Understanding Mobility Needs and Designing Inclusive CCAM Solutions: A Literature Review and Framework

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Abstract. In our increasingly interconnected world, ensuring inclusive and reliable mobility is paramount. Cooperative, Connected, and Automated Mobility (CCAM) solutions can play a pivotal role in addressing the diverse needs of people with mobility challenges. Through an extensive literature review, this paper constructs a theoretical framework to understand mobility needs within the context of CCAM comprehensively. It delves into individual characteristics, including socioeconomic, psychological, cognitive, and physical factors influencing mobility needs and behaviors. Using an extended version of Ajzen's Theory of Planned Behavior and models on motives and needs, it describes the dynamics between user characteristics, CCAM service characteristics, and the formation of intentions that subsequently affect the actual usage. The framework covers three levels: 'Mobility Needs,' 'CCAM Design Requirements,' and 'Intention & Use.' In conclusion, this theoretical framework offers practical utility by informing the design of CCAM solutions to foster higher adoption rates and heightened mobility satisfaction across diverse user groups. The gathered results can be directly applied to evolve future CCAM solutions by researchers, service providers, and manufacturers.

Keywords: CCAM, mobility, inclusion, mobility framework.

1 Introduction

Inclusive and reliable mobility is becoming increasingly important in a more connected world. Mobility innovations, particularly Cooperative, Connected, and Automated Mobility (CCAM) solutions, hold immense potential to consider the unique transportation needs of people with mobility challenges. However, in the past, the design and quality of many public transport services and car manufacturers focused on the average user and developed standardized mobility solutions (Deakin, 2022). In recent years, equity and accessibility have become increasingly crucial in transport research, and transport service providers aim to make public transport more inclusive (Martens, 2016). To account for the needs and requirements of people with mobility challenges, it is first necessary to understand these needs. Therefore, this paper presents the results of an extensive literature review, resulting in a theoretical framework on mobility needs and CCAM, which can be used for further research and development. It highlights the

importance of understanding the specific user requirements to ensure the development of equitable and inclusive CCAM solutions. It builds a theoretical foundation for the EU project SINFONICA (Anke & Ringhand, 2023), aiming to capture the mobility needs of European citizens through a bottom-up approach, with particular attention to the needs of people with mobility challenges and under-researched groups. The paper is structured as follows: Chapter 2 presents the literature review results to identify mobility needs, motives, and theories on intention and behavior formation. These build the foundation for the framework presented in Chapter 3 and the conclusion in Chapter 4.

2 Empirical and theoretical foundation for the framework

2.1 Needs, motives, and motivation

In an everyday understanding, needs describe basic human requirements that need to be fulfilled, or if not, one would like to satisfy. Therefore, needs are strongly associated with a person's intrinsic motivation. Focusing on understanding human motivation and well-being, the basic psychological needs theory by Ryan and Deci (2017) proposes three basic needs that must be satisfied to enable self-determination. According to this theory, the first need is *competence*, which describes the experience of efficacy in interactions. The second need, *autonomy*, describes the ability to effectively interact with the environment, master challenges, and feel a sense of achievement. Finally, *relatedness* expresses the desire to connect to others and to be part of a social group (Ryan & Deci, 2017). According to the theory, if all these needs are met, people are likelier to experience a sense of self-determination, intrinsic motivation, and general well-being.

When these needs are not fulfilled, it can lead to frustration and decreased motivation. Other theories consider further needs, such as physical thriving, influence, self-actualization/meaning, self-worth, popularity, security/safety, and pleasure/stimulation (Sheldon et al., 2001). Needs can act as dynamic motivational forces that direct and energize behavior, influencing individuals' choices and actions (Sheldon & Gunz, 2009). These processes are described as motives, which provide a more dynamic perspective, representing the individual and varied reasons behind goal-directed behavior. They shed light on the individual and situational factors that lead individuals to take specific actions to satisfy those needs (Nuttin, 1984).

