapter addresses WISE-ACT MoU Task 10, namely the analysis of user preferences and choices towards AVs. Numerous studies about public acceptance of AVs can be found in the literature. However, only a few studies until 2020 used stated-preference (SP) experiments to capture people's opinion and preferences regarding automated driving technology is currently available. Krueger et al. (2016), for instance, in a study including 435 Australian residents show that service attributes including travel cost, travel time and waiting time may be critical determinants of the use of shared AVs. Differences in willingness to pay for service attributes indicate that shared AVs with dynamic ride sharing and without dynamic ride sharing are perceived as two distinct mobility options. Dynamic ride sharing refers to near-live time adjustable AV fleet and ride management based on user requests and bookings. The results imply that the adoption of shared AVs may differ across cohorts, whereby young individuals and individuals with multimodal travel patterns may be more likely to adopt them. This is an important finding which should be researched in more detail. An SP study conducted by Kolarova et al. (2019) found that AV is preferred on commuting trips, but not on short leisure or shopping trips, which reinforces the argument by Thomopoulos et al. (2021) about the need to focus on non-commuting trips at the early stages of AV deployment. Also, AV seems to be an attractive option on long-distance trips (Kolarova and Steck, 2019, Ashkrof et al., 2019).

On the other hand, Haboucha et al. (2017), conducted a stated preference questionnaire study with 721 individuals living across Israel and North America. The authors determined interest about technology, environmental concern, driving enjoyment, public transit attitude, and pro-AV sentiments as the five most relevant latent variables to describe the attitudes of individuals. Results show that high hesitations towards AV adoption exist overall, with 44% of choice decisions remaining regular i.e. conventional vehicles. Early AV adopters will likely be young, students, more educated, and people who spend more time in vehicles. In case of rides in shared autonomous vehicles, the authors found that even if such service was offered completely free, only 75% of respondents would be willing to use it. The authors also found various differences regarding the preferences of individuals in Israel and North America, more specifically that respondents in Israel are overall more likely to shift to AVs than their US peers. The latter raises the need to test for any cultural factors influencing responses.

More recently Asmussen et al. (2020) examined the individual-level AV adoption and timing process, considering the psycho-social factors of driving control, mobility control, safety concerns, and tech-savviness. Via an online web survey study distributed in Texas, US, the authors analysed the responses of 1021 individuals. Results reveal a strong influence of gender and age on AV adoption and shared AV use in relation to AV adoption. Findings also suggest that, in line with Kyriakidis et al. (2020), underscoring the expected safety benefits of AVs and also addressing concerns about child transport would be the most effective strategies to increase AV and shared AV uptake among women, much more so than, for example, tech-savviness campaigns. The length of time required to adopt AVs results also indicate that the sub-population of men and of individuals from high income households may be more prone in embracing AVs as first-buyers. The age effect gets manifested through the latent constructs, but also has a strong direct effect on the AVD and DAD decisions, with older individuals (age ≥ 64 years) more likely to spurn AV technology of any kind or to never buy an AV. The effects of employment status, education, and household income on both the AV and shared AV use are relatively modest overall, while in terms of AV fixed cost, a decrease of $50 per month can lead to seven additional individuals out of 100 choosing the AV alternative. The corresponding shared AV variable cost, shows that a decrease from $1.75 to $1.25 cents can lead to about 3 additional individuals out of 100 choosing the SAV alternative.

As part of the Action CA16222 of the European Cooperation in Science and Technology (COST) entitled "Wider Impacts and Scenario Evaluation of Autonomous and Connected Transport" (WISE-ACT) the members of WG4 contributed to the overall discourse on user preferences about AVs by analysing the behaviour of AV end users through the comparison of their preferences and choices based on hypothetical mobility options through Stated-Preference experiments. WG4 researchers investigated and modelled the mode choice of two modes: **[1]** conventional passenger vehicles **[2]** and private automated vehicles in six participating countries: Cyprus, Hungary, Iceland, Montenegro, Slovenia, and the UK. A mixed multinomial logit heteroskedastic error component type model was estimated based on the WISE-ACT survey which included a stated preference part and was distributed across Europe. Along with the relevant JRC – European Commission Eurobarometer survey findings, results suggest significant hesitation towards AVs in all countries, as conventional vehicles are preferred by 70% of the survey participants, which is also in line with the findings by Haboucha et al. (2017). Differences in the responses of individuals were also found at country level. More specifically, people from Slovenia and Cyprus show higher AV acceptance, while people in more affluent countries, including the

