Deliverable 1.1

Mobility needs and requirements of European citizens

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Executive Summary

Mobility innovations, such as CCAM solutions, can provide services that better fit the specific needs of populations with transport disadvantages (Butler et al., 2020). To design the most beneficial CCAM solutions and, foremost, to prevent exclusion for any type of user, it is necessary first to gain knowledge about those specific user needs. To close this knowledge gap, create an application framework, and provide a basis for the subsequent tasks and the work packages of the SINFONICA project, an extensive literature review was carried out.

Basic psychological needs, like the need for competence, autonomy, or (social) relatedness, as well as instrumental (e.g., speed, financial costs), symbolic (e.g., expression of self, and social position), or affective (e.g., pleasure, relaxation) motives form travel behaviour and mobility needs. Other impacts on mobility needs are the users' characteristics (e.g., physical, abilities, socioeconomic), situational factors (e.g., rural/urban location, trip purpose, vehicle ownership), attitudes, social context (e.g., influence of peer groups) and habits (e.g., main transport mode regularly used). Thus, within the SINFONICA project, needs are defined as all physical or psychological user-related requirements towards mobility solutions, like CCAM, that arise from users' individual psychological needs, characteristics, and situational factors and determine the (intention to) use.

Derived from the literature, four groups of mobility needs are described as a prerequisite for equity in transportation: availability, accessibility, affordability, and acceptability (Arup, Urban Transport Group, 2022; Shrestha et al., 2017). In addition, the research groups within SINFONICA, involving people with different mobility challenges, were described regarding their specific transportation barriers and respective background factors.

Following, gaps where mobility needs are not met and offer the potential to be filled by CCAM solutions as well as general CCAM requirements were derived as literature-based hypotheses by comparing the four groups of mobility needs with the research groups. As a result, the most important categories of mobility needs for the different research groups emerged as follows:

- Low-income and unemployed: Availability, Affordability;
- Elderly: Availability, Accessibility, Acceptability;
- People with disabilities: Availability, Accessibility, Acceptability;
- Migrants, ethnic minorities and people with language barriers: Availability, Acceptability;
- Young people: Availability, Acceptability;
- Women and gender-related aspects: Availability, Accessibility, Acceptability;
- People living in rural areas: Availability, Acceptability;
- Digitally non-connected people: Availability, Accessibility, Affordability.

These hypotheses will be evaluated in subsequent SINFONICA work packages to identify the most significant potential of CCAM solutions.

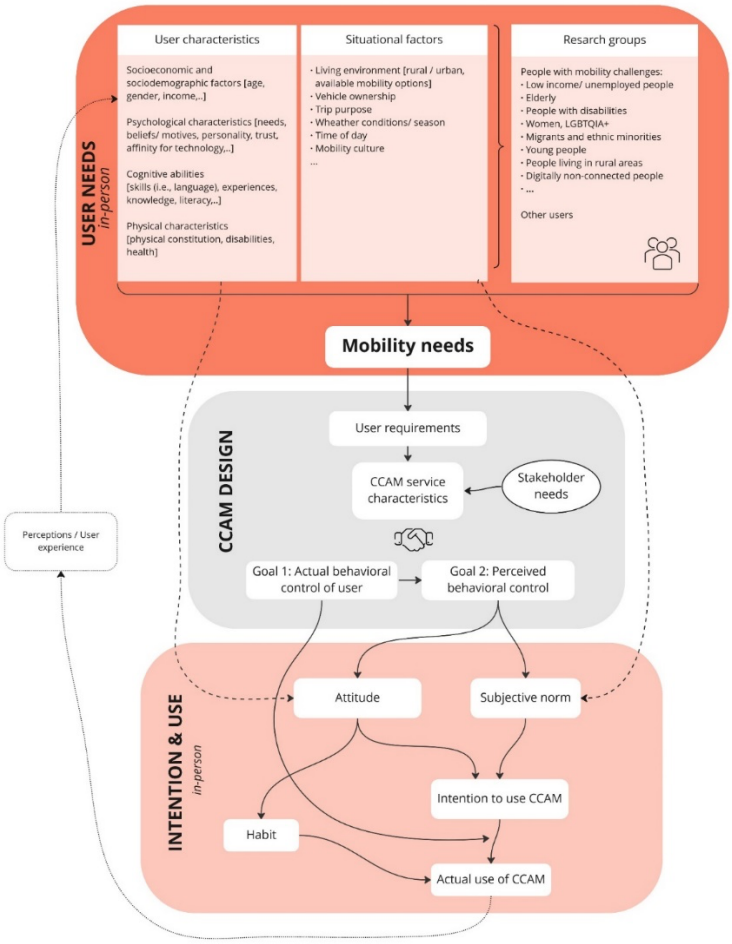
Dependent on how future CCAM solutions are able to address the needs of specific user groups through their service characteristics, they provide the option to use. On the user side, having this new transport option is perceived, ideally, as expanding the users' behavioural options with regard to transportation. If these actual (objectively available options) and perceived behavioural controls

(having the skills and opportunity) are high, then an intention to use can be formed, and subsequently actual use can be expected.

As a result of the literature review a general theoretical framework (see figure below) of the mobility needs relevant to CCAM is set up. The framework is based on three levels: 'Mobility Needs', 'CCAM Design requirements', and 'Intention & Use':

- *Mobility needs* are a combination of users' individual characteristics and situational factors and determine the users' requirements towards CCAM service characteristics,
- *CCAM Design requirements* contain the user requirements towards CCAM service characteristics that arise from mobility needs.
- *Intention & Use* describes the process of forming an intention to use and actual use of CCAM solutions.

Indeed, according to an extended version of Ajzen's theory of planned behaviour (Ajzen, 1991), the process of forming an intention to use and actual use of CCAM solutions is based on the users' individual and situational factors, attitudes, and subjective norms. An intention to use is formed and translated into actual behaviour, dependent on perceived behavioural control, actual behavioural control, and habits.



SINFONICA Framework – a general theoretical framework about mobility needs relevant to CCAM solutions, own illustration

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Abbreviations

AV	Automated vehicle
BAME	Black, Asian and Minority Ethnic
CAV	Connected, automated vehicle
CCAM	Connected, cooperative and automated mobility
Dx.x	Deliverable x.x in SINFONICA
EU	European Union
LGBTQIA+ questioning, Asexual	Lesbian, Gay, Bisexual, Transgender, Intersex, Queer/
PTW	Powered Two-Wheeler
TAM	Technology Acceptance Model
TPB	Theory of Planned Behaviour
Tx.x	Task x.x in SINFONICA

UITP Association of Public Transport	Union Internationale des Transports Publics / International
UTAUT	Unified Theory of Acceptance and Use of Technology

1 Introduction

1.1 Goal of this document

The vision of SINFONICA is to develop functional, efficient, and innovative strategies, methods, and tools to engage CCAM users, providers, and other stakeholders (e.g. citizens - including people with mobility challenges - transport operators, public administrations, service providers, researchers, vehicle, and technology suppliers) to collect, understand and structure their needs, desires, and concerns related to CCAM in a manageable and exploitable way. SINFONICA will use this knowledge to co-create final decision support tools for designers and decision makers with the scope to enhance its seamless and sustainable deployment, to be inclusive and equitable for all citizens.

In this deliverable, the mobility needs and the psychological backgrounds of different groups relevant to the project (e.g. low-income, elderly, people with disabilities) are analysed by a literature review as well as by reviewing existing reports and projects.

A focus is put on gaps where certain mobility needs are not met, which could be potentially filled by CCAM solutions, with regard to different user groups, as mentioned prior. The main output of this task is a general theoretical framework that will guide the next project tasks, especially the co-creation and data collection activities in Trikala, Hamburg, West Midlands metropolitan area, and in the province of Noord-Brabant. The results of this deliverable also input the task on structuring end-users and stakeholders' needs and interrelations in a taxonomy (T1.3). In addition, this deliverable serves as a base for the task where both the research and target groups will be defined (T1.4). For a more complete overview of the tasks within work package 1, see Table 4 in the Appendix. Regarding the further work packages of SINFONICA, this deliverable will also be relevant input for the data collection activities (D3.2), the equity practices and social indicators (D5.1), the CCAM solutions and vulnerable user: Opportunities and constraints (D5.2) and the vision policy recommendations for user-centric CCAM (D5.3).

1.2 Intended audience

The target groups for this deliverable are all SINFONICA partners and stakeholders of the project. In addition, researchers with a focus on CCAM or smart mobility solutions can benefit from the literature review as it reflects the current state of knowledge. Based on this overview, a framework is given for persons, authorities, institutions and manufacturers aiming to consider user needs to develop and build CCAM solutions and fulfil unmet mobility needs.

1.3 Structure of this document

The deliverable is structured as follows: after the introduction sections in chapter one, the second chapter 'Psychological background of (mobility) needs', describes key concepts and factors from the perspective of traffic and transportation psychology, elaborating on how the term 'Mobility needs' can be defined for subsequent tasks and work packages. This section describes the base level 'Mobility needs' of the SINFONICA framework in more detail. The third chapter is about the SINFONICA research groups, current findings on their specific mobility needs, and the resulting requirements towards mobility. Building up on this, the fourth chapter, 'CCAM design

requirements', presents the requirements for CCAM solutions corresponding to the mobility needs. This chapter reflects the transition between the 'Mobility needs' and the 'CCAM design' level of the SINFONICA framework. Chapter five 'Intention and behaviour formation', includes aspects of the 'Intention & use' level of the framework, describing the theory of planned behaviour as an explanatory model towards the intention to use CCAM and the actual CCAM use. In addition, the concept of habit is explained, and why it might be relevant in the context of CCAM. Chapter six presents the developed SINFONICA framework as a whole with short descriptions of every level.

1.4 Background and motivation of this document

The SINFONICA project, and thus this deliverable, focuses on Cooperated, Connected, and Automated Mobility (CCAM) in the public transport sector that allows vehicles, transport infrastructure, and other road users to communicate and coordinate (see also vocabulary in Deliverable 1.2). Smart mobility, which includes CCAM public transport solutions, is expected to lead to a future where mobility changes the way transportation is conceived[1]. SINFONICA aims to facilitate the shift toward innovative, smart mobility concepts in an inclusive and equitable way.

Before addressing the relevant concepts and theories of user needs of European citizens, it is necessary to consider equity as a fundamental right for providing mobility solutions. Within the SINFONICA project, D5.1 will focus more specifically on the best practices in social equity with respect to smart mobility, focusing on CCAM solutions and issues.

In the EU Charter of Fundamental Rights, the rights to equality before the law; non-discrimination; cultural, religious, and linguistic diversity; equality between women and men; the rights of the child; the rights of the elderly, and integrations of persons with disabilities are set (article 20-26)[2]. With this common foundation of rights to equity, CCAM systems must follow these rules. More importantly, future mobility must also provide equity, especially for people with mobility challenges, such as the elderly, the disabled, those with low incomes, and many others. In contrast to equality, which aims to provide equal resources to each individual or group, equity means acknowledging that different user groups face relative disadvantages. These disadvantages must be understood and taken into consideration when designing future mobility systems (European Commission, Directorate-General for Mobility and Transport et al., 2022a).

More specifically, the International Association of Public Transport (UITP) adopted a declaration to include everybody in public transport[3] (Lecco declaration) in July 2022. This declaration encompasses the following principles, which are highly relevant for equity in the transport system and are partly a result of the EU project TRIPS (see for more detail 2.2.4).

- Freedom of movement is a human right and personal mobility should be a guarantee to all.

[1] smartcitiescouncil.com

[2] https://ec.europa.eu/info/aid-development-cooperation-fundamental-rights/your-rights-eu/know-your-rights/equality_en

[3] https://www.uitp.org/news/uitp-signs-declaration-improving-user-accessibility/

- Mobility is related to other rights such as participation, access to education and employment.
- Public transport supports social and environmental policies and values. It connects places and people and fosters social and economic development. Everyone should be able to use it.
- Technological developments have the potential to reduce or overcome access barriers, providing new solutions.

These principles imply that not meeting equity standards and goals can lead to several societal disparities, including social exclusion. In the context of mobility, transport poverty might be such a consequence, which can be defined as an inability of an individual or a household to access essential transport services due to the lack of alternatives to cover the distance between the place of departure and the destination (Mejía Dorantes & Murauskaite-Bull, 2022). Besides financial disadvantages caused by the increased transport expenditure, people affected by transport poverty might be prone to social exclusion if they have to give up certain activities and, thereby, professional and education opportunities (Mejía Dorantes & Murauskaite-Bull, 2022). This, for instance, might result in a limited choice of schools for children from families with low socioeconomic status if the distance between their homes and the education facilities is large (Li & Zhao, 2015). Due to the high costs of owning and using a private car, transport poverty is often determined by the availability of affordable and reliable public transport options.

Therefore future CCAM public transport systems, such as shared automated vehicles and mobility on demand, offer the chance to mitigate transport poverty and provide opportunities for improved accessibility and availability of transportation options (Shaheen et al., 2022). However, if equity aspects are not considered when designing, planning, or installing those systems, contrary effects might occur, and social exclusion could increase. For these reasons, future mobility services must be affordable, inclusive, and available not only (but also) in highly educated, densely populated, high-income urban communities (Shaheen et al., 2022). Besides social aspects, increased equity in CCAM public transport systems might also lead to further beneficial consequences such as higher well-being (Vella-Brodrick & Stanley, 2013).

2 Psychological background of mobility needs

Travel behaviour and mobility needs are impacted by various factors such as basic psychological needs, motives (e.g., getting from A to B within a specific time), attitudes, social context, user characteristics, habits, and situational factors. This section gives an overview of these concepts relevant to CCAM solutions and describes how those concepts relate to each other and the formation of mobility needs.

2.1 Needs and motives

In an everyday understanding, a need expresses that something is missing in combination with the desire to satisfy the need. There are numerous psychological theories on *needs* and motivation to date (e.g., Ajzen, 1991; Alderfer, 1969; Deci & Ryan, 2000; McClelland, 1985). All those theories tried to describe motivation or what "moves" people to action (Deci & Ryan, 2000).

Within the theories of motivation, some considered the concept of physiological needs (e.g., hunger/ thirst) and needs that arise from psychological processes (Ryan & Deci, 2017). The basic psychological needs theory[4] proposes a core set of three universally essential human needs (see Figure 1) independent of cultural settings and prerequisites for self-determined motivations. These three basic needs foster "growth, integrity, and well-being" (Ryan & Deci, 2017, p. 10). The first of these three is the need for *competence*, in other theories labelled "self-efficacy," which describes the experience of efficacy in interactions (Ryan & Deci, 2017). The second need for *autonomy* includes the experience of integration and freedom when behaviour conforms to inner beliefs and is attributed to a certain task significance (Ryan & Deci, 2017). The third innate need, the need for *relatedness*, expresses the desire to connect to others and to be part of social groups (Ryan & Deci, 2017). The satisfaction of these basic needs can facilitate self-determination. *Self-determination* means acting intrinsically motivated out of free commitment and individual interest, despite possible difficulties (Ryan & Deci, 2017). Therefore, the concept of self-determination might also be promising in the context of CCAM, especially in relation to people with mobility challenges (section 3). On the other end of the self-determination continuum are controlled motivations resulting from external pressure, forces, instrumental reasons, like material outcomes (Ryan & Deci, 2017). The literature review within a study by Zhang et al. (2019) showed that each of the three basic psychological needs can more or less facilitate self-determination. They report that for psychological barriers, rather than objective barriers, autonomy is most significant for self-determination, whereas competence or relatedness are much less relevant (Koestner et al., 2015). In contrast, when the barriers are mainly objective rather than psychological, competence and relatedness can play a more significant role in self-determination than autonomy (Bidee et al., 2017; Custers et al., 2012).

Other theories proposed additional basic psychological needs, e.g., Sheldon et al. (2001) described ten candidate needs, three of which are identical to the needs proposed by self-determination theory. The remaining seven needs include: physical thriving, influence, self-actualization/meaning, self-worth, popularity, security/safety, and pleasure/stimulation.

Figure 1: Three basic psychological needs as proposed by Ryan and Deci (2000)

In contrast to the concept of needs, *motives*, in the sense of desires or fears, provide reasons for specific actions and, at the same time, are directed towards a desirable goal (Nuttin, 1984). Motives can be salient (explicit) or not consciously present (implicit) (Ryan & Deci, 2017).

[4] The basic psychological needs theory is one of the mini-theories within the self-determination theory, see Ryan and Deci (2017).

A big part of the studies on acceptance of and preferences for using automated vehicles focused on instrumental motives, e.g., speed, financial costs, accessibility, travel time, and other service characteristics (Correia & van Arem, 2016). But as studies on car use and ownership revealed, also symbolic motives, e.g., prestige, expression of self, and social position, as well as affective motives, that describe emotions evoked by using a vehicle (e.g. pleasure, relaxation) can have significant effects on travel behaviour (Steg et al., 2001; Steg, 2005). As a factor analysis by Steg (2003) showed, all three motive dimensions are not independent but rather influence each other. Regarding car use, Gardner and Abraham (2008) assume that affective motives, in turn, could impact attitudes, perceived control, and intention formation (Ajzen, 1991) (see section 5).