In the context of mobility, several motives are influential regarding mode choice and the adoption of new mobility services, such as CCAM. Regarding mode choice, instrumental motives, such as speed and accessibility, have been identified as influential (Correia & van Arem, 2016), and symbolic motives, for instance, the prestige and social position associated with a vehicle (Steg et al., 2001). On the other hand, the attitude towards new mobility solutions is influenced, amongst others, by the perceived travel time savings and additional comfort they offer (Pigeon et al., 2021). Therefore, considering needs and motives is integral to understanding the intention to use CCAMs and the attitude toward them.

To achieve equity in transport, four essential user requirements are identified in transport literature that must be addressed based on the user needs mentioned above.

These are availability, accessibility, affordability, and acceptability (Arup, Urban Transport Group, 2022; Cirella et al., 2019; Dabelko-Schoeny et al., 2021). To meet the availability requirement, CCAM solutions must be accessible to users regardless of location or mobility constraints and provide timely and connected services with simplified information. Accessibility includes CCAM design and infrastructure to ensure freedom from barriers. Affordability requires transparent cost information, easy access to pricing, and seamless payment options. Finally, acceptance requires CCAM solutions to be convenient, secure, comfortable, and responsive to user needs.

2.2 Individual differences in mobility needs

We define mobility needs 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.' (Anke & Ringhand, 2023, p. 18) From the perspective of user characteristics, people can differ in terms of their socioeconomic and sociodemographic, psychological, cognitive, and physical characteristics.

Socioeconomic and sociodemographic factors (such as age, gender, income, etc.) have been found to influence mode choice and travel behavior. For instance, people in more deprived neighborhoods are likelier to walk and use public transport (Rachele et al., 2015). Furthermore, needs and motives are affected by certain socioeconomic and sociodemographic factors, such as gender. A study in the UK has found in this context that women show a higher need for safety and security than men (Innovate UK, 2022). Finally, challenges arise from factors such as age, as older people face more cognitive and physical challenges than younger people (GOAL, 2013).

Psychological factors, in turn, relate more to intrapersonal factors, such as personality traits and the subjectively weighted importance of motives and needs. These factors can also influence mobility behavior. For instance, a study revealed an association between a more agreeable and not conscientious personality and increased public transport use (Roos et al., 2022). When it comes to future mobility options, trust in technology has been found to influence the adoption of driverless cars, as well as having a positive attitude toward them and perceiving them as safe (Kaur & Rampersad, 2018; Launonen et al., 2021).

The *cognitive characteristics* of a person cover their skills, intelligence, experiences, knowledge, mental models, and literacy. Certain services requiring skills, such as language proficiency and digital skills, have been identified in studies as potential barriers to public transport (Dabelko-Schoeny et al., 2021). Furthermore, research on the acceptance of autonomous vehicles indicates that a greater understanding of the technological facets of autonomous driving is correlated with increased acceptance or intention to use autonomous mobility (Charness et al., 2018).

Finally, *physical characteristics* such as health and physical constitution can lead to mobility challenges. This is especially the case for people with disabilities. When walking, hearing, or seeing are impaired, people often need assistance to travel, which is frequently lacking and thus hinders their community participation (Bezyak et al., 2020).

Besides the user characteristics, situational factors also play an essential role in forming mobility needs. These can be the living environment, vehicle availability, trip purpose, cultural characteristics, and environmental conditions like weather and time of the day. All these factors characterize not only individuals but also allow groups with similar characteristics to be considered regarding mobility specifics. Groups that might be considered are low-income and unemployed people, older people, people with disabilities, migrants, ethnic minorities, people with language barriers, young people and children, women and queer people, people living in rural areas and digitally non-connected people. This selection is not exhaustive but is intended to consider people whose needs and motives might be underrepresented in current research (for a detailed description of groups with mobility challenges see Anke & Ringhand, 2023; Di Gregorio & Renzi, 2023).