UK and Iceland, indicate more hesitations towards them. Gender, income, current travel habits, and age are the most dominant characteristics on user choice and their preferences between conventional and fully automated vehicles. In particular, results showed that men, younger than 60 years old, with higher incomes, who currently use a private vehicle car, are more likely to be early adopters of AVs. Interpretation of the mixed multinomial logit heteroskedastic error component type model's results revealed that (Kyriakidis et al., 2020):

- Women prefer conventional vehicles over automated vehicles. This result is consistent with previous findings which showed that men are more open than women to automated technologies. This could possibly be explained by affective reactions or more concerns with automated driving (Hohenberger, Spörrle, &Welpe, 2016; Kyriakidis, Happee, & de Winter, 2015). This tendency was significant in Iceland.

- Individuals of higher household income groups tend to favour automated over conventional vehicles. This is likely related to their ability to afford the potentially higher trip costs of automated technology. Interestingly, this effect was significant in the UK and Iceland, which are on average more wealthy than the other countries included in this analysis.

- Less affluent countries show, in general, higher acceptance of AVs regardless of respondents' income level, while in more affluent countries, it is the wealthier respondents who are more likely to choose AVs. This may be linked with contemporary car ownership levels or with other socio-economic and cultural factors.

- Individuals older than 59 years old prefer conventional over automated vehicles. While younger individuals tend to be more open to new technologies, older individuals may feel more intimidated by technological innovations, such as AVs and perceive them as a distant future option. This effect was found to be most significant in the UK through this analysis.

- Individuals who use private passenger vehicles for their regular commute prefer conventional over automated vehicles. This could be explained by the direct access to a private car, habits, familiarity with this transport mode and joy of manual driving. This effect was the found to be the strongest in Cyprus through this analysis.

- The alternative specific constant of AVs could show the tendency to favour AVs, while all other parameters are kept equal. This parameter was negative and significant in all models except those of Cyprus and Slovenia. This may indicate that individuals from Cyprus and Slovenia are those most likely to adopt AVs. Further research is required to understand why this may be the case. On the other hand, respondents from the UK were found to be the least likely to adopt AVs, followed by those in Iceland and Hungary.

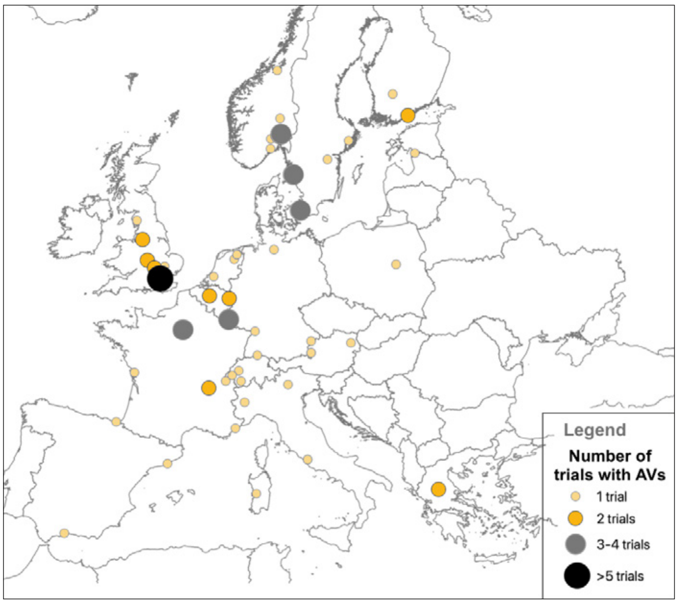
Chapter 5
AV trials overview and a proposed taxonomy

This chapter addresses WISE-ACT MoU Task 11 by offering an overview of AV deployment sites in Europe and by contributing in the creation of a relevant taxonomy, which would be valuable for local, regional and national authorities worldwide. Building on various WISE-ACT activities and outputs, this chapter offers a snapshot of existing ACT trial sites in an attempt to inform the development of a relevant taxonomy based on diverse spatial characteristics. Such a task is essential to inform contemporary and future ACT policies based on lessons learnt, best practice and joint efforts, all of which build on the broader COST objectives. Information presented in this chapter is founded on the outputs of one of the first and most successful WISE-ACT STSMs, which were presented at the WISE-ACT Workshop #1 in Bratislava (Canitez et al., 2018). The AV trial database was launched through that STSM, which currently includes more than 300 entries. This chapter presents further WG4 members desk-based research, which focused on existing trials including AVs by reviewing a wide range of documentation available online e.g. project deliverables and websites, journal articles, industry reports.