A household survey by Steg (2003) points to the potential of public transport in comparison to privately owned car use regarding the instrumental aspects of convenience, independence, flexibility, speed, and reliability, as well as regarding the affective motive pleasure and the symbolic motive status. Here cars were judged more positively in comparison to public transport, indicating that it might be beneficial for the attractiveness of CCAM to address these motives when designing such services explicitly.

In addition, a study by Gatersleben and Uzzell (2007) that compared the modes of driving, cycling, walking, and using public transport for commuting, shows that the negative perceptions of public transport users are linked to the experiences of loss of control (through delays or congestion), boredom and stress. One implication for a public transport CCAM solution might be to create a more arousing experience that emphasizes the benefits of relaxation (e.g., the ability to read, listen to music, or look at the passing scenery) and excitement (e.g., interacting with others) (Gatersleben & Uzzell, 2007).

Also, the EU-project REBALANCE (Schaefer & Schade, 2021), aiming at exploring mobility culture, emphasizes the role of instrumental, affective, and symbolic values broadening the view from driving motives (Steg et al., 2001) to general motives for mode choice (Table 1) (see also appendix with an overview of several related EU projects).

Table 1: Mobility motives adapted from driving motives (Steg et al., 2001), following Schaefer and Schade (2021)

Instrumental motives	**Symbolic, socially expressive motives**	**Emotional, intrinsic, affective motives**
Transport motive Reachability and accessibility Availability at any time Time savings Low travel costs Reliability Comfort/convenience Security Safety Environmental, health, social benefits (or no harm)	Communication of status, prestige Superiority, power Fulfilment of social norms/expectations Social participation/contact Freedom of choice over privacy and contact Equality of opportunity in social comparison, no sense of disadvantage (equity)	Freedom of choice Feeling of independence Sense of control, ability to plan and orientation Self-activity (activation value), self-expression and self-esteem

Instrumental motives	Symbolic, socially expressive motives	Emotional, intrinsic, affective motives
	Communication of ecological, health, social benefits	

2.2 User characteristics

Individual user characteristics and their interplay impact people's needs and motives and are, therefore, also significant in the context of CCAMs. The user characteristics can be further divided into the following factors:

- Socioeconomic and sociodemographic factors,
- Psychological characteristics,
- Cognitive abilities, and
- Physical characteristics.

Apart from this single-factor listing, transport research showed that user characteristics could also be clustered to describe different mobility types (Hauslbauer et al., 2022), which can help define the various user groups resulting from the single factors.

For the SINFONICA project, special research groups evolve from the four municipalities, as described in more detail in section 3.

Socioeconomic and sociodemographic characteristics include *age, gender, marital status, social context, household size, education level, employment, and income status*. The latter three determine an individual's socioeconomic status. These classifications are widely used in mobility research as socioeconomic and sociodemographic differences indirectly influence mobility behaviour, especially mode choice and travel behaviour (Rachele et al., 2015). Regarding gender-related aspects, research results in differences between men and women, e.g., a higher need for safety and security in women than men (Innovate UK, 2022). A person's age plays a significant role in travel behaviour as well. For example, Mikkelsen and Christensen (2009) point out that children's mobility patterns are pretty diverse. The elderly experience various challenges in their mobility, e.g., due to declined physical or cognitive abilities (GOAL, 2013). This exemplary research stresses the importance of socioeconomic and sociodemographic characteristics for travel behaviour and mobility in general. As several research groups, e.g., low-income and unemployed people, within the SINFONICA project arise from those characteristics, these groups are discussed in more detail in section 3.

Psychological characteristics describe a person's *needs*, *beliefs/motives,* and *personality* traits. In the context of CCAM, *trust, affinity for technology,* and *technology adoption* are relevant. Basic needs, such as the need for autonomy and motives/beliefs like time savings or social participation, strongly influence travel behaviour, and thus also the use of CCAM. Section 2.1 is dedicated to these essential psychological background factors, discussing them in detail. In addition, motives/beliefs form the base of attitudes, norms, and behavioural control, components of the intention and behaviour formation process described in section 5.

Research on the influence of personality traits, such as openness to experience, neuroticism, extraversion, agreeableness, conscientiousness, or environmental personality, on travel behaviour and mode choice, is relatively scarce (Roos et al., 2022). The few research results indicate that a more agreeable, pro-environmental, and not-conscientious personality is positively related to public transport use (Roos et al., 2022).

Especially in the context of autonomous vehicles, technology adoption theories like the technology acceptance model (TAM) (Davis et al., 1989) and the unified theory of acceptance and use of technology (UTAUT) (Venkatesh et al., 2003) have gained importance. Studies already demonstrated technology acceptance as a predictor for the intention to use autonomous bus shuttles (e.g., Wicki et al., 2019). Following technology adoption theories, the main factors for the adoption of CCAM are performance expectancy, reliability, security, privacy, and trust. Trust, as one factor in the context of technology acceptance, expresses the user's willingness to take a vulnerable position by using the technology due to the expectation of a positive outcome/experience (Mayer, 1995 as cited in Kaur & Rampersad, 2018). As Kaur and Rampersad (2018) demonstrated, trust positively influences the adoption of driverless cars. By performing inductive content analysis, Launonen et al. (2021) described the following subcategories of trust in technology toward autonomous bus shuttles: “Autonomous vehicle as a future solution,” “Human error,” “Automated driving errors,” and “Interest in technology.” On the same basis, the authors describe the following trust level indicators: “Confidence,” “Curiosity,” “Calm,” “Excitement,” “Fear,” and “Interest” (Launonen et al., 2021). Furthermore, the results indicate that attitudes towards autonomous vehicles are more positive if trust in technology, in general, as well as the perception of safety and security are high (Launonen et al., 2021).

Cognitive abilities describe a person’s *skills* (e.g., language, working with digital devices), *experiences* (e.g., with public transport), *knowledge* (e.g., regarding the technical background of autonomous mobility), *mental models* (i.e., functioning of public transport), *literacy,* and *intelligence*. As studies confirm, various skills (e.g., language skills, skills associated with digital services) can be a barrier to using public transport or certain services, e.g., online ticket purchase or service schedule updates (Dabelko-Schoeny et al., 2021). These skill dimensions are of great importance for the user groups “Elderly” and “Migrant and ethnic minorities” and therefore are discussed in more detail in section 3.2 and 3.4. Mental models, which are also closely related to knowledge and habits, help navigate the world by representing of how things work and can be used (Allen, 1997). If people lack an accurate mental model of public transport due to a lack of knowledge about public transport (e.g., because their current main mode of transport is the car or because they are new to the country), they might be unaware of this mobility option and consequently less likely to use it. Thus, the introduction of CCAM must be accompanied by information campaigns to raise awareness to this new transport option. This is especially important for groups not using public transport at present, e.g., “Elderly”, “Migrant and ethnic minorities”, “People with disabilities” or “People living in rural areas”. In addition, studies focusing on the acceptance of autonomous vehicles showed that higher knowledge of the technological aspects of autonomous driving predicts a higher acceptance or intention to use autonomous mobility (Charness et al., 2018; Pigeon et al., 2021). In order not to exclude people with cognitive or intellectual disabilities, e.g. low literacy, the CCAM solution must provide accessible information (Article 9 of the Convention on the Rights of

Persons with Disabilities[5]). The European standards for making information easy to read and understand[6] can be used as a guideline in this regard.

Physical characteristics

One person's physical characteristics are determined by the *overall health constitution*, *physical disabilities*, and *physical constitution*. The overall health constitution can vary broadly for different user groups. For example, the age-related decline in physical abilities and occurrence of various health impairments at the same time can lead to mobility challenges, e.g., limited walking ability paired with hearing loss (GOAL, 2013). The group of elderly users therefore forms one of the SINFONICA research groups discussed in more detail in section 3.2. Physical disabilities, e.g., vision and hearing impairments, or limited physical mobility are of relevance for all age groups and are often associated with assistive devices (e.g., white cane) or the need for a chaperon. People with physical disabilities often experience barriers in public transport, which, in turn, limits their community participation (Bezyak et al., 2020). In addition, the physical constitution, i.e., height and weight of the users can lead to implications for (public transport) CCAM requirements. Children or wheelchair users, for example, might have a need for low handles or stop request button positioning. Therefore, especially "People with disabilities" as one of the SINFONICA research groups are discussed in section 3.3.

2.3 Situational factors

Besides the user characteristics, situational factors also contribute to shaping the users' mobility needs. In the following, the most relevant situational factors are described.

The *living environment* relates to the user's location, ranging from urban to rural, and includes the available mobility options that determine the infrastructural connectivity and access to various means of transport. Especially, a location outside a major city can be a barrier to using public transport due to non-availability, poor service schedules, or long distances to service stations and, thus, a form of mobility-based social exclusion (Lucas et al., 2018; Mattioli, 2021). As this situational factor is of such great importance in the context of users' mobility needs, one of the research groups represents "People living in rural areas," described in more detail in section 3.7.

Another situational factor is *trip purpose*, e.g., commuting, running errands, accompanying others (e.g., children, elderly), recreational travel. It is apparent that depending on the trip purpose, different mobility needs gain more or less importance. For example, travel time might be a key factor for work-related trips, whereas accompanying others may require certain trip chains. The factor of trip purpose also highlights that the users' mobility needs underlie dynamic changes and highly interact with user characteristics, such as gender (see section 3.6) or age (see sections 3.2 and 3.5).

[5] https://www.un.org/development/desa/disabilities/convention-on-the-rights-of-persons-with-disabilities/article-9-accessibility.html

[6] https://www.inclusion-europe.eu/wp-content/uploads/2017/06/EN_Information_for_all.pdf

Vehicle ownership/ availability of bicycles, e-scooters, cars, or PTWs in a household expands users' mobility options and thus impacts users' mobility needs. Having more mode choice alternatives through ownership or shared use decreases the requirements or even dependence on public transport. For example, while cyclists or e-scooter riders might need to take their vehicles on public transport to chain trips, car owners in peripheral areas might be dependent on their private vehicles due to the non-availability of public transport options. As vehicle ownership, especially car ownership itself, strongly depends upon income level (Dargay et al., 2008; Nolan, 2010), public transport could contribute to social inclusiveness by fulfilling the mobility needs of people with low socioeconomic status or people unable to use individual mobility solutions (see also 3.1, 3.3, and 3.4).

The current weather/season and time of day can be summarized as *environmental conditions* that can also impact users' mobility needs. Travelling by public transport in the dark might be a barrier to some users, e.g., women or LGBTQIA+[7] people (see 3.6), whereas, the weather/season can play a significant role for other users, e.g., the disabled or the elderly, as they might not be able to wait at a station in bad weather for a longer time and might instead have a higher need for on-demand services.

Mobility culture, as another situational factor, consists of people's travel behaviour, the infrastructure, transport design, the mobility-related discourses in society, and the policies that provide the legal framework for mobility, e.g., through planning practice (Deffner et al., 2006). Mobility culture is not uniform throughout the EU. Still, it can be clustered into different European mobility culture groups (car-oriented, transport-oriented, and cycling-oriented) (Haustein & Nielsen, 2016). Similar to vehicle ownership (see above), depending on the primary transport mode, there might be different mobility needs and, thus, different requirements towards public transport and CCAM solutions. A PTW rider or cyclist may need a covered parking space next to a station, while a higher availability of public transport could provide forced car drivers (e.g., in peripheral areas) a real mode choice.

2.4 Defining mobility needs

Mobility can be considered at different levels: from a global perspective, simply as the ability to move or as a temporal change of location (Flade, 1994), or from a more specific view as forced or voluntary transportation (Schaefer & Schade, 2021). In the Eltis[8] glossary and SINFONICA D1.2, mobility is defined 'as the potential for movement and the ability to get from one place to another using one or more modes of transport to meet daily needs'. In the light of CCAM, this definition addresses daily forced transportation mobility (e.g., systematic and non-systematic trips like work, school, or errand-related, getting to leisure activity places, etc.) where location changes come with a functional movement.

In describing mobility needs, many terms, such as 'transport,' 'transportation,' 'travel,' and 'user,' needs, as well as 'determinants' or 'barriers' are used in parallel in the literature (e.g. Butler et al.,

[8] Eltis - The Urban Mobility Observatory (www.eltis.org)

2020). Sometimes the terms describe what can be understood as "basic" or "psychological" needs (see section 2.1). But in most cases, the terms are used to describe user requirements for the transport system as whole or specific travel modes and their design, e.g., public transport.

As illustrated in the previous paragraphs, mobility needs can be approached from two angles: first as “needs for mobility” to change location, e.g. work-related, to run errands, and second more in the sense of “mobility needs towards transport”. The second meaning applied in the SINFONICA project refers to mobility needs as requirements for the transport systems, describing the user needs that must be met to use the service.

> Mobility needs can be defined as all physical or psychological user-related requirements towards mobility solutions, like CCAM, that arise from users’ individual psychological motives, characteristics, and situational factors and determine the (intention to) use. [SINFONICA project definition]

This definition implies that mobility needs derive from the combination of individual characteristics and situational factors. The transportation literature repeatedly cites four global groups of requirements/needs that must be met to achieve equity in transport: *Availability, Accessibility, Affordability,* and *Acceptability* (Arup, Urban Transport Group, 2022; Cirella et al., 2019; Dabelko-Schoeny et al., 2021; Millonig & Fröhlich, 2018; Shrestha et al., 2017). Designing CCAM solutions according to these formulated mobility needs addresses the three basic human needs for competence, autonomy, and relatedness. In the following, all four principles are described. To meet *Availability*, CCAM solutions must be within reach for the user, regardless of whether the user lives, for example, in a rural area or is unable to walk. Moreover, availability includes that the CCAM solution provides connections to destinations relevant to the user, operates when the user requires transport (travel and waiting time limited to a minimum), is linked with subsequent connections, and provides service information in a simple manner. *Accessibility* refers to the CCAM solution design, e.g., specific shuttle design, and the design of the respective infrastructure, e.g., hub or station. To enable all people to use a CCAM solution, the service, and its surroundings must be free of physical, skill, or equipment-related barriers. A CCAM solution that meets *Affordability* is transparent about the service's costs, provides easy access to prices, and makes payments easy to do. Similar to all mobility needs, affordability can also pose a travel barrier if unmet. To meet *Acceptability*, a CCAM solution must be convenient, safe, comfortable and provide assistance when required.

We built upon a visualization by Arup, Urban Transport Group (2022), and compiled an even more comprehensive overview of mobility needs and relevant questions guiding the design process of CCAM solutions, enabling equitable future mobility, as shown in Figure 2.

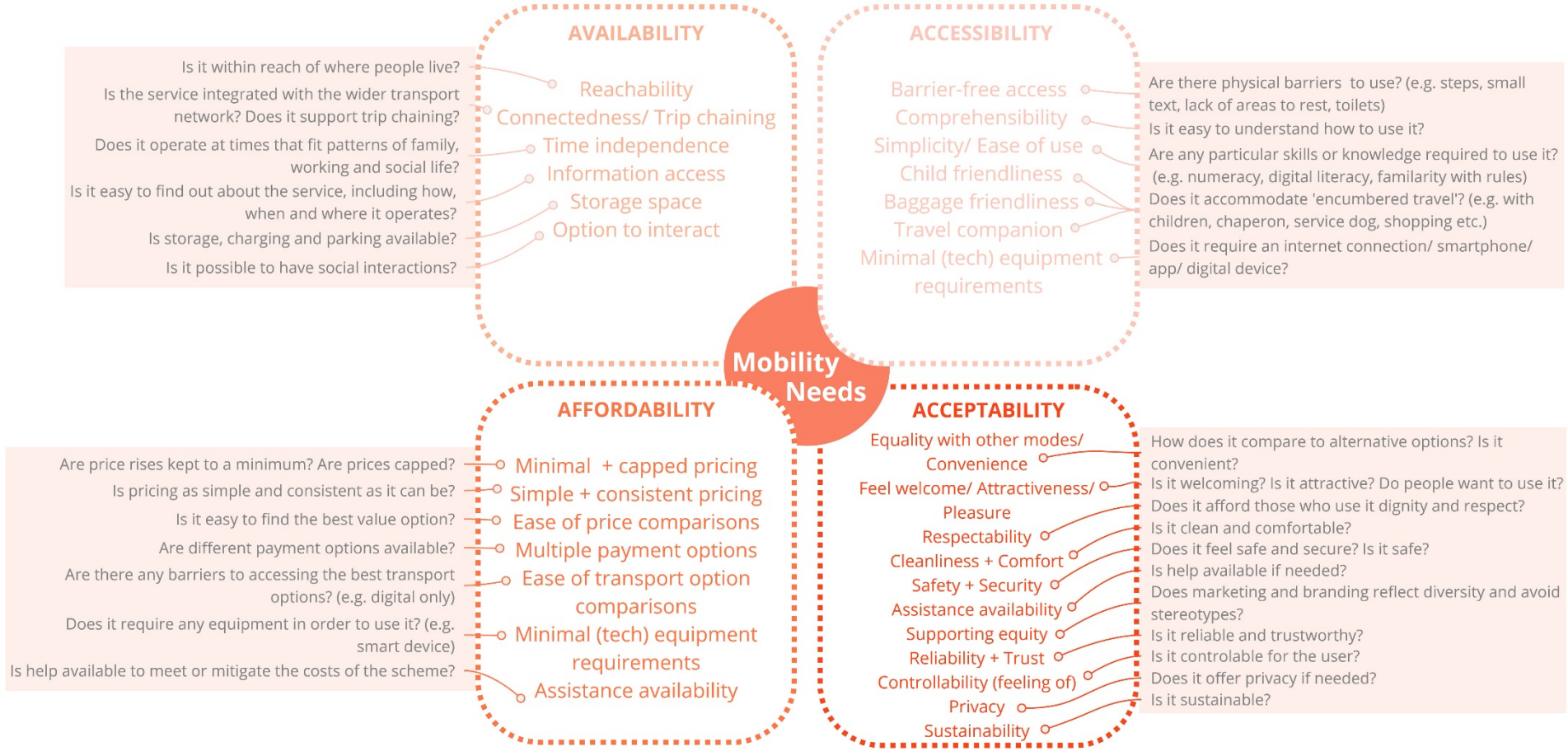


Figure 2: Mobility needs, adapted from Arup, Urban Transport Group (2022)

3 SINFONICA research groups: Characteristics, specific mobility needs, and user requirements

The mobility needs of CCAM users (and non-users) derive from combining their individual and situational factors when using mobility services. In the SINFONICA project, eight research groups (user groups) are defined by individual needs deriving from the combination of individual user characteristics (section 2.2) and situational factors (section 2.3). A variety of these groups and their mobility patterns were described in the context of future transport by the European Commission, Directorate-General for Mobility and Transport et al. (2022a; European Commission, Directorate-General for Mobility and Transport et al., 2022b). It includes a detailed description of women, citizens with poor IT literacy, persons with disabilities and reduced mobility, people living in remote areas, young people and children, as well as people with low income and those at risk of poverty or social exclusion.