80 AV trials have been identified across Europe, most of which were part of research and innovation projects aiming at testing AV impacts on passenger or freight transport. The majority of AV trials reviewed in this chapter (81%) took place between 2016 and 2020. More than half (55%) of these trials had been completed at the time of review, whereas 45% were still ongoing. Interestingly, ca. 20% of AV trials were launched after the COVID-19 pandemic outbreak and the relevant restrictions implemented in most countries around Europe during that time. This is an indicator of interest to proceed with ACT even during such acute crises affecting both passenger and freight transport, along with the international economy.

The geography of AV trials revealed interesting findings, which are aligned with Canitez et al. (2018) who reviewed 35 countries and certainly point to the need for further research. Despite identifying trials in 18 countries, it is evident in Figure 1 that the vast majority of AV trials have been located in Northern and Western Europe where higher GDP per capita is reported: United Kingdom (18%), Germany (17%), France (16%), Norway (10%) and Sweden (6%), while Switzerland is ranked lower with around 6% out of the total number of trials included in this chapter analysis. Not surprisingly, there are even intra-country differences as the example of Germany demonstrates, where 14 trials were completed or ongoing by the end of 2020 (BMVI, 2020). As mentioned by Canitez et al. (2018) and also shown in Figure 1, there had been only a handful of trials in Southern Europe and almost none in Eastern Europe until early 2020. Northern Italy is an exception due to its heavy industrialisation and links with the automotive industry, whereas more trials have been planned or taken place while this WG4 activity was being concluded at the last stage of WISE-ACT. So Figure 1 should be only perceived as a snapshot of this continuously evolving sector for both passenger and freight transport.

Figure 1: Geographical coverage of AV trials in Europe



This review also indicated that the trials identified have mostly focused on urban areas (62%) and campuses (16%), while the low volume of experimental settings in rural areas (7%) and highways (1%) is an issue which has not been widely addressed and should be the focus of future research (Thomopoulos et al., 2022). Equally important is the funding source of these AV trials. More than one third (38%) of the 80 trials included in this analysis have been co-/funded by various European Union programmes such as FP7, H2020, Interreg. The remaining 62% of projects have been funded by other agencies based on government subsidies or industry funding. These findings are aligned with Canitez (2021) who reported the WISE-ACT 2018 STSM outputs with 47% being funded by city authorities and 29% by national authorities. Equally interesting has been the fact that 65% of trials included in this WG4 activity have been carried out in roads with mixed traffic conditions. Such trials have been found to assist in offering further input for analysis, but also in allowing the general public to engage with ACT directly and understand the relevant challenges and opportunities (Paddeu et al., 2020). This is noteworthy because it contributes to conducting real-world testing, which may eventually lead to more widespread implementation if this corresponds with wider policy objectives.

90% of the trials included in this chapter, used SAE levels of automation higher than Level 2. 29% tested Level 3 automation, 52% tested Level 4 automation and 11% tested Level 5 automation. However, it should be noted that a lot of AV trials have taken place in protected environments such as airports, technology parks, University campuses i.e. SAE Level 4 automation. Vehicles used in AV trials varied, but despite the use of some Personal AVs or Autonomous buses, the majority used shuttles of variable capacity, between 4-15 passengers per vehicle.

In summary, the AV trials approach deployed in several countries provides valuable insights and real-world evidence. This is in line with the WISE-ACT suggestions (Canitez et al., 2018; Canitez, 2021), yet a more co-ordinated approach is required. Thus, WISE-ACT MoU Task 11 has suggested providing a taxonomy to facilitate such an approach and share best-practice. This would also be helpful regarding ACT simulation and ODD – Operational Domain Design (see WISE-ACT WG5 Thematic Report). A range of indicators need to be developed, covering all key areas of policy and sustainability. A sample suggestion may include:

- Geographical indicators e.g. area type: urban, rural
- Economic indicators e.g. ACT trial funder: national authorities, EU
- Transport indicators:
    - Vehicle type e.g. Private AV, AV Shuttle
    - SAE level of automation 0-5
    - Traffic environment e.g. ACT dedicated lanes, mixed traffic, highways
- Environmental indicators e.g. use of automated EVs (see Nikitas et al., 2021)
- Social indicators e.g. fellow passengers in a SAV – Shared AV (see Polydoropoulou et al., 2021)

As AV trials continue to be conducted and as best-practice, but also unsuccessful trial experiences, are being shared, it will be possible to further develop this WISE-ACT taxonomy and assist local, national and international policy makers to take better informed decisions.