The research groups in SINFONICA do not consider the complexity of the personal level of one person [e.g. an older man with visual impairments living in a rural area.] Instead, it defines a group of users with similar characteristics leading to group-related mobility needs. In real life, combinations of different groups can lead to even more significant mobility challenges. Besides, being a member of a research group does not automatically mean that the person is vulnerable or experiences mobility challenges. Lastly, mobility challenges exist for people who are not covered by these eight groups and should not be excluded by this categorization.

> Disclaimer: The eight SINFONICA research groups are not exhaustive to present all people with mobility challenges. Besides, a single person is often part of several groups and might experience combined mobility challenges.

3.1 Low-income and unemployed people

In the EU in October 2022, the unemployment rate was 6.4 % for women and 5.7 % for men, making up around 13 000 000 persons[9]. The unemployment rate is higher for younger people than for older people. On average, about 35 % of the working-age EU population at risk of poverty is not covered by the minimum income or other social benefits.[10] An obvious challenge for people with low or no income is the affordability of transport modes. Although public transport services offer in bigger cities perks to the monthly and annual fees for unemployed people, this benefit is not given everywhere. Especially in rural areas, problems arise due to a lousy provision of transport services (frequency and daytime), making it necessary to use individual mobility. However, many people do not have high enough salaries to afford a car, especially with the increasing energy and rent prices. Affordable prices for transport positively affect employment opportunities and access to basic services.

The psychological consequences of unemployment are negative feelings, dependence on job proposals, stress to adapt to the job market, dissatisfaction, stressful experiences in everyday life

[9] https://ec.europa.eu/eurostat/web/products-datasets/-/tepsr_wc170

[10] https://ec.europa.eu/social/main.jsp?langId=en&catId=1092

such as stigmatization and exclusion due to the reduction of financial resources, a decline of self-esteem, sadness, stress, and anxiousness. These phenomena result in higher rates of illness and suicide (Blakely et al., 2003).

The group of people having low or no income is very diverse. Besides the need for CCAM to be affordable, other requirements exist depending on the correlation of unemployment / low-income with other factors. Statistics show that unemployment rates are higher for young people, women, people with migrant backgrounds, and older persons. Fransen et al. (2019) developed a model to predict transport accessibility and unemployment. They showed greater chances in remaining unemployed when having reduced transport accessibility, migrant background, and higher age (above 55 years). In addition, low-income jobs can be related to working in shifts and the off-peak time for services like cleaning, fast food, retail, and sale of goods of daily use (Enchautegui, 2013). In these cases of non-standard working times and low income, several problems occur because a private car is not easily affordable and public transport availability at off-peak times is rare. With affordable and available CCAM solutions, these challenges could be met.

3.2 Elderly

The group of older people is not, per se, a group experiencing mobility challenges. Nevertheless, older people can become vulnerable if they experience changes in their everyday life or their physique that decrease their mobility. Therefore this group has a higher chance of being or becoming vulnerable. Getting older can be described from different perspectives (biological, psychological, sociological).

Biologically, with increasing age, the physical constitution of the body changes. Physical changes and health effects are, for instance, visual impairments, neurological impairments (e.g. Dementia), issues related to the cardiovascular system (e.g. exertion, hypertension), the respiratory system (e.g. chronic bronchitis) and the endocrine system (e.g. diabetes), as well as, musculoskeletal impairments (e.g. atrophy, muscle strength) (Freund & Smith, 2011).

Changes in the physical constitution also affect psychological domains with a decline in cognitive processes (attention, memory, problem-solving, information processing). With these changes, mobility options like car driving can become more challenging for older people because age reaction times increase, and the vast amount of information might not be adequately processed. For this reason, some countries require drivers to renew their driving licenses, for instance, in the UK or New Zealand.

From a sociological perspective, it is very important to consider the effects of birth cohorts (the year/decade a person is born). For some aspects, it is more important when a person is born rather than being a certain age. For instance, Koppel and Berecki-Gisolf (2015) that in Victoria (Australia), the share of people holding a driver's license with an age of 60 years was higher in the baby boomer cohort (b. 1946-1965) than in the cohorts that were born earlier. With this, the ageing of the baby boomer generation has a very high impact on mobility composition due to its size and the shares of licensed drivers. Besides, growing up in different decades means that experiences with transport systems differ. Consequently, (due to past habits and prior experiences) some elderly people might

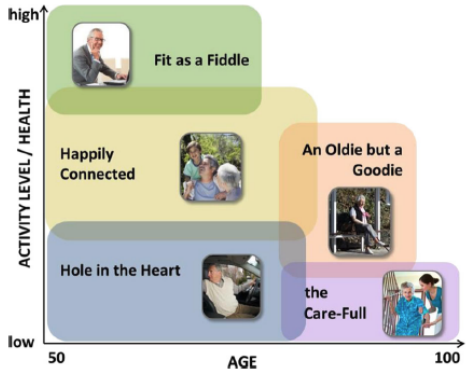
be more reluctant to use digital transport services and favour individual transport over public transport.

Some studies found that the impact of the social norm is higher for older people than younger people when experiencing automated vehicles (Launonen et al., 2021). In other words, becoming older is associated with the increasing importance of other people's opinions. Besides, the study of Launonen et al. (2021) also showed that older people considered automated vehicles as more beneficial when it comes to certain mobility challenges like having no driver's license and carrying goods. However, they also reported a wish for a board assistant if the bus had no driver.

In the EU project GOAL (Growing Older, stAying mobiLe: The transport needs of an ageing society), five different groups of elderly people were defined, as can be seen in Figure 3 (GOAL, 2013; Mandl et al., 2013; Shrestha et al., 2017). The group 'Fit as a Fiddle' is the youngest and most active group. The group named ‘Care-Full’ includes frail, impaired, and immobile elders who are dependent on the help of others. The members of the profile ‘an Oldie but a Goodie’ are quite mobile and independent despite their old age. The ‘Happily Connected’ group includes the fit, active, and satisfied elderly with excellent social networks, and the group ‘Hole in the Heart’ consists of older people suffering from mental as well as severe physical problems at younger ages' (GOAL, 2013).

Older people’s mobility patterns change: the number of trips to work decreases, and travel purposes associated with leisure activities, medical healthcare, and shopping increase. With this, also the trip frequency and distances change. Some further transport-related challenges arise for older people who have other vulnerabilities as well, e.g., a migrant background (Dabelko-Schoeny et al., 2021). While driving a car is the most common mode of transport for adults, this tendency drastically changes for people aged 65 years and above (see Figure 4) (Mobility in Germany, 2019). As shown in Figure 4, the total number of trips decreases for older people, which is the result of either reduced *or* unmet mobility needs. The review by Luiu et al. (2017) shows that research is ambiguous about whether older people's mobility needs are satisfied or not. Focusing on the car as the only suitable alternative is discussed thoroughly. In addition, unmet travel needs are mostly mentioned in combination with leisure trips like visiting friends and family. The reduced number of trips can also be associated with the fact that the ability to drive a car decreases with a certain age (see above). If people fail to adapt to their changed life and health situations, severe psychosocial effects and reduced well-being can be a consequence of reduced mobility (Freund & Smith, 2011).

To sum up, there is a drastic need for safety, accessibility, and availability for elderly people, requiring a CCAM to be comfortable, easy to use, and allow enough time for hopping on and off and for walking short distances. Besides, safe and secure transport must be guaranteed, and access to information (timetables, destinations) must be enabled. Standard options for the elderly are not appropriate, as they differ within their cohort and across cohorts. Nevertheless, CCAM might address the mobility needs of older people that are either not fully fulfilled (visiting friends or family) or not fulfilled anymore (due to reduced car mobility).



Issue		Fit as a Fiddle	Hole in the Heart	Happily Connected	An Oldie but a Goodie	Care-Full
Accessibility	X	Health related	X	✓	✓	
Affordability	X	✓	X	✓	✓	
Availability	X	X	X	X	✓	
Acceptability	Safety	✓	✓	Y	✓	X
	Driver attitude	X	✓	X	✓	
	Information	X	✓	X	✓	
	Transition support	✓	✓	✓	X	

✓ – Relevant issue, X – Less relevant

Figure 3: Five profiles of age and activity level of the profiles of older people (left) and their transport issues (right) (Shrestha et al., 2017)

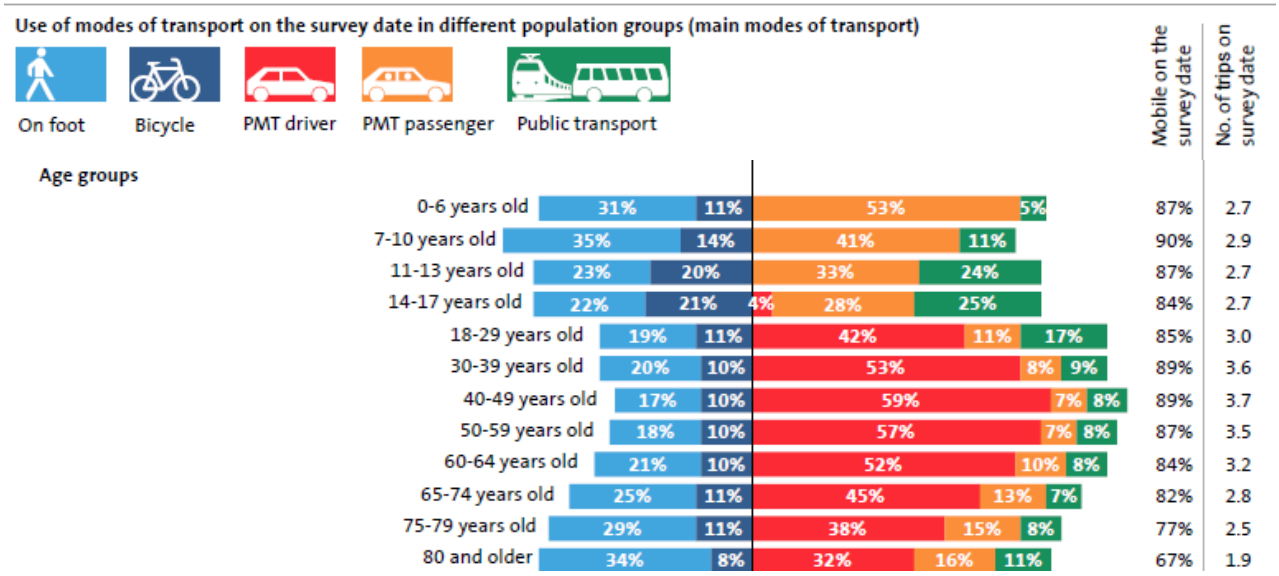


Figure 4: Mobility patterns of Germans in 2017, depending on age (Mobility in Germany, 2019)

3.3 People with disabilities

The UN Convention defines people with disabilities as 'those who have long-term physical, mental, intellectual or sensory impairments which in interaction with various barriers may hinder their full and effective participation in society on an equal basis with others' (European Commission, 2022b). Around 87 million people in the EU have some form of disability. This means that with 448 million inhabitants, people with disabilities make up 19 % of all EU citizens.

The biggest challenges for people with disabilities, according to European Commission (2022b), are:

- A higher unemployment rate
- A higher risk of poverty and a lower level of education
- Feeling discriminated against (experienced by around half of all persons with disabilities)

Experiencing discrimination and exclusion in everyday life can be a relevant aspect of why people with disabilities have other needs and motives than those without disabilities. Regarding mobility

and transport, these groups have, for instance, other requirements of trip distances (e.g., more frequent medical visits) than others.

Special and unique transport services (especially prototypes) can lead to exclusions if the requirements of disabled people are not considered. But also, in terms of standard options for production manufacturing, they are not considered for cost reasons.

People with disabilities can be distinguished[11] regarding their:

- Physical impairments
  - Mobility impairments (e.g. wheelchair, tall stature, low stamina)
  - Visual impairments (e.g. blindness, low vision)
  - Hearing impairments (e.g. [partial] deafness)
- Mental health impairments (e.g. depression, dementia)
- Intellectual impairments (e.g. autism)

The EU-project TRIPS showed via social media analysis that disabled persons' experience barriers in public transport systems, especially concerning 1) infrastructure (stairs, elevators, access to public transport), 2) public awareness and assistance of transport employees, other passengers, and assistance services (pre-registration for using a bus/train as a form of discrimination, no service from transport staff) and 3) inaccessible vehicles (esp. getting on and off via broken ramps) (Alčiauskaitė et al., 2020; S. Harms, 2020). Further important findings of qualitative interviews and the social media analysis within the project are listed below (Alčiauskaitė et al., 2020; S. Harms, 2020; Hatzakis et al., 2021)

- Technological solutions that can provide mobility assistance for people with an impairment are often unknown.
- Technologies that would make transportation more accessible are often not used at all, not used in the right way, or broken, like elevators, escalators, or audio announcements on buses.
- The behaviour of public transport staff (especially bus drivers) can sometimes be unaccommodating to the mobility needs of disabled users.
- *[The behaviour of the driver is essential for the accessibility of vehicles as well as comfort during the ride.]* – not relevant for CCAMs
- Disabled users see no need for apps to provide technical assistance.
- Social media users, as well as interviewees, emphasize the need for policy and transport providers to take the next steps in improving the accessibility of public transport.
- Disabled people are unaware of opportunities for local participation and lack information about possible ways for user involvement.
- Disabled users have been largely ignored when submitting a complaint to transportation providers.

[11] This categorization is no exhaustive and, for instance, some chronical diseases might lead to mobility impairments (eg. Arthritis) while others lead to mental health impariments (eg. Chronic depression).

- Disabled people lack flexibility in their transport choices. Public transport has only a limited number of vehicles/services that are accessible. Specialized transport options require long pre-order lead times, often up to three days in advance.
- Overcrowding is a practical barrier, especially for wheelchair users and persons with mental impairments, due to space restrictions and difficulties in embarking.
- Social distancing rules due to COVID-19 challenged persons with visual impairments by restricting physical contact with the driver, who often serves as an information source.
- Noise from vehicles and other passengers, as well as information overload, are stressors for persons with mental impairments.
- Public awareness and assistance comprise a category of social barriers for disabled people.

The project also showed that people with visual impairments would welcome accessible navigation systems, robots, and augmented reality solutions when talking about future mobility (Hatzakis, 2021).

Regarding single CCAM vehicles, external communication is essential when having visual impairments. Colley et al. (2020) showed, for instance, that visually impaired persons prefer longer acoustic information about crossing opportunities than non-visually impaired persons. In addition, participants suggested 'to have an omniscient narrator that solely communicates with the pedestrians' (Colley et al., 2020, p. 9), which could also solve the problem of several vehicles approaching. However, the visually impaired persons did not know about the possibilities of future CCAMs providing the such requested information via communication with, for instance, a personal digital assistant. Trust in automation and technology, as well as experience, plays a big role here.

3.4 Migrants, ethnic minorities, and people with language barriers

The group of migrants, ethnic minorities, and people with language issues is diverse and not homogenous. Therefore, we present the mobility patterns and needs of all user groups, one after the other.

In the European Union, 23.7 million people (5.3%) of the 447.2 million in the EU on January 1, 2021, were non-EU citizens[12]. The challenges being experienced by migrants are described by the European Commission (2022a):

- Worse labour market outcomes compared to EU nationals: the average employment rate of working-age non-EU migrants residing in the EU was 55% in 2017 (against 68% of the host-country nationals).
- Wider labour-related gaps among women.
- Unfavourable outcomes in education, skills, and social inclusion: 39% of third-country nationals (or 5.7 million) live in relative poverty, over twice the rate for EU nationals (17%).

The reasons for gaps in the integration of non-EU migrants mainly relate to lagging in education, language barriers, discrimination, uneven access to employment and decent housing and social

[12] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Migration_and_migrant_population_statistics number of people residing in an EU Member State with citizenship of a non-member country

services, or mismatching jobs and over-qualification in the case of highly educated migrants (European Commission, 2022a).

Studies prove that indigenous and immigrants' mobility and transport use differ (L. Harms et al., 2014; Smart, 2015; Welsch et al., 2014). Migrants are less likely to own a car due to less stable economic conditions, are less likely to drive cars, and use public transport more often than indigenous people. In addition, language barriers and unfamiliarity with the local (public) transport system make access to transport modes challenging, and migrants also might experience discrimination in public transport.

It is difficult to obtain robust data on the mobility patterns of migrants because most people with a migration background are underrepresented in scientific surveys. Especially language barriers can make it challenging for those with migration backgrounds to participate in surveys. Since (in Germany and likely elsewhere in Europe) the average educational level of people with an immigrant background is somewhat below the German average, a so-called education bias can be suspected. This describes the problem that people with non-academic education are generally less likely to participate in scientific studies.

A focus placed not only on migrants but also on ethnic minorities is highlighted in the chapter by Egmond et al. (2021). It is shown that the share of foreign-born people is significantly higher in Europe's biggest cities. Still, differences exist as some cities more strongly attract migrants from all over the world. For example, London has an estimated 40% “Black, Asian and minority ethnic (BAME)” population (cited after Transport for London 2014), while Berlin has an estimated 18% non-European population. Besides low income and language barriers, people not born in the European Union might experience social exclusion and religious discrimination. In addition, the project HiReach (Egmond et al., 2021) showed that younger migrants in Germany might adapt better to the public transport systems due to better digital skills and experiences with smartphone applications and the Internet than older migrants. Still, being new to a country might also mean unfamiliarity with the local (public) transport system, e.g., ticket options, where to buy tickets, location of the nearest station, and information on the public transport route network.

Besides a migrant background, language barriers are an overall challenge for participating in transport systems. Being not familiar with the official language(s) of a nation can lead to exclusion and a failure to fulfil essential mobility needs if, for instance, a ticket for a transport option cannot be purchased. People with language barriers may struggle to understand instructions, guidelines, and announcements. Bigby et al. (2019) show that the challenges that people with communication disabilities experience depend on individual impairments and the service design characteristics of public transport. However, the challenges can be clustered into aspects of 1) variable information accessibility, 2) the negative impact of large and complex service systems, and 3) the uncertain culture of help-seeking and giving. Suggestions were: “better staff training, more use of communication tools, mechanisms to enable passengers to seek help and attention to making information easier to understand” (Bigby et al., 2019). These suggestions can be directly applied to CCAM services.

3.5 Young people (and children)

Young people and children are the future of mobility. According to Eurostat, as of January 1, 2021, approximately 447 million people were living in the European Union (EU). Of these, around 73 million (16%) were young people aged 15-29 (Eurostat, 2022). Children younger than 15 years old account for 15% of the total population of the EU. These two age groups make up 31% of all EU citizens, showing the importance of this user category for CCAMs. The distribution of young people across the EU varies significantly, with some countries having higher proportions of younger populations than others. In 2021, the youth share of the population ranged among the EU Member States from 14.2 % in Bulgaria to 20.7 % in Cyprus.

Young people, especially children, are dependent on their parents up to a certain age to fulfil their mobility needs and have lesser needs for self-autonomy. Children stick to their parents' mobility options and are mainly passengers in cars (see Figure 4, Mobility in Germany, 2019). Also, Limtanakool et al. (2006) showed that among one-worker and two-worker households, the presence of children increases the probability of using the car for medium- and longer-distance commute trips. An issue of relevance is how families with little children master everyday mobility needs. As shown by McCarthy et al. (2017), the accompaniment of young children aged 0-4 years has several factors that support the usage of cars. These are structural factors (e.g. larger travel distances, poor pedestrian and cycling infrastructure), psychosocial factors (e.g. having no car in a car-dominant environment → social norms), household characteristics (e.g. an increasing number of children), and characteristics of travel with young children (e.g. carrying additional child-related equipment). Some of these mechanisms coincide with the descriptions of women in the following section. With the beginning of elementary school, the mobility patterns of children change, and walking becomes more relevant.

From 11 to 17 years old, the share of trips made by public transport and bicycles rises. Despite regular trips to school, training, or work, young people also have a variety of leisure activities that require transportation. To get autonomy and have an inexpensive means of transport, young people are very keen on cycling and other alternatives to car transport at this age. However, transportation is crucial in accessing education, work, and social interactions (exacerbated for low-income families and prioritized locations).

For young people and children, the risk of crashes is very high (Huang & Winston, 2011; Will, 2011). On the one hand, young people behave riskier when driving or cycling and are very sensitive to the influence of their peers. On the other hand, young people and children are more likely to be involved in road traffic crashes with motorized vehicles without being the perpetrator of the accident.

Young people and children will be the ones who will shape and drive the transportation systems of tomorrow as they will be the ones who will ultimately use and benefit from these systems. Involving young people and children in the planning process can help ensure that the transportation systems of the future are designed with their needs and preferences in mind. In the context of automated driving and its acceptance, Launonen et al. (2021) showed that the social norm (opinions of others) is less relevant for young people than for older people. For this reason, they might be more free from the influences of others.

Young people and children also have a unique perspective on mobility and transportation. They are often more open to trying new technologies and modes of transportation and can provide valuable insights and ideas for how to improve current systems. As stated by Sweet and Laidlaw (2020), studies on consumer interest in shared automated vehicles showed, for instance, that younger users are more interested in these vehicles. Being male, having a higher income, and being more highly educated are also predictors of interest in automated cars.

In the SINFONICA project, no participants under the age of 18 years will be included as active contributors to data collection. However, children's mobility needs should be covered by addressing parents.

3.6 Women and gender-related aspects

Gender equality is a primary goal within the European Union. The aim of transportation is to give everyone the same changes to use different transport modes and reduce the dissonance of travel modes (i.e. people cannot travel with their preferred transport mode for various reasons (Hu et al., 2023)). Mobility patterns and mode choices of men and women differ significantly. A recommendable overview of gender equality, especially in terms of shared mobility, is given by Singh (2020). She showed that previous research paid very little attention to the mobility needs of women. However, the EU project DIAMOND[13] had a strong focus on women in transport and gender-inclusive future transport systems. In the white paper (DIAMOND, 2022), an overview of the project findings and relevant literature is provided. The main findings on key factors affecting women's travel choices were: *safety & security* clustered by - 'Police force, security or staff personnel' + 'Visibility of the surrounding area of the station', and issues of *accessibility* of the service - 'Operational hours & intervals' + 'Travel & Wayfinding information provision' + 'Service availability and efficiency.' The project also delivers information on concrete influences on travel decisions (public transport, autonomous driving, bike sharing).

Women are more likely to have trip chains and combine several trip purposes (home, kindergarten, shopping, work). They are also more likely to work in part-time jobs (Ortega Hortelano et al., 2019). With some modes of transport, they perceive difficulties in transporting goods and children (e.g. with shared bicycles) (Ramboll, 2021). In addition, they stop driving earlier in life than men (Mitchell, 2011) and use public transportation more often than men (Limtanakool et al., 2006). However, research also showed that women feel very insecure and unsafe when using public transport. This leads to strategies of adopting these fears, e.g., by making detours and changing clothes for travelling in public transport. Schuß et al. (2022) refer to the "Physical Vulnerability Theory", saying that 'people who lack physical abilities will be more fearful of crime since they will be unable to defend themselves effectively in a criminal attack'.

Very recently, Innovate UK (2022) conducted online surveys and interviews with UK women and girls, identifying the main barriers to daily travel. As seen in Figure 5, women mainly perceive safety aspects relevant to their daily travel choices, followed by journey time and convenience. The study also showed that safety concerns arise if women carry children or are pregnant. The importance of

[13] https://diamond-project.eu/

journey time for mode choice is partly grounded in the combination of women's trip purposes and limitations due to children's schedules of childcare and school. Also, convenience aspects are stated in combination with the trip purposes of accompanying (young) children. For instance, walking is perceived as more challenging for women when they have very young children (or more than one child). In addition, extra luggage space is required to carry the children's stuff, and greater flexibility is needed to pick up children from school in case of illness.

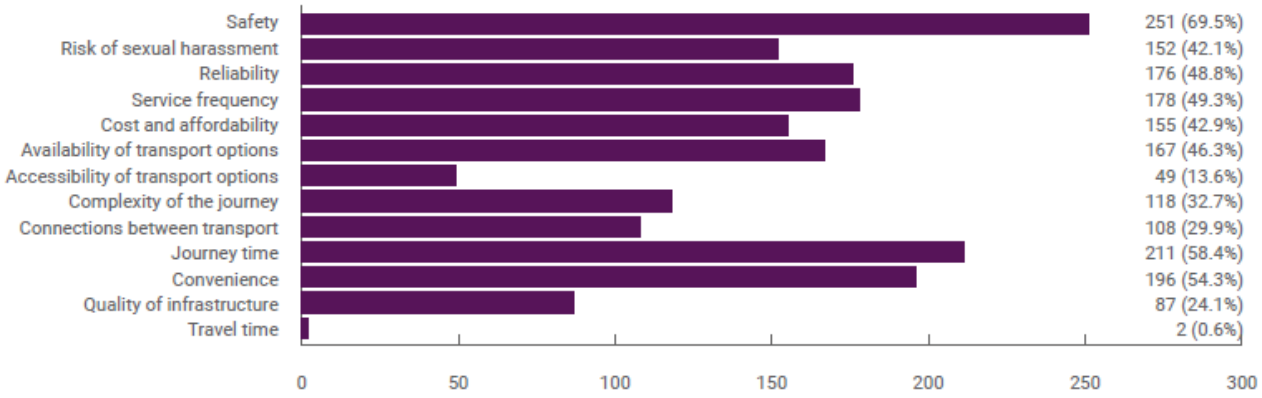


Figure 5: Identified challenges of travel for women from Innovate UK (2022)[14]

Research on (highly-, fully) automated vehicles (AV) shows that women have more concerns regarding the usage of this technology, especially when they are older (Hohenberger et al., 2016; Lee et al., 2020; Schuß et al., 2022). They have security and safety concerns regarding their own well-being as well as the transport of children in AV (with respect to the technology itself, the vehicle behaviour, and the possible loss of control) (Grosso et al., 2022; Lee et al., 2020). However, the differences between men and women are not always replicated in real-world testing of autonomous buses under secure and slow driving conditions (Launonen et al., 2021). Positive expectations of AV are a better driving experience, more comfort, better use of driving time, and increased safety (Grosso et al., 2022). The report of Grosso et al. (2022) provides a detailed literature overview and results of interviews and questionnaires with women in Europe that cover the concerns of women on AV. These include, in particular, strategies to enhance trust in AV regarding data privacy, safety standards, and equal access. According to the report, AVs can be beneficial for women 'in relation to daily transport activities and time management' considering 'the rather complex daily travel habits'. Though, Ortega Hortelano et al. (2019) pointed out that 'Transport safety and security are critical factors in women's mobility choices, and the introduction of new innovative technologies, and increased automation, are not necessarily gender neutral, with women less willing to use them.' Certainly, the needs of women should be considered when designing future CCAMs.

With CCAM, existing barriers and hurdles for women could be overcome. In the study of Innovate UK (2022), the following suggestions were made that address public transport and might be relevant for future CCAM systems:

- Short internal stops so women can be dropped closer to home

[14] 'Research has identified a number of challenges to everyday travel for women. Of this list […], select which impact your travel choices the most' 361 responses

- Night transport for women
- Increased number of bus services and infrastructure to different destinations
- Build natural surveillance into places where women move alone to deter assault
- Designated women / family-friendly spaces across the transport network
- Ability to book female cab drivers (female cabs) only

The study of Schuß et al. (2022) provided design implications to enhance safety and security in AVs for women (see Figure 6) by having an adjusted emergency button (left), a buddy system (middle), and a digital companion (right).

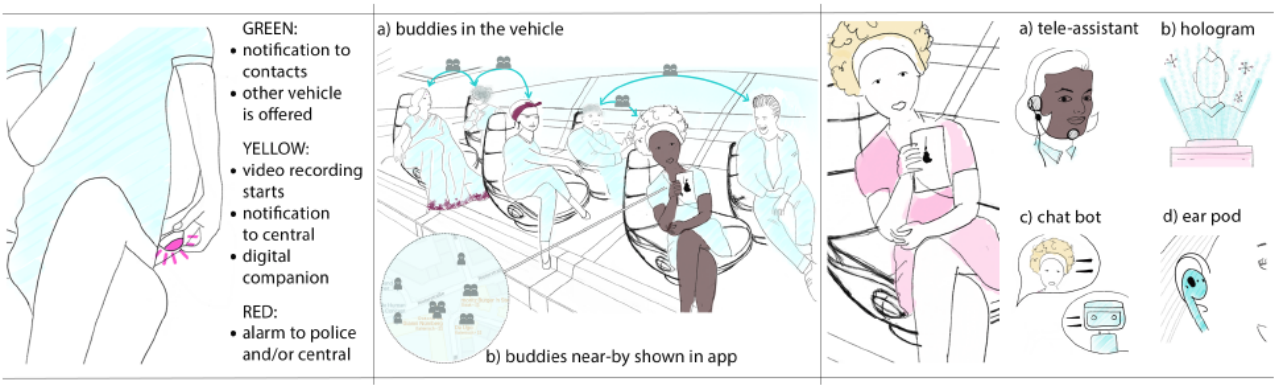


Figure 2: Main design implications (from left to right): 1) emergency button, 2) buddy system, 3) digital companion. ©Martina Schuß.

Figure 6: Design implications for AV in Schuß et al. (2022)

Besides the challenges of women and families with young children in transport, another key issue is how to account for LGBTQIA+ people when designing CCAMs. People having sexual and gender-nonconforming identities experience gender and homophobic-based violence and discrimination more often in public transport compared to heterosexual people (Weintrob et al., 2021). Especially everyday travel patterns might be changed to avoid these hostilities. A study in the UK and Israel by Weintrob et al. (2021) showed that queer people use more expensive travel alternatives, such as taxis, or take less direct routes to tackle their issues with unsafe and inaccessible public transport options.

To sum up, CCAMs should provide women and LGBTQIA+ people advantages in terms of accessibility, affordability, and safety considering the following application areas: carriage of small children, being pregnant, having trip chains, transport of goods, trips at night, and fear of experiencing discrimination or sexual harassment.

3.7 People living in rural areas

Living in peripheral, remote, or rural areas can be a challenge when it comes to fulfilling mobility needs. Of course, one of the main challenges faced by people living in rural areas is the lack of access to transportation options. Many rural areas might have limited or no public transportation, which can make it difficult for residents to access essential services such as healthcare, education, and

employment. However, people living in rural areas are no homogenous group, nor is the term 'rural area' specified.

In 2021, some 38.9 % of the EU population lived in a city, with lower shares living in towns and suburbs (35.9 %) and rural areas (25.2 %).

The differentiation between rural and urban areas is defined by the EU with the following classification[15]:

- Predominantly urban regions, NUTS level 3 regions where more than 80 % of the population lives in urban clusters;
- Intermediate regions, NUTS level 3 regions where more than 50 % and up to 80 % of the population lives in urban clusters;
- Predominantly rural regions, NUTS level 3 regions where at least 50 % of the population lives in rural grid cells.

In some European countries, there is a rather large share of rural areas, but they also have a small share of people living in rural areas (like Sweden and Norway). As shown in Figure 7, "over the last few years, the population rose at a relatively fast pace (at least 0.3% per year) in 108 predominantly rural regions of the EU. By contrast, the number of people fell at a relatively fast pace (less than -0.3% per year) in 155 predominantly rural regions"[16]. With this, trends for depopulation can be seen in rural areas, especially in countries like Spain, Romania, and some parts of Italy and Poland.