Industry Outlook

Navya trial in France without a safety operator onboard | Copyright: Navya

Different countries are adopting different ACT deployment policies and approaches, varying according to wider policy objectives, environmental targets and funding available. As Shiftan et al. (2021) have highlighted though, it is the user perspective that is missing. On a positive outlook based on the review and analysis of this chapter, AV shuttles have the potential to form a deployment template for public transport.

Applied Autonomy trial in Kongsberg, Norway | Copyright: Applied Autonomy

The EasyMile trials in Trondheim and Kongsberg in Norway offered valuable insight to key scheme partners such as Applied Autonomy. Due to the low speeds of the AV shuttle (16km/h), it was decided to only travel on roads with low speed limits e.g. up to 30k/h. To address technical challenges while serving travel demand, a DRT (Demand Responsive Transport) service was offered. Furthermore, conducting the trials in Norway allowed to test the vehicles in different weather conditions, including rain and snow. Similarly, Navya and Keolis have conducted AV shuttle trials without a driver or safety operator onboard in Châteauroux, France, providing user evidence through revealed data experiments in contrast to the stated preference data WISE-ACT survey distributed across 25 countries (Kyriakidis et al., 2020).

More trials are required, both at small and large scale. The H2020 SHOW project provides insight about relevant issues through pilot site trials in its mega-sites, satellite-sites and follower-sites across Europe.

Chapter 6
Conclusions: Policy Recommendations and Future Research

This WG4 Thematic Report focused on user attitudes and preferences to evaluate transport system demand issues. In such it addressed the respective WISE-ACT MoU Tasks 9, 10 and 11 (see Chapter 1).

Despite the widespread view that shared AVs (SAV) may contribute in addressing wider sustainability goals e.g. congestion and emissions reduction, ride sharing remains an unclear area within the AV domain. Findings of the WISE-ACT survey (Kyriakidis et al., 2020) imply that the adoption of shared AVs may differ across cohorts, whereby young individuals and individuals with multimodal travel patterns may be more likely to adopt them. Linking AV deployment with technology acceptance and environmental goals appears to obtain better outcomes, so it is suggested to adopt such approaches.

This report has demonstrated that research findings are consistent regarding the vital role of attitudes in the acceptance of AVs. Nevertheless, a lot of existing studies are based on survey questions which have been developed without theoretical underpinnings. Future studies could be improved by studying the interaction between attitudes and AV acceptance from a clear theoretical framework such as TAM, UTAUT and AAM. A full operationalization of such theoretical models in the field of AV acceptance remains limited.

Furthermore, although the empirical basis is growing quickly, the vast majority is based on not representative data often limited to very particular case studies. Researchers and practitioners urgently need more representative datasets and more comparative studies to understand cultural differences in AV acceptance (Etzioni et al., 2020; Polydoropoulou et al., 2021), which has been one of the key recommendations of WISE-ACT.

Moreover, a set of clear policy recommendations can be formulated on the basis of existing studies:

- Before the general public decides to use AVs, they must first perceive them as useful and trust such vehicles. Especially safety concerns seem to have been a factor of distrust until 2020. In order to change this, information and user experience are key. The WISE-ACT suggestion is to first inform people about AVs and then let them experience AVs, not only in driving simulators and controlled testbeds but also in real-life situations to which people can relate e.g., the autonomous bus services in Stockholm, Sweden (Guo et al., 2020). This stepwise approach of first informing and then experimenting also conforms with models of attitudinal and behavioural change such as MaxSem (Van Acker et al., 2012).

- When designing such information and experimental campaigns, it is advisable to take different personalities into account. Personality itself has no direct effect on AV acceptance, but it is associated with attitudes towards AVs. A personality segmented campaign can thus lead to better results.

- AV acceptance is not only influenced by attitudes towards AVs, but also towards other objects, especially the environment and technology in general. Combining projects and research about AVs with climate change for example, can increase impact.

- AV trials provide valuable insight, particularly when combined with Living Labs. Living Labs are an innovative approach used across Europe in the past decade, where (potential) users of a technology or service are directly involved in the development of new technologies or services at their early development stages. Sharing both successful and unsuccessful experiences is crucial to facilitate further development of the WISE-ACT taxonomy and to assist local, national and international policy makers to take better informed decisions.

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