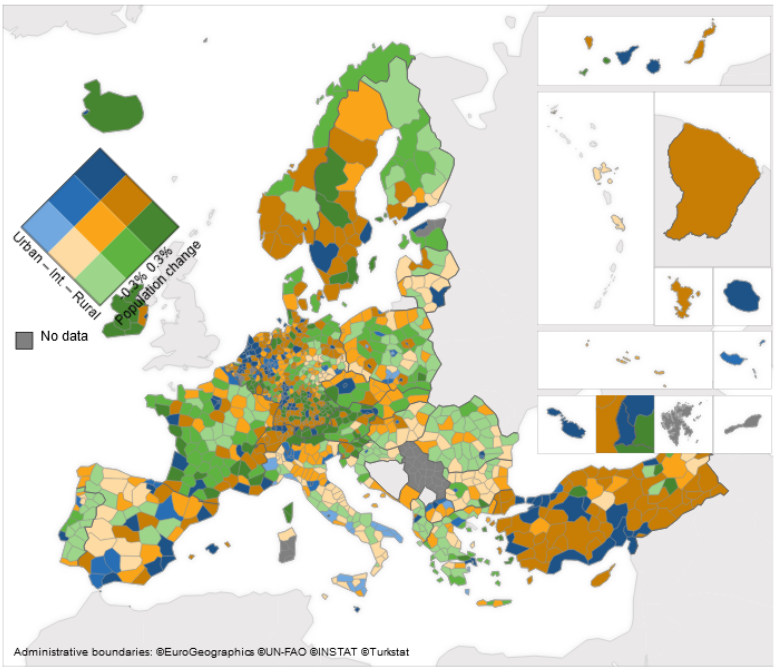


Figure 7: Average annual population change by urban-rural typology, 2015–2020 (%)

[15] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Urban-rural_typology

[16] https://ec.europa.eu/eurostat/de/web/products-eurostat-news/w/ddn-20230117-2

While some say that the depopulation of rural areas is an overall European trend, with the emergence of the COVID-19 pandemic, there were also some findings of people moving back to rural areas (Colomb & Gallent, 2022). Therefore, forecasting of depopulation and developments in rural areas is uncertain. One aspect of concern in peripheral areas is the principle of equal living conditions: Rural areas might be disadvantaged by public transport options which can cause further urbanisation and spatial polarization. With this, a vicious circle of reduced mobility options and a further shrinkage of peripheral regions can occur.

In addition, people living in rural areas might have long ways to fulfil their basic needs (work, medical care, groceries, leisure activities), so they need more time and have to combine different trip purposes. Together with a low flexible public transport service, people might prefer cars. With the trend of bus and coach driver vacancies set to increase across the EU and already 20.000 unfilled positions in 2021[17], rural areas are likely to suffer even more from low availability of public transport in the future.

Living in rural areas can lead to social and economic isolation, negatively impacting the overall well-being of rural communities. In terms of younger people, especially for children going to school, there might be risks of social exclusion in low-density regions (Stanley et al., 2019). In addition, people with low income or people from rural areas are bound to the available mobility options, thus limiting their options of choosing a school or workplace further away from home (Li & Zhao, 2015).

In many rural areas, in particular scenic areas with a high level of tourism, a significant proportion of housing is second homes or holiday accommodation. This presents the challenge of a lower permanent population and uneven demand for transport between seasons (holiday vs. non-holiday periods), and the fact that holiday visitors make less use of local services (including public transport).

One EU project that addresses the mobility patterns and challenges of people living in rural areas is SMARTA – smart rural transport areas[18]. They state, "It is important to address the widespread opinion that everyone has a car in rural areas. This is, for sure, not true. Many people cannot drive because of age, condition, or affordability. When the household car(s) is in use, other household members cannot access it. Low-income households and individuals may not have a car. In the absence of good public transport or shared mobility services, many people can't get around. This serious gap limits their participation in society, earning potential, and contribution to the economy. In addition to the human cost, many will inevitably leave, putting even more pressure on the remaining facilities in a village or rural area." (Lorenzini et al., 2021)

[17] https://www.iru.org/resources/iru-library/iru-intelligence-briefing-bus-and-coach-driver-profession-europe-access-and-attractiveness-executive-summary
[18] https://ruralsharedmobility.eu/about/

Figure 8: Project findings of SMARTA – policy goals of rural shared mobility initiatives and strategies to achieve rural shared mobility

To address the challenges of people living in peripheral areas and ensure access to the necessary transportation options, it is essential to design CCAM transportation systems that meet rural communities' specific needs and preferences. This can help bridge the transportation divide between urban and rural areas. In addition, regardless of bus and coach driver shortages, CCAM could enable rural areas to continue providing and even improve public transport services.

3.8 Digitally non-connected people

Digital inclusiveness is a primary goal for future transport systems. However, the so-called digital divide (digital disparity) is a challenge. It describes the gap between those with high access to digital tools and those with low or no access. Reasons can be missing access to equipment and Internet connection, inadequate skills and capabilities, or not feeling appealed by technology for doing everyday tasks differently (Ciommo et al., 2021). In 2021, people with at least basic digital skills made up 54% of the EU population (aged 16-74)[19]. And the numbers also show that low digital skills are more prominent for older people.

People with low digital literacy and/or no access to digital services (combined: digitally non-connected people) can face difficulties in accessing information, booking tickets, and making payments for transportation services if digital knowledge and access are needed (like cashless paying). They may also struggle with using digital devices like smartphone applications and navigating digital platforms. Further, these people might experience a risk of paying higher fares for paper tickets than for online tickets, or fail to be notified of service changes or disruptions. As a result, their mobility patterns can be limited, and they may face greater challenges in accessing essential destinations such as work, healthcare, and education.

The EU project INDIMO focused very strongly on methods to enhance digital inclusion for smart mobility systems. They also shared key recommendations to make transport more inclusive, focused

[19] https://ec.europa.eu/eurostat/web/products-eurostat-news/-/ddn-20220330-1

on the concept of a UNIVERSAL DESIGN[20] , and provided a toolbox to contribute to an inclusive, universally accessible, personalized digital system. This toolbox includes the following:

- A Universal Design Manual for digital transport services, see Figure 9
- Universal Language Interface for transport services
- Guidelines for cyber security and personal data protection
- A Policy Evaluation Tool

With COVID-19, many local authorities, health insurance carriers, or agencies (e.g. Employment offices) implemented their services for citizens only online. With these developments, people with low digital literacy or no access to the Internet became disadvantaged at some point. And although most of the services are back to normal, the trend of digitalization and a reduction of local offices continues. Such developments can also be observed in the transport industry. The sharing of vehicles is also often only available through smartphone applications and, for instance, credit card or digital banking services. Ticket counters at train stations are being substituted in favour of ticket vending machines and sometimes discount or entitlement cards are virtual in an app rather than physical cards. With this, people with no or low access to information technology might face further hurdles. It is, therefore highly relevant for future CCAM services to adapt to these needs and provide opportunities to use the transport system with low digital skills or access.

Figure 9: INDIMO – Universal design manual. Copyright @INDIMOproject.eu

4 CCAM opportunities and design requirements for people with mobility challenges

Against the background of individual and user group-specific mobility needs, different design requirements for CCAM service characteristics arise. This section provides the requirements of the prior described research groups that are part of the subsequent SINFONICA project's participation

[20] https://www.polisnetwork.eu/news/indimo-key-policy-recommendations/

and engagement activities (not part of this report). In addition, an overview of relevant CCAM service characteristics is given.

Against the background of a person's individual psychological needs, motives, user characteristics, and specific situational factors (see 2.1 - 2.3), mobility needs form a specific profile per research group (and even per individual user) that was implied in section 3. Ideally, mobility services would be tailored or adapted to the individual users and their current situational factors. A step towards this ideal is to consider different user groups, such as the research groups addressed in section 3, that share some specific mobility needs.

Based on the literature research of the previous sections, Table 2 presents a formulation of the most important mobility needs and requirements for CCAM design for each research group. This collection of hypothesized mobility needs will be validated and adapted throughout the SINFONICA project's participation processes (e.g., the focus groups and survey). The most important mobility needs are sorted according to the four groups: availability, accessibility, affordability, and acceptability (see 2.4). The most relevant aspects are described below for each research group.

> The following opportunities, gaps, and CCAM requirements for people with mobility challenges are literature-based hypotheses. The SINFONICA project aims to validate and adapt these assumptions in WP2 and WP3.

Low-income and unemployed people

The most significant barrier to using CCAM solutions for low-income and unemployed people is presumably the affordability of the service. CCAM prices must be kept to a minimum. The same goes for the (tech) equipment requirements, as the user group might not be as equipped as the average user. Apart from that, the users should be able to find the option that offers the best value for money easily. As low income does not allow for private car ownership (3.1), this user group is more dependent on CCAM solutions in the public transport sector and needs CCAM to be within reach of where they live. In addition, CCAM needs to operate when users need to travel (time independence). Low income and unemployment are associated with lower education levels. Therefore, it is also crucial that information about the service is easy to find. The most considerable potential of CCAM solutions on a social level would be to support equity in transport by providing a comparable transport alternative to private vehicle ownership and thus promoting participation for all citizens. At the same time, the greatest challenge could be figuring out how minimum pricing can be reflected economically.

Elderly

CCAM solutions offer a lot of potential for elderly users. Where the elderly cannot operate a car anymore, public transport CCAM services could fill this gap. In doing so, elderly users would benefit from not becoming excluded from social participation. Elderly users, therefore, need the CCAM service within reach of where they live and easily accessible service information. As some of the elderly do not have the average user's tech affinity, the CCAM solution should require only a minimum of tech equipment and/or provide additional assistance (digital or in person). Moreover, elderly users are more likely to have disabilities and require barrier-free access to CCAM services.

For this user group, the need for safety, security, and trust are assumed to be of great importance for the acceptance and intention to use CCAM services.

People with disabilities

Similar to the previous two groups, people with disabilities might be disadvantaged by current transport options, especially regarding the need for reachability and barrier-free access. From a social perspective, CCAM solutions could allow people with disabilities more self-determined transport and support equity in this regard. For example, on-demand CCAM solutions that pick the users up in the direct vicinity of the home could fill the gap that arises due to scheduled buses that only operate at stops further away. In addition, people with disabilities have a higher need for assistance availability, e.g., concerning schedule or price information and assistance options on the journey itself.

Migrant and ethnic minorities

Migrants and ethnic minorities are more likely to experience language barriers, have lower incomes and education, and are also less likely to own a vehicle (see 3.4). Because of the language barrier, providing easy access to service, schedule, and price information or assistance is essential. To enable the group to use CCAM, another relevant aspect that needs to be considered is affordability. CCAM solutions could narrow the social equity gap by providing a convenient and comparable mode of transport, especially regarding the lower rates of private car ownership. Making the vehicle design (interior and exterior) welcoming and appealing to this user group could enhance acceptance and prevent future private car ownership.

Young people

Making CCAM solutions attractive to young people can also encourage more use of sustainable mobility in the future. One can also expect that compared to the average user, young people value the fact that the CCAM solution is sustainable. Young people can benefit in regards to the social objective of participation as CCAM might enable more parent-independent travel. Prerequisites would be fulfilling the need for safety and security and minimum prices, as well as creating a welcoming, attractive, and pleasant CCAM vehicle design.

Women and gender-related aspects

For women and other people experiencing gender-related mobility challenges, the need for safety and security is highly relevant. For this reason, CCAM must provide protection against sexual harassment in transport. Parents (esp. mothers) have unique needs due to accompanying children. Because of this, CCAM solution requirements for trip chaining and reliability are of great importance. The CCAM solution needs to be as convenient as, or even more convenient than the private car to compete with vehicle ownership and convince parents with complex trip-chaining requirements. Providing a CCAM solution that fulfils those requirements supports equity in transport and a social objective in general. Moreover, an environmental benefit will arise when this group is enabled to switch to CCAM solutions.

People living in rural areas

With CCAM, there is a chance to enhance social participation for those living in peripheral areas because they deal with public transport that is not easily reachable or time-dependent. Therefore, availability is the most crucial need for people living in peripheral regions. Here, CCAM solutions have the potential to bridge the gap to using future public transport services, e.g., through on-demand services. People in rural areas need to have the service within reach and connections to the broader transport network, thus allowing for trip chaining with service times that fit the users. Similar to family-related trip chaining, the service needs to be at least as convenient and reliable as the private car. Moreover, information campaigns should be an integral part of CCAM implementation as people in rural areas might be unaware of these transport options, e.g., due to the habit of driving a private car. Providing such features can increase the acceptance of CCAM, especially for people living in rural areas with low incomes who might perceive private car ownership as a financial burden. Mobility services tailored to these needs can extend the radius of employees for job positions. With this, a company could hire people in rural areas more efficiently, which can positively affect the economy in peripheral regions.

Digitally non-connected people

Because of the non-connectedness of this group, providing easy access to service, schedule, and price information or assistance is essential to them. To enable digitally non-connected people, the needs for availability (of information) as well as barrier-free accessibility must be considered. In addition, people with low digital literacy might need more assistance, e.g., concerning schedule or price information and on the journey itself. In addressing these requirements, CCAM solutions can help bridge the social equity gap by enabling more social participation for this user group.

*Table 2: Highly relevant user requirements of the SINFONICA research groups *Disclaimer: These are author ratings that are not validated. There is no order of importance, and the research groups do not fully cover people with mobility challenges. The aim of the SINFONICA project is to analyse the needs of different research groups, cells highlighted in bold font indicate more important mobility needs group(s) per research group.*

	Availability	**Accessibility**	**Affordability**	**Acceptability**
Low-income and unemployed	▪ **Time independence** ▪ **Reachability** ▪ **Information access**	▪ Comprehensibility ▪ Minimal (tech) equipment requirements ▪ Simplicity / Ease of use	▪ **Minimal + capped pricing** ▪ **Ease of price comparisons** ▪ **Minimal (tech) equipment requirements**	▪ Supporting equity ▪ Safety + Security ▪ Feel welcome/ attractiveness/pleasure
Elderly	▪ **Reachability** ▪ **Option to interact** ▪ **Information access**	▪ **Barrier-free access** ▪ **Simplicity / Ease of use** ▪ **Minimal (tech) equipment requirements [use]**	▪ Minimal (tech) equipment requirements [pricing] ▪ Minimal + capped pricing ▪ Assistance availability	▪ **Safety + Security** ▪ **Reliability + Trust** ▪ **Assistance availability**
People with disabilities	▪ **Reachability** ▪ **Connectedness/trip chaining** ▪ **Information access**	▪ **Barrier-free access** ▪ **Simplicity / Ease of use** ▪ **Travel companion**	▪ Ease of price comparisons ▪ Minimal (tech) equipment requirements [pricing] ▪ Assistance availability	▪ **Supporting equity** ▪ **Safety + Security** ▪ **Assistance availability**
Migrant and ethnic minorities	▪ **Information access** ▪ **Reachability** ▪ **Connectedness/trip chaining**	▪ Comprehensibility ▪ Simplicity / Ease of use ▪ Baggage friendliness	▪ Minimal + capped pricing ▪ Assistance availability ▪ Simple + consistent pricing	▪ **Supporting equity** ▪ **Equality with other modes/convenience** ▪ **Safety + Security**
Young people	▪ **Connectedness/trip chaining** ▪ **Reachability** ▪ **Time independence**	▪ Baggage friendliness ▪ Comprehensibility ▪ Simplicity / Ease of use	▪ Minimal + capped pricing ▪ Multiple payment options ▪ Simple + consistent pricing	▪ **Sustainability** ▪ **Safety + Security** ▪ **Feel welcome/ attractiveness/pleasure**
Women and gender-related aspects	▪ **Connectedness/trip chaining** ▪ **Time independence** ▪ **Reachability**	▪ **Barrier-free access** ▪ **Child friendliness** ▪ **Baggage friendliness**	▪ Ease of transport option comparisons ▪ Minimal + capped pricing ▪ Ease of price comparisons	▪ **Safety + Security** ▪ **Reliability + Trust** ▪ **Supporting equity**
*People living in rural areas *specific needs based on region*	▪ **Reachability** ▪ **Connectedness/trip chaining** ▪ **Time Independence** ▪ **Storage space**	▪ Baggage friendliness	▪ Ease of transport option comparisons	▪ **Equality of other modes /convenience** ▪ **Reliability + trust**
People with low digital literacy and/or no access to digital services	▪ **Information access** ▪ **Reachability**	▪ **Comprehensibility** ▪ **Simplicity/ Ease of use** ▪ **Minimal (tech) equipment**	▪ **Simple + consistent pricing** ▪ **Ease of price comparisons** ▪ **Minimal (tech) equipment** ▪ **Assistance availability**	▪ Assistance availability ▪ Reliability + Trust ▪ Controllability (feeling of)

The design process of CCAM must carefully consider the user requirements of potential CCAM users for the CCAM service characteristics. From the literature on automated vehicles and public transport, several studies are recommended that give an overview of relevant attributes and factors affecting the acceptance of the new transport options (Colley et al., 2020; Golbabaei et al., 2020; Hohenberger et al., 2016; Kaur & Rampersad, 2018; Launonen et al., 2021; Paddeu et al., 2020; Pigeon et al., 2021; Redman et al., 2013; Wicki et al., 2019). Overall, the following text passage by Pigeon et al. (2021) summarizes the steps toward acceptance very well:

"As suggested by the MAVA model (Nordhoff et al., 2019), the process of acceptance starts with the exposure of the individual to the autonomous vehicle in a first stage. The exposure can consist of a real usage or simply to some knowledge about the autonomous vehicle. This first stage is crucial because it moves to the formation of either a favorable or unfavorable attitude towards autonomous vehicles (stage 2) which can influence the decision to adopt it (stage 3) and to use it (stage 4). In accordance with the MAVA model, a negative experience with an autonomous vehicle may affect the future usage of non-rail autonomous public transport vehicles.

As shown in the present literature review, individuals who have experienced negative exposure related to vehicle safety, to on-board security or abrupt braking experience on an autonomous shuttle may have an unfavorable attitude towards this type of vehicle in the future, limiting their intention to use it. At the opposite, many factors may lead to the formation of a favorable attitude increasing willingness to use non-rail autonomous public transport vehicles. These factors relate mainly to the ways in which non-rail autonomous public transport vehicles could improve mobility services and were also found by Nordhoff et al. (2019) and presented at the domain-specific system evaluation level. Potential users estimate that they would save time and money, be more comfortable on-board and have good visibility from the vehicle. Free internet access, comfortable and well oriented seats are also factors contributing to a positive attitude towards the non-rail autonomous public transport vehicles.

Most of the personal factors which are consistently found to be positively associated with willingness to use non-rail autonomous public transport vehicle scan be influenced by the vehicle's characteristics or by the level of mobility service offered. Trust in autonomous vehicles, users' performance expectancy and effort expectancy, social influence and perceived pleasure might therefore be greater when users or potential users interact with non-rail autonomous public transport vehicles which are secure, reliable, useful, efficient, comfortable, accessible, easy and pleasant to use. In this perspective, positive exposure to an autonomous vehicle (through experience, word-of-mouth or the media) can increase the likelihood of using an non-rail autonomous public transport vehicles." (Pigeon et al., 2021)

In order to develop CCAM that fits these descriptions and meets the user requirements, it is necessary to establish a common ground for rating the CCAM service characteristics. The article of Redman et al. (2013) provides an overview of service quality attributes that can be a basis for assessing CCAM by potential users. The categories are shown in Table 3.

Table 3: Definition of CCAM service quality attributes, adapted from Redman et al. (2013)

	Attribute	Definition
Physical	Reliability	How closely the actual service matches the route timetable
	Frequency	How often the service operates during a given period
	Speed	The time spent travelling between specified points
	Accessibility	The degree to which *CCAM* is reasonably available to as many people as possible
	Price	The monetary cost of travel
	Information provision	How much information is provided about routes and interchanges
	Ease of transfers/ interchanges	How simple transport connections are, including time spent waiting
	Vehicle condition	The physical and mechanical condition of vehicles, including frequency of breakdowns
Perceived	Comfort	How comfortable the journey is regarding access to seat, noise levels, driver handling, air conditioning
	Safety	How safe from traffic accidents passengers feel during the journey as well as personal safety
	Convenience	How simple the *CCAM* service is to use and how well it adds to one's ease of mobility.
	Aesthetics	Appeal of vehicles, stations, and waiting areas to users' senses

5 Intention and behaviour formation

Depending on how well the CCAM design meets the user requirements, there are different influences on factors, which in turn impact the intention to use CCAM and, thus, the actual use of CCAM. This section provides an overview of these factors relevant to intention and behaviour formation in the CCAM context and describes how the factors interrelate. The contents of this section and the corresponding "Intention & Use" level of the SINFONICA Framework are especially relevant to work packages two and three concerning the surveys on user factors that affect the future deployment of CCAM.

This section is mostly based on the theory of planned behaviour by Ajzen (1991) that incorporates all constructs explained below, except habit. The core of the theory of planned behaviour is the intention which is the most important determinant of behaviour (Ajzen, 1991). Ajzen (1991) postulates that the intention to show (or not show) a specific behaviour, and thus ultimately also the behaviour itself, are in turn determined by three main predictors: attitudes, subjective norms, and perceived behavioural control (see Figure 10) (Ajzen, 1991). These factors are each based on specific beliefs that strongly resemble the description of motives discussed in section 2.1. As Ajzen (1991) notes, depending on the behaviour in question, the importance of the three main predictors may vary. In our context and concerning the SINFONICA research groups, we hypothesize that perceived behavioural control, followed by attitudes, has a significant impact on intentions while subjective norm plays a minor role.

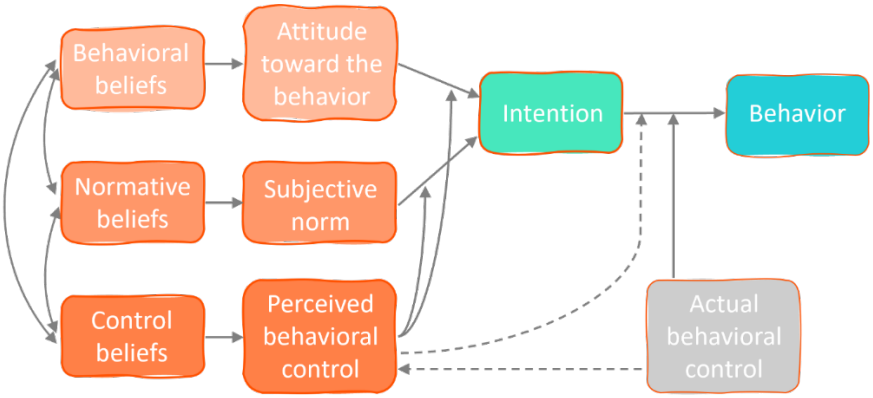


Figure 10: Theory of Planned Behaviour, following Ajzen (2019)

Attitudes & behavioural beliefs: Attitudes are a result of the **behavioural beliefs** that a person associates with certain consequences that are more or less desirable (e.g., arriving in time; having to stand for the duration of the ride) and are linked to a subjective likelihood to occur due to experiences (Ajzen, 1991). Based on these beliefs, the behaviour, in our context using CCAM, is valued more positively or negatively, comprising the attitude. In turn, the attitude directly influences the intention to use (Ajzen, 1991) and has been researched in various studies (e.g., Bamberg & Schmidt, 2003; Heath & Gifford, 2002; Steg, 2005) within the mode choice context.

The **subjective norm** reflects the feelings of social pressure, e.g., to use a CCAM service, and provides a sense of belonging when conforming (Ajzen, 1991). In relation to the self-determination theory (see 2.1), the concept of subjective norm corresponds to the basic need for relatedness. Research by Steg (2005) showed the importance of subjective norms/social context for mode choice in the example of car use. Results demonstrate that others driving to work, as well as the expectation of the family to drive to work, highly influence commuters' choice to commute by car. Subjective norms are based on **normative beliefs** that describe how significant others (e.g., friends, family) would encourage the behaviour (injunctive norm) and how likely they would perform the behaviour themselves (descriptive norm).

Perceived behavioural control within the theory of planned behaviour describes the perceived difficulty of performing a behaviour, i.e., a person thinks to have the skills (self-efficacy) and opportunity (perceived controllability) to use a CCAM service. This perception depends on control beliefs about the present impeding (travel difficulties and barriers) and beneficial conditions and the perceived power of each condition concerning the behaviour, e.g., CCAM use (Ajzen, 1991). Perceived behavioural control can be used as a proxy for actual behavioural control, and as of now, no existing CCAM solutions are available; thus, no actual behavioural control can be measured. As Ajzen (1991) mentions, perceived behavioural control can only be realistic (as a proxy for actual behavioural control) when the person has sufficient information about the behaviour and its requirements. For the measurement of intentions, this means that only well-informed respondents, e.g., instructed with detailed scenarios, can provide data with high predictive validity. In the light of travel mode choice and public transport use, in particular, perceived travel difficulties can be investigated, such as perceived accessibility and perceived service quality (Ingvardson et al., 2022).

With the component of **actual behavioural control**, the conditions that objectively hinder (actual travel barriers) or enable behaviour performance (Ajzen, 1991), the use of CCAM solutions is described. For example, for a person with reduced mobility, these barriers might be the actual accessibility of a CCAM shuttle or, for a person with low income, the actual affordability of a CCAM ticket. Even when there is an intention to use, a lack of actual behavioural control makes using CCAM solutions impossible, as actual behavioural control is a prerequisite. The ability to perform the behaviour, determined by the person's situational factors and resources (e.g., the help of others, money, skills), is the first criterion that must be met to design a service with high usability, especially for people with mobility challenges. Within the SINFONICA framework, this factor resembles the level of "Mobility Needs" as well as stating one of the goals of the second level of "CCAM Design" (see 5). As stated above, perceived behavioural control can be used as an estimator for actual behavioural control.

When behaviour is performed repeatedly, goal-directed **habits** are formed, meaning that specific behaviour is triggered by situational cues and is automatically initiated (Aarts et al., 1997; Neal et al., 2006). Within the transport context, habits play an essential role (Aarts et al., 1997), especially concerning mode choice. Over time, the decision for a specific mode becomes the default, meaning there is no extensive decision-making process, and other psychological factors, such as attitudes, become irrelevant (Triandis, 1980). For example, when commuting (situational cue: trip purpose "work"), some people take the tram as their default option simply because they have done so over and over again. As a review by Havlíčková and Zámečník (2020) showed, habit in research on travel mode choice was often investigated as a single concept (e.g., Friedrichsmeier et al., 2013) or with regard to existing theories such as the theory of planned behaviour (e.g., Bamberg et al., 2003). From testing an extended Theory of Planned Behaviour (Donald et al., 2014), it appeared that while car use was influenced by intention and habit, public transport use was determined exclusively by intention (Havlíčková & Zámečník, 2020). Gardner (2009) noted the relationship between motivation and behaviour gets weaker with stronger habits. Often the frequency of a particular behaviour, e.g., frequency of public transport use, is used as an indicator of habit strength (Bamberg, 2000). The latest approaches for measures in habit research are based on the Self-Reported Habit Index (SRHI) by Verplanken and Orbell (2003). The SRHI was adapted by various researchers (e.g., Haustein et al., 2009). Nordfjærn et al. (2015) and Şimşekoğlu et al. (2015) extended the SRHI, which initially consisted of 12 items, to a 19 items scale, while Klöckner and Blöbaum (2010) developed a short version of six items.
One of the main conclusions of the habit research review by Havlíčková and Zámečník (2020) is that habit should always be addressed when measuring travel mode choice as it has such a strong impact. As the existing research implies, habit plays a relevant role in both the intention to use and the actual use of CCAM solutions. Therefore, the habit construct will be included within the SINFONICA framework.

6 The SINFONICA Framework

The SINFONICA framework (see Figure 11) is a general theoretical framework about the mobility needs relevant to CCAM. The framework is based on extensive literature research provided in this deliverable's previous sections. The first level of the framework is the users' *mobility needs* (see 6.1). The second level describes the requirements for *CCAM design* and the objective of actual and perceived behavioural control from the users' perspective (see 6.2). The third level builds on top of the needs and the CCAM design and is described as *Intention and use* as part of the preceding decision-making process (see 6.3).

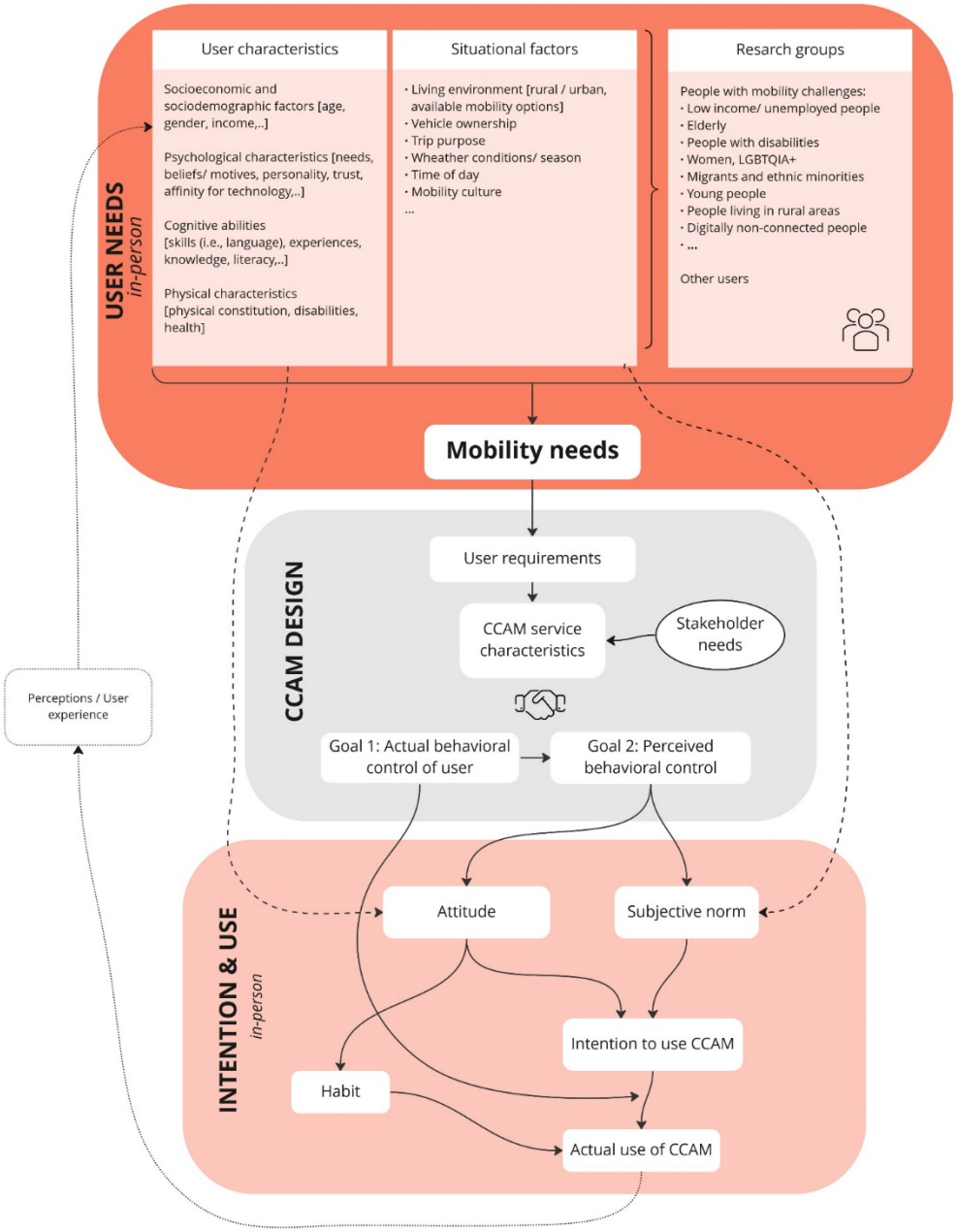


Figure 11: SINFONICA Framework – a general theoretical framework about mobility needs relevant to CCAM solutions, own illustration

6.1 Mobility Needs

The core of the SINFONICA framework (see Figure 11) are the *mobility needs* of European citizens. Mobility needs (see also 2.4) are a combination of users' *individual characteristics* and *situational factors* determining the users' requirements towards CCAM service characteristics. For example, the primary mobility needs of an elderly user with low affinity and trust towards technology might be easy information acquisition and interface design. In contrast, for a physically disabled user, one primary mobility need might be the easy accessibility of the service. Those individual user characteristics act in the context of present situational factors, e.g., trip purpose, environment (rural/urban), or time of day. For example, the elderly might be more tolerant of bad interface design if living in a rural area (situational factor) where the CCAM service represents the best option to get around. In addition, mobility needs are not static but subject to change due to varying situational factors and individual user characteristics. Based on the combination of particular user characteristics and situational factors, *user groups* that share similar mobility needs can be formed. In light of the SINFONICA objectives, the framework differentiates the user groups: *people with mobility challenges* and *other users*. The people with mobility challenges, like low-income or unemployed people, elderly, people with disabilities, women and LGBTQIA+, young people, people living in rural areas, or digitally non-connected people, also comprise the research groups within SINFONICA and are described in more detail in section 3.

6.2 CCAM Design

The second level of the SINFONICA framework contains the *user requirements* towards *CCAM service characteristics* (see also section 4) that arise from mobility needs. Based on the user requirements, e.g., integration of an audio information system, and on the *stakeholder needs*, e.g., low maintenance of passenger information systems, the CCAM solution is designed, resulting in specific *CCAM service characteristics*. The objective of the CCAM design process should be to increase the user's actual behavioural control and perceived behavioural control. *Actual behavioural control* and *perceived behavioural control* (see also chapter 5) are high when all necessary conditions are met that enable the user to perform the behaviour (here, the use of a CCAM solution, which is also perceived as such by the user). Depending on how well the service characteristics ultimately match the user requirements (and thus their mobility needs), the users have more or less actual behavioural control. For example, even when the intention to use is high, the user might be unable to use the service if the service network is not available nearby (Mobility need: availability), resulting in the actual behavioural control being low and the use of CCAM being impossible.

6.3 Intention & Use

The last framework level describes the process of forming an intention to use and actual use of CCAM solutions in the form of an extended version of Ajzen's theory of planned behaviour (TPB) (Ajzen, 1991). Based on the users' individual and situational factors (section 2), *attitudes,* and *subjective norms,* an *intention to use* is formed and translated into *actual behaviour*, dependent on *perceived behavioural control*, *actual behavioural control,* and *habits*. The TPB components and habit construct were described in detail in section 5.

7 Conclusion

In order to get the maximum benefit from CCAM public transport systems, it is necessary to make the services as inclusive as possible for any type of user. The current deliverable addressed this challenge by providing a knowledge basis on the specific needs of groups with mobility challenges.

In this deliverable, the mobility needs and the psychological backgrounds of different groups relevant to the project (e.g. low-income, elderly, people with disabilities) are analysed by a literature review as well as by reviewing existing reports and projects.

The main output of this work is a general theoretical framework about mobility needs relevant to CCAM solutions. Psychological needs, motives, user characteristics, and situational factors form these needs. The collection of hypothesized mobility needs will be validated and adapted throughout the SINFONICA project's participation processes (e.g. the focus groups and survey). The most important mobility needs are sorted according to the four groups: availability, accessibility, affordability, and acceptability.

This deliverable guides the next project tasks, especially the co-creation processes in the project municipalities Trikala, Hamburg, West Midlands metropolitan area, and in the province of Noord-Brabant. Moreover, further tasks within the first work package, such as structuring end-users' and stakeholders' needs and interrelations in a taxonomy or the definition of research and target groups will be based on this deliverable.

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9 Appendix

1. Tasks in Work package 1

Table 4: Tasks within the SINFONICA work package 1 "Setting the SINFONICA framework"

Task	Description
1.1 Mobility needs and requirements of European citizens	• Analysis of needs of different groups relevant to the project (e.g. vulnerable users, elderly, women) by literature review • Development of a general theoretical framework about mobility needs relevant for CCAM solutions
1.2 CCAM vocabulary and stakeholders' needs and requirements for CCAM solutions	• Creation of a common vocabulary for CCAM • Understanding the vision, priorities and dilemmas of key stakeholders of CCAM, based on literature review
1.3 Understanding the gap of CCAM solutions deployment	• Investigation of current practices of CCAM assets and services deployments, based on literature review • Study of hindering factors for large scale demonstration; also regarding the end-users and stakeholders needs • Development of a taxonomy of end-users and stakeholders requirements towards CCAM solutions
1.4 Definition of the research groups and creation of groups of interest	• Definition of categories of people who will compose the groups of interest, and who will be involved in the co-creation activities of the SINFONICA project • Formulation of research areas

2. Related EU-projects

The most relevant projects funded by the European Union that focused on user needs and requirements as well as acceptance of CCAMs (and CAMs, CAVs & AVs) are SUaaVE, TRIPS, Cities4People and Rebalance. Other relevant projects in the domain of CCAMs can be found under Connected Automated Driving[21]. In the following, main results of the projects are shown. Projects follow an alphabetical order.

Acronym, website, duration	**ARCADE** **https://www.connectedautomateddriving.eu/about/arcade; https://cordis.europa.eu/project/id/824251** **01.10.2018 - 31.07.2022**
Full name	Aligning Research & Innovation for Connected and Automated Driving in Europe
Partner SINFONICA	Yes ERTICO, ICCS
Relevant findings	The mission of ARCADE is to coordinate consensus-building across stakeholders for sound and harmonised deployment of Connected, Cooperative and Automated Driving (CAD) in Europe and beyond. ARCADE supports the commitment of the European Commission, the European Member States and the industry to develop a common approach to development, testing, validation and deployment of CAD in Europe and beyond. ARCADE involves 23 partners, 43 associated partners and over 500 subscribers, jointly forming the CAD network of European experts and stakeholders from the public, industry and research sectors, with international outreach. ARCADE uses a dual approach to identify and overcome bottlenecks and in parallel maximise consensus and synergy between stakeholders. Using a road metaphor, ARCADE focusses on "removing road blocks, paving the road, prevent traffic jams and providing navigation to a common destination". In an annual cycle, ARCADE positions the CAD Network (WP2) centrally which brings together the CAD community at national, European and International levels. The Thematic Areas (WP3) work on content creation leading to consensus-based positions, needs and scenarios. The Knowledge Base (WP4) consolidates the CAD knowhow baseline and serves as public one-stop shop overview of CAD.

[21] https://www.connectedautomateddriving.eu/projects/

	The main results of ARCADE will be: • Knowledge Base on CAD regulations and policy, on organisations & projects, on standards, on testing methodologies & data and lessons learned • Scenarios, positions, gap analysis and recommendations on 12 thematic CAD areas • Updates of CAD roadmaps • Common Research & Innovation approaches across EU, US, Japan and other countries involved • Web and news flash promotion of national, European and international CAD activities
Importance	*Technology or user-oriented?* Very technology oriented *CCAM or other mobility services oriented?* Focusses completely on CCAM solutions

Acronym, website, duration	**CATAPULT** **https://catapultproject.eu/** **March 2021 – February 2024**
Full name	Policies for inclusive autonomous mobility solutions for cities
Partner SINFONICA	No
Relevant findings	tba (results are yet to be published)
Importance	*Technology or user-oriented?* User-oriented with a focus on more inclusive transportation (especially use cases for children, the elderly and people with temporary and long-term sensory and / or physical disabilities are created). The results aim to propose policies and step-by-step recommendations. *CCAM or other mobility services oriented?* Yes. Demand-driven automated mobility solutions are part of the aim to create policies and recommendations.

Acronym, website, duration	**Cities4People** **https://cities4people.eu/** **https://cordis.europa.eu/project/id/723194** **01.01.2017 - 30.11.2020**
Full name	Towards people-oriented Transport and Mobility New approaches for community-driven sustainable mobility innovations at the neighbourhood and urban district level
Partner SINFONICA	Yes E-Trikala, FHH
Relevant findings	D1.3: existing mobility challenges of users to deal with traffic congestion, affecting both public and private modes of transport; poor infrastructure to support cycling, walking, and access to public transportation or other shared modes of transport (such as car or bike sharing). (Tatum et al., 2020) – experiences and guidelines how to do co-creation processes with the example of Hamburg Altona Living Lab (Angelidou et al., 2020) – experiences and guidelines how to do co-creation processes with the example of Trikala
Importance	*Technology or user-oriented?* A special focus on user needs, Co-creation processes involved *CCAM or other mobility services oriented?* not especially focussed on CCAMs, but rather oriented to future mobility services in general (People-Oriented Transport and Mobility)

Acronym, website, duration	**DIAMOND** **https://diamond-project.eu/https://cordis.europa.eu/project/id/824326** **November 2018 – January 2022**
Full name	DIAMOND – Revealing fair and actionable knowledge from data to support women's inclusion in transport systems
Partner SINFONICA	No
Relevant findings	DIAMOND developed tools and guidelines to promote gender equality in the transport and mobility sector, based on the assessment of transport users' needs and drawing on big data and machine

	learning techniques. A toolbox for assessing the inclusivity of particular transport services, including recommendations for assisting particular profiles, was tested and validated with transport sector companies across Europe, to be targeted at transport operators, public planners and transport employers. The team produced a white paper outlining key actions for a more inclusive transport system, alongside recommendations specific to autonomous cars. Curriculum guidelines and Corporate Social Responsibility (CSR) protocols were also developed to increase female employment in this sector. (DIAMOND, 2022): DIAMOND focused on three key areas impacting women's engagement with public transport: capacity to address basic mobility needs, physical and monetary accessibility, and safety and security. The team carried out trans-European qualitative and quantitative data collection on diversity and gender-sensitive issues focused on: railways and public multimodal transport, autonomous vehicles, bicycle-sharing services, alongside CSR and employment. Transport user data, collected from over 1 000 on-site surveys in Barcelona, Dublin, Warsaw and Paris, was combined with social media analysis of messages related to satisfaction with transport options. These were complemented by in situ observations of transport infrastructure. Focus groups and workshops were also undertaken, and in the autonomous vehicles case study a driving simulator was developed to better understand women's needs. An overarching finding was that for women, feeling safe at all times was crucial for ensuring continued public transport use. "Furthermore, we found safety and security were particularly important for women in low-income groups and those belonging to ethnic minorities – the groups most reliant on public transport," says Maria Chiara Leva, DIAMOND dissemination manager and Technological University Dublin lecturer. The team also found that travelling with dependents often pushes women towards alternative transport, mainly private cars.
Importance	*Technology or user-oriented?* User-oriented with a focus on women. The results aim to propose recommendation concerning fair inclusiveness for women in each identified use case. *CCAM or other mobility services oriented?* For a focus on public transport

Acronym, website, duration	**Drive2theFuture** **https://www.drive2thefuture.eu/ https://cordis.europa.eu/project/id/815001** **May 2019 to April 2022**
Full name	Drive2thefuture - Needs, wants and behaviour of 'Drivers' and automated vehicle users today and into the future
Partner SINFONICA	Yes NTUA (Athens)
Relevant findings	Transport automation is a reality; it is now a matter of how to make the best of it. User awareness, acceptance and training formulate priority challenges. Questions on vehicle taking over control from humans, change of mobility habits and experience, cost of future commuting and travelling, ethical decisions of a machine vs. a human, the need of new driver training incentives for adapting to the technological evolution in future vehicles, require research-based answers. Drive2theFuture develops training, HMI concepts, incentives policies and other cost efficient measures to promote and comparatively assess alternative connected, shared and automated transport use cases for all transport modes and types of users (drivers, travelers, pilots, VRUs, fleet operators and other stakeholders), in order to understand, simulate, regulate and optimize their sustainable market introduction; including societal awareness creation, acceptance enhancement and training on use. Its mission is to prepare future "drivers", travelers and vehicle operators to accept and use connected, cooperative and automated transport modes and the industry of these technologies to understand and meet their needs and wants. The overall goal of the Drive2TheFuture project is to raise awareness and enhance acceptance for automated vehicles (AV) in the public. In this view, AVs development should be coherent, in order to support their behaviour understanding and their acceptability by the public. The D6.4 is therefore a support for the current European Statements of Principles update. It should be considered as a set of "principles" that are recommended to allow for better safety of AVs, in self-driving, transition phase & automated driving. As of today, some policies are not updated to fit with automated driving so that the updated ESoP might be a support to adapt those policies, as they will obviously have to evolve to be adapted to automated driving.

	(Al Haddad & Antoniou, 2022) – Driving behaviour modelling
Importance	*Technology or user-oriented?* Both. Focus on training, HMI concepts, incentives policies and other cost-efficient measures to promote CCAM for all types of users. *CCAM or other mobility services oriented?*
Acronym, website, duration	**ELVITEN** **https://cordis.europa.eu/project/id/769926** **01.11.2017 - 31.10.2020**
Full name	Electrified L-category Vehicles Integrated into Transport and Electricity Networks
Partner SINFONICA	Yes UNIMORE, ERTICO, Trikala
Relevant findings	Despite offering cities a smart, green mobility solution, consumers are wary of electric light vehicles. ELVITEN tracked usage and perceptions across six European cities to inform adoption campaigns. 225 electric light vehicles were made available including an App, data was collected (41 000 trips and 9820 questionnaires) "By the end of ELVITEN's pilots, we detected a positive shift in attitudes towards EL-V use. Of those who had used the vehicles, the vast majority stated that they would use EL-Vs more than 4 days a week. However, despite positive perceptions of speed, comfort, safety and green credentials, there were cost concerns"
Importance	*Technology or user-oriented?* Both, technology and user-oriented *CCAM or other mobility services oriented?* Focussed on electric light vehicles, such as electric bicycles, tricycles, scooters and quads
Acronym, website, duration	**INDIMO, DIGNITY, SMARTA** **https://www.indimoproject.eu/** **https://cordis.europa.eu/project/id/875533** **https://www.dignity-project.eu/** **https://cordis.europa.eu/project/id/875542** **https://ruralsharedmobility.eu/** **January 2020 – December 2022**
Full name	INDIMO: Inclusive digital mobility solutions DIGNITY: DIGital traNsport In and for society SMARTA: Smart Rural transport areas
Partner SINFONICA	No
Relevant findings	Joint recommendations of the 'sister projects' Indimo Dignity and Trips: 1. **Focus on users**: Involve a wide range of stakeholders, users, and non-users in particular, in the co-design of inclusive and accessible transport products and services. 2. **Focus on policy makers:** Embrace inclusive co-design principles in the next EU transport strategy, in the guidelines for local sustainable urban mobility plans (SUMP) and national transport plans as overarching planning principle and define key performance indicators to monitor progress. 3. **Focus on the industry:** Prioritise accessibility and inclusion over market dynamics and explore the business case and market potential for inclusive and accessible transport products and services. 4. **Focus on continuity:** Create a common European platform for accessibility and inclusiveness to act as a one-stop shop for inclusive co-design solutions and planning tools, ensuring continuity of project results. 5. **What comes after our projects?** INDIMO, TRIPS and DIGNITY have only laid the foundations for the transition towards a more accessible and inclusive transport system. Further funding for new research, innovation and demonstration of best practices is needed to maintain the momentum'.
Importance	*Technology or user-oriented?* Srongly user-oriented *CCAM or other mobility services oriented?* Not only focused on CCAM, but also to other mobility services.

Acronym, website, duration	**LEVITATE** **https://levitate-project.eu/** **2018 - 2021**
Full name	Societal Level Impacts of Connected and Automated Vehicles
Partner SINFONICA	Yes NTUA (Athens)
Relevant findings	(Weijermars et al., 2021) Several aspects of CCAM were investigated. Concerning road safety the findings on long-term impacts were: • Drop-off spots could affect pedestrian safety, via unexpected interactions between pedestrians and cyclists or cars (for instance through pedestrians getting out of a car and suddenly trying to cross the road). • the replacement of on-street parking with other facilities is expected to have the largest direct effect on VRUs due to its close proximity to walking and cycling facilities • dedicated CAM lanes could reduce risky interactions between human drivers and AVs • Shift from human-driven private car to shared automated taxis reduces human factor crash risks • crash rates of car-car crashes decrease with increasing MPR of CAVs • Microsimulation results predict: At 100% market penetration rate of CAVs, conflicts per 1000 vehicle-kilometre are estimated to be reduced by almost 90% • Based on crash statistics from a number of countries, they assume that about 70% of the crashes is caused by human-driven vehicles. In that case, 70% of the VRU-car crashes can be prevented in case of a 100% penetration level of CAVs. Taking into account the extra reduction in (severe) crashes • due to the reduced impact speed, it is estimated that 91% of all fatal crashes between VRUs and cars can be prevented in the case that all cars are fully automated. • According to estimations the distance travelled by car will increase by around 8%. This is due to a decrease in active travel of 2% and a decrease in travel by public transport of 6%. An increase in travel by private car transport is expected to have a slight negative effect on road safety.
Importance	*Technology or user-oriented?* Tendency to user orientation but a strong focus on policies. *CCAM or other mobility services oriented?* Yes. The goal of the overall project is an estimation of the current and future impacts of CCAM.

Acronym, website, duration	**Rebalance** **https://rebalancemobility.eu/** **https://cordis.europa.eu/project/id/101007019** **01.12.2020 - 30.11.2022**
Full name	futuRE moBility vALues ANd CulturE
Partner SINFONICA	Yes TUD, ISINNOVA
Relevant findings	Which values do travellers express currently?(Pourhashem et al., 2021) • all countries show an overall strong emphasis on power and stimulation • orientations towards security, benevolence and universalism reach in most countries no positive mean • convenience was found to be a main motivator independent from the actual mode and for all genders and ages • Most car users drive because of convenience and speed considerations • Half of the PT-users, pedestrians and cyclists choose their transport mode for convenience reasons • Price considerations matter for about a quarter of bicycle and PT-users and cyclists are additionally motivated by speed and environmental reasons. • In the overall means environmental considerations matter recognisable only for the decision to cycle (22% of bicycle users). • Many car users and pedestrians would prefer using another mode of transport (especially the bike). This travel mode dissonance appears to be the biggest problem among users of PT • A mixed but falling trend in driver license acquisition in most EU countries • Many agree on the fact, that the traffic situation needs to be improved and motorized traffic-related environmental problems are by about 70% of Europeans perceived as very important or fairly important problems • most people prefer to adopt ridesharing for work compared to other trip purposes

	• the biggest motivator for respondents to share a ride is cost saving or financial benefit • Regarding the question which ICT (Information and communication technology) related activities lead to the travellers' perception of travel time satisfaction and worthwhileness, reading on electronic devices was perceived as the most worthwhile ICT related activity
Importance	*Technology or user-oriented?* User-oriented regarding motives for mobility and basic needs of European people regarding mobility *CCAM or other mobility services oriented?* No focus on CCAMs (or on other services), rather a societal approach concerning mobility in general

Acronym, website, duration	**SUaaVE** https://www.suaave.eu/results/ https://cordis.europa.eu/project/id/814999 **01.05.2019 - 30.10.2022**
Full name	SUpporting acceptance of automated Vehicles
Relevant findings	Finding determinants of acceptance of automated vehicles, adoption of Theory of Planned Behaviour (strongest predictors for acceptability: perceived safety, perceived convenience, perceived environmental sustainability) (Post et al.) Individual differences may play a role in the acceptability and acceptance of CAV. Gender and age may have limited effects, while experience with the technology may be a more reliable predictor. Perceived characteristics of CAV may be the most important predictor of acceptance. Discussed perceived safety, pleasure, convenience, comfort, trust, and control as being particularly relevant. The focus groups showed that the predictability of CAV's behaviour, perceived environmental sustainability of CAV, the existence of a clear legal framework of liability, and the capability of communicating with other road users may be additional factors that could influence CAV's acceptance. It was found that drivers and non-drivers may have different requirements for CAV, which could lead to differences in their acceptance levels. The finding also points out that marketing strategies should target different factors based on user group characteristics and needs.
Importance	*Technology or user-oriented?* Very user-oriented for general citizens but also regarding gender, age and (slightly) vulnerable groups *CCAM or other mobility services oriented?* Focussed on connected automated vehicles (but not on CCAM full-service provision)

Acronym, website, duration	**TRIPS** https://trips-project.eu/ https://cordis.europa.eu/project/id/875588 **01.02.2020 - 31.03.2023**
Full name	TRansport Innovation for vulnerable-to-exclusion People needs Satisfaction
Relevant finding	When designing future transport systems, attention should be paid to the most frequently mentioned complaints around: (Hatzakis, 2021) • Getting on and off the means of transport • Reaching the transport mode • Using station facilities • Travel delays • Comfort on board • Limited access to information • Autonomy • Social barriers • Accessing help • Friendliness of the surrounding environment
Importance	*Technology or user-oriented?*

	special focus on user needs of vulnerable groups, focus groups, online surveys and co-creation processes *CCAM or other mobility services oriented?* Rather less CCAM oriented, focussed on e-scooter

3. Related projects of the four municipalities/regions of SINFONICA

West Midlands

Acronym, website, duration	**AUTOPLEX** **https://uk.yunextraffic.com/portfolio/connected-mobility-solutions/autoplex/** **March 2019 to September 2022**
Full name	Autonomous Cars Negotiating Complex Environments Using V2X
Partner SINFONICA	Yes West Midlands (Transport for West Midlands)
Relevant findings	Another consortium-led project brought together to tackle the issue of autonomous vehicles navigating complex junctions. Using on-vehicle sensors, message delivery from the vehicle to static infrastructure and dynamic mapping, this project has been tested successfully on the M40 and further development is in the pipeline.
Importance	*Technology or user-oriented?* Technology oriented. The aim of the project was to allow for a connected and automated vehicle to be able to merge onto a highway. To achieve this, the merging point was equipped with technology to allow the vehicle to "look ahead". *CCAM or other mobility services oriented?* CCAM was involved, since a connected and automated vehicle and V2X technology were used.

Acronym, website, duration	**MFM** **https://midlandsfuturemobility.co.uk/** **March 2018 – still running**
Full name	Midlands Future Mobility
Partner SINFONICA	Yes West Midlands
Relevant findings	One of the UK's most ambitious testing facilities utilises over 200 miles of live urban, inter-urban and rural roads. The scheme was delivered in 2021 by a consortium of diverse partners from the public & private sectors and academia.
Importance	*Technology or user-oriented?* Tendency to technology orientation but human factors are also taken into consideration. Human Factors related assistance is offered to potential stakeholders who want to use the provided technology and infrastructure. *CCAM or other mobility services oriented?* Approximately 300 miles of roads are equipped as test fields for CCAM solutions. Since the project offers more of a framework and expertise-based assistance, which third-party institutions/ companies can use to test new technology, the inclusion of other mobility services is possible.

City of Hamburg

Acronym, website, duration	**DiVA** https://bmdv.bund.de/goto?id=370748 https://www.dlr.de/vf/en/desktopdefault.aspx/tabid-2974/1445_read-50181/ **July 2017 – March 2020**
Full name	Gesellschaftlicher Dialog zum vernetzten und automatisierten Fahren (Participatory approach for connected and automated driving)
Partner SINFONICA	Yes City of Hamburg
Relevant findings	The aim of the project was to analyze the full potential of autonomous and connected driving and to create a dialogue between the relevant stakeholders who play a crucial role in the implementation of the technology in the traffic system in Germany. In-depth research analysis on the po-tential opportunities and risks from the implementation and use of vehicle automation were build the base for this dialogue. This work aimed to ensure that automated and connected driving con-sider residents´ mobility needs, contributed to create a sustainable and more efficient traffic system, and supported Germany as a market leader for this technology. *The authors give the following recommendations to achieve a successful societal dialogue:* • The structuring in terms of time and content, as well as the constellation of actors, should correspond to the objective and the innovation phases • Identify diverse interests and requirements, allow them to be negotiated and bring them together in a common direction. • Include society's requirements in the development processes, promote open innovation processes • Encourage expert dialogue by incentivising and actively involving different groups of actors • Define a target direction based on scientific findings and societal interests. • Create field tests of greater everyday utility, active involvement of the population, professional support of the communication process • Promote realistic expectation management, take citizens' requirements into account • Encourage innovation and the learning process • Identify the challenges in the transition phase with mixed traffic, develop solution approaches • Promote exchange between project plans and facilitate a learning curve • Continuously develop the knowledge base, document it and make it accessible (Kolarova et al., 2020)
Importance	*Technology or user-oriented?* User-oriented on a societal level. The aim of the project was the elaboration of a concept for the social dialogue on automated and connected driving *CCAM or other mobility services oriented?* CCAM oriented

Acronym, website, duration	**HEAT** https://www.ikem.de/en/projekt/heat/ https://www.hamburg.com/mobility/its/12778724/heat/ **January 2018 to December 2021**
Full name	HEAT – Hamburg Electric Autonomous Transportation
Partner SINFONICA	Yes City of Hamburg

Relevant findings	The HEAT project will make autonomous driving with locally emission-free shuttle buses visible and tangible in a first test area in Hamburg's HafenCity. The aim is to demonstrate that fully automated or autonomous driving can be successfully integrated into road traffic as a complete system on level 5, i.e. without a driver. The aim is to develop, prepare, test and use electric, autonomously driving vehicles and systems for use in normal road traffic. In the project HEAt, an autonomous bus drove in the city district HafenCity in Hamburg on a fixed route of 800 m. Results of the passenger surveys showed that the abrupt and unexpected braking of the bus was criticized. Requirements exist regarding the spatial design of the shuttle referred to aesthetic aspects of design (clear, simple, functional, modern, futuristic or distinctive design, attractive design and light colours), spatial aspects (large windows on all sides, good panoramic view, lightness in cabin, spacious interior), aspects of autonomous driving (route information) and electric driving (positive aspect of silence and environmental protection). Participants also highlighted the seat design and suitability to wheelchairs and a safe, interesting and comfortable riding experience. (Dreßler & Höfer, 2022)
Importance	*Technology or user-oriented?* *CCAM or other mobility services oriented?*

Acronym, website, duration	**Real Lab HH** **https://www.bmdv.bund.de/SharedDocs/DE/Artikel/DG/AVF-projekte/reallabhh.html** **https://www.hamburg.com/mobility/its/15090224/reallab-hamburg/** **April 2020 – December 2021**
Full name	Reallabor Digitale Mobilität (Real Lab Digital Mobility)
Partner SINFONICA	Yes (City of Hamburg)
Relevant findings	Hamburg has tested the digital mobility of tomorrow in RealLabHH. In ten subprojects, 32 project partners from industry and science researched the extent to which digital mobility solutions can contribute to making municipal transportation systems more sustainable, safer, more comfortable and more reliable. Hamburg residents were involved in the entire research process through constant participation and dialog events. Demand-oriented services to supplement scheduled and timetabled public transportation, such as autonomous on-demand shuttle services in Hamburg-Bergedorf and on-demand shuttles in the rural areas of the Stormarn district, Harburg district, Ahrensburg city and Lurup/Osdorf, are also inconceivable without digitization. The on-demand services were successfully implemented in the Reallabor Hamburg and were so well received by the users in the study areas that they will continue to be operated in the communities even after the end of the project period. The simulation results also demonstrate a measurable effect on the modal split. • The project showed that people want participation. They want to be heard and to help shape the newly introduced technologies. They even want more information on the technologies and target-group-specific information material. • Having an autonomous on-demand shuttle in Hamburg (including the duration of ITS world congress), results of the passenger survey showed that 67 % of passengers intended to use autonomous shuttles in future. However, 29 % would use them only if the shuttles were more mature/longer tested, faster, safer and if they did not have abrupt braking manoeuvres. • The results of public participation in the dialog process show that in people's minds, the model of the car-oriented city and owning a car in the countryside is dissolving and being

	replaced by the vision of low-traffic and emission-free cities and mobility in the countryside that is guaranteed at all times even without owning a car.
Importance	*Technology or user-oriented?* Very user-oriented wit participatory approaches *CCAM or other mobility services oriented?* CCAM oriented – Automated driving and shuttles

Trikala

Trikala was and still is project partner in several EU projects that are related to CCAM and user-oriented implementation of future mobility systems. In detail, these are CityMobil2, ELVITEN, Harmony, FABULOS, Cities4People and the national project AVINT in which two electro automated vans will run the streets of Trikala.

Noord-Brabant

The Provincie Noord-Brabant and Arriva are project partner in several EU projects that are related to CCAM and user-oriented implementation of future mobility systems. In detail, these are MOVE2CCAM, FABULOS and the national projects Bavo Flex by Arriva. With the Smartwayz.nl mobility programme, citizens can be easily addressed.

4. Related projects from other nationalities

Acronym, website, duration	**4All** **https://www.drivesweden.net/en/project/4all** **November 2019 – November 2020**
Full name	For all – mobility services with self-driving bus in Sweden
Relevant findings	The authors give the following recommendations for making mobility more inclusive (Skogsmo & Anund, 2021): • AVs can complement public transport and/or provide opportunities for new routes that are not possible today due to e.g. spatial constraint or the capacity of the shuttles (number of passengers, tour frequency, speed). They should be shaped to enable integration into the PT system. • Solutions with AVs are also expected to make it easy and smooth to move between two points, preferably on demand and to provide a realistic alternative to privately owned cars. • Despite the vehicle and technology focus of numerous initiatives there is a need for vehicle developments of the shuttles. Workshop participants stress that a shuttle ride must feel safe, secure and comfortable, preferably be climate-friendly, and offer stable operations at decent speeds, allowing an acceptable duration of travel. The business dimension and alternatives for providing persisting, and economically sustainable 4all services, also need to be developed. They conclude that "Targeting wide enough groups and taking a systems approach, by applying the checklists and considering all the building block aspects, might increase the chances for future solutions that indeed provide "mobility for all".
Importance	*Technology or user-oriented?*

	Strongly user-oriented. The project aims to “develop solutions that can contribute to sustainable mobility in the form of demonstrators/pilots, being useful "for all" and then being applied in a wider context”. *CCAM or other mobility services oriented?* Self-driving shuttles

Acronym, website, duration	**AHA** **https://www.drivesweden.net/en/project/aha-human-approach** **June 2018 - September 2019**
Full name	A Human Approach
Relevant findings	This project aimed at raising awareness and engagement for how human-centred perspectives on how the use of (Automated Vehicles (AVs) and Mobility as a Service (MaaS) in commuting can be part of city development and planning in a multi-stakeholder context that involves the car manufacturing industry, cities and social scientists. It would do so by developing a transferable and scalable design anthropological methodology template (that uses design ethnography and designs future methods) and an online dissemination platform for this to share insights and mindsets to create similar projects in other contexts. 7 overall principles and recommendations for urban city planning (Final Report): • Planning for social values - Everyone who lives in the city should be able to feel that they are part of it and that they can influence and be involved in the planning and development of the city. • Planning for simpler everyday life - We plan for good quality of life at all levels; individual, family, community, neighbourhood, the whole city, with mobility solutions and services that contribute to making everyday life easier for more people and leaving a sustainable footprint. • Planning for shared and combined mobility - The transport system must be robust and work for both people and goods. • Planning for accessibility and flexibility. - Accessibility and flexibility are central to achieving attractive and effective mobility and a sense of freedom for the individual. • Planning for transparency - Attractive mobility requires coordination of different modes of transportation in an efficient way • Planning for collaboration and a holistic approach - Future mobility is based on the cooperation of several actors and a holistic approach can be applied. • Planning for integrated city use - In the city, existing constantly meets new. To some extent, the existing sets the framework and / or conditions for the new. Future access to land, electricity and fossil-free fuels also provides prerequisites for future mobility.
Importance	*Technology or user-oriented?* Both. The project aims to develop a proof-of-concept study and working model for the research, co-design and development of services, technologies and space planning for future intelligent cities *CCAM or other mobility services oriented?*

Acronym, website, duration	**None** **https://www.drivesweden.net/en/project/guidance-journeys-highly-automated-vehicles-blind-deaf-and-deaf-blind-persons** **January 2019 - July 2020**
Full name	Guidance for journeys with highly automated vehicles for blind, deaf, and deaf-blind persons
Relevant findings	Ranjbar (2022): • people with functional impairments such as blindness, deaf-blindness, and deafness can perform trips independently if given information adapted to their needs through auditory, tactile, or visual information channels. • It would be difficult for the target groups to travel without any additional communication aid, such as a vibro-tactile guidance aid for all phases of the trip, especially for those with blindness. • In all rides with the simulated autonomous car (Wizard-of-Oz set up) without vibro-tactile guidance, the driver or assistant (in at least one phase of the trip) had to intervene for the research participants with blindness to complete the trip and continue the study. • The study also highlights the usability of the vibro-tactile guidance aid and identifies areas in need of improvement
Importance	*Technology or user-oriented?* Both, vibro-tactile guidance is used to allow blind, deaf and deaf-blind people to travel independently on autonomous vehicles *CCAM or other mobility services oriented?* Automated Mobility

Acronym, website, duration	**none (no project attached)** **https://doi.org/10.1016/j.jth.2021.101022** **2021**
Full name	Facilitating independent commuting among individuals with autism – A design study in Singapore
Relevant findings	From a total of 25 parents, details of their children's frequency of travel, independent public transport experiences (if any) and challenges of independent commuting were examined. Based on the survey findings, a requirement list was compiled as a basis for creating a design concept to address public transport barriers of individuals with ASD: Requirements included: • quiet environments • assistance in alighting • assistance in boarding • predictable travel routines • simplified ways to ask for help • supervision or support • more visual aids • emergency buttons • learning to ask for seats and priority seating. ViCo, a Virtual Companion at bus stops and in buses and trains is proposed in the current paper to address the requirement list of individuals with ASD as highlighted in the survey findings.
Importance	*Technology or user-oriented?* User-oriented. Focus on individuals with autism. *CCAM or other mobility services oriented?* No CCAM, but experiences with public transport were surveyed.

Acronym, website, duration	**none (no specific project attached)** **https://doi.org/10.1145/3507472** **2022**
Full name	The Influence of Robot Designs on Human Compliance and Emotion: A Virtual Reality Study in the Context of Future Public Transport
Relevant findings	The study investigated how the human-likeness of a robot influences the compliance and emotions of public transport users. A Virtual Reality experiment was conducted (N=33) to evaluate two different robot designs in a bus stop boarding scenario. The two robot designs differed in terms of humanoid appearance. In different experimental trials, participants had to perform a given task that was nullified by instructions from one of the two robots. Additionally, the dissonance of the situation was altered so that the environment either justified the robot's interference or not. Compliant behaviour, pleasure, and arousal ratings, as well as task processing times were recorded. Results: • Future deployment of service robots has the potential to redirect passengers. • In dissonant situations, clear reasoning must be given to make the robot effective. • The robot's visual appearance has a more substantial impact on arousal and subjective preferences than on evoked behaviour. • The presence of a service robot can influence peoples' choices and give hints about the importance of giving a reason. • The level of the robot's humanoid appearance did not make a difference.
Importance	*Technology or user-oriented?* Both. The impact of assistant robots with differing levels of human likeness on human decision-making was assessed. *CCAM or other mobility services oriented?* No CCAM but public transport was involved.

Acronym, website, duration	**none (no specific project attached)** **https://doi.org/10.1016/j.trip.2021.100443** **2021**
Full name	Engaging citizens in driverless mobility: Insights from a global dialogue for research, design and policy
Relevant findings	Dialogues on driverless mobility attended by 945 citizens in 15 cities across North America, Europe and Asia. Findings: • optimism for driverless mobility • citizens exhibited lower levels of trust and acceptance as vehicle automation increased • public transport was the preferred implementation model for driverless mobility • national governments were most trusted to lead the development and implementation of driverless mobility • need for further investigation into how trust and acceptance are related to perceptions and understandings of automation levels, and how vehicle automation should be communicated to citizens more effectively
Importance	*Technology or user-oriented?* User-centred view on technology. *CCAM or other mobility services oriented?* Yes, personal attitudes on automated driving were collected.