2.3 Intention and behavior formation

One prominent theory about the formation of intentions and the subsequent eventual behavioral execution is the Theory of Planned Behavior (Ajzen, 1991). It proposes that a person's intentions precede their behavior. These intentions are shaped by three primary predictors: attitudes, subjective norms, and perceived behavioral control. Attitudes are influenced by behavioral beliefs that associate certain consequences with the desirability of a behavior. Positive attitudes increase the likelihood of forming an intention to engage in that behavior. On the other hand, subjective norms reflect the perceived social pressure and sense of belonging to a peer associated with conforming to a particular behavior (Ajzen, 1991). These norms are influenced by normative beliefs, which represent the expectations of others regarding the behavior. Finally, perceived behavioral control involves the perceived ease or difficulty of performing a behavior, including self-efficacy and controllability. According to the theory, the interplay of these three prerequisites may lead to the formation of intentions, which can lead to behavior. Whether intentions lead to behavior depends on the actual behavioral control. It refers to factors that objectively facilitate or hinder behavior execution (Ajzen, 1991). Within the context of inclusive mobility, those factors, for instance, might be the low availability of a service or personal prepositions, which impede the use of mobility services. The Theory of Planned Behavior provides a comprehensive framework for understanding and predicting mobility behavior in various contexts and is included in the CCAM framework as a theoretical foundation focusing on actual and perceived behavioral control.

3 The CCAM framework

Based on the research results, a theoretical framework focusing on the mobility needs of CCAM was developed (see Fig. 1). The framework consists of three levels. The first level of the framework (highlighted in purple) revolves around forming mobility needs, combining individual user characteristics and situational factors. These determine requirements for CCAM service characteristics, which, in turn, affect the users' mobility

behaviors. For instance, a digitally non-connected user with low-tech affinity may prioritize easy information acquisition and interface design, while a physically disabled user may emphasize the service's accessibility. These individual characteristics interact with situational factors, such as trip purpose or the environment. Therefore, mobility needs are dynamic and influenced by changing situational factors and individual characteristics. The framework includes exemplary user groups with mobility challenges.

The second level (highlighted in orange) is the centerpiece of the framework, as it deals with how people's requirements and the respective CCAM characteristics come together to enable people to use CCAM. The CCAM service characteristics are determined by the users' mobility needs and corresponding requirements, but stakeholder requirements are also considered. The CCAM design process should aim to improve the user's actual and perceived behavioral control. This is achieved when all the conditions necessary for the user to perform the behavior (using a CCAM service) are met and perceived as such. The matching between service characteristics and user needs influences the level of actual behavioral control. For example, high intention to use may be hindered if the service network is unavailable, leading to low actual behavioral control and making CCAM use impossible.

The third level of the framework (highlighted in green) reflects the relationship between forming an intention to use and the subsequent real-world use of CCAM services, incorporating components of the Theory of Planned Behavior (Ajzen, 1991) and habits (Fu, 2021). The formulation of an intention to use is influenced, next to the various individual and situational factors, by attitudes and subjective norms. The realization of this intention depends on nuanced factors such as the perceived behavioral control, the actual behavioral control, and pre-established habits. Besides these interrelations, user and situational characteristics also influence attitudes and subjective norms.

In summary, the structure of this framework shows that future CCAM solutions must consider different levels of user needs to develop inclusive services that enhance mobility experiences for diverse user groups.

4 Conclusion

This article provides a theoretical framework that helps develop future CCAM services by considering the needs of people with different mobility prerequisites right from the design stage. The framework was developed based on a literature review identifying mobility needs and respective interindividual differences in the importance of those needs. Furthermore, the Theory of Planned Behavior by Ajzen (1991) was used as a theoretical foundation, helping to explain how needs and situational factors influence the intention to use CCAM and then the actual use of CCAM.

This framework provides practical utility by enabling researchers to conduct user-centric studies and as a first guiding point for service providers and manufacturers that design CCAM solutions considering diverse user needs, ultimately fostering higher adoption rates and more inclusive transport. It will be used within the SINFONICA project as a theoretical foundation to capture the needs, individual factors, and requirements toward CCAM for different groups of people with mobility challenges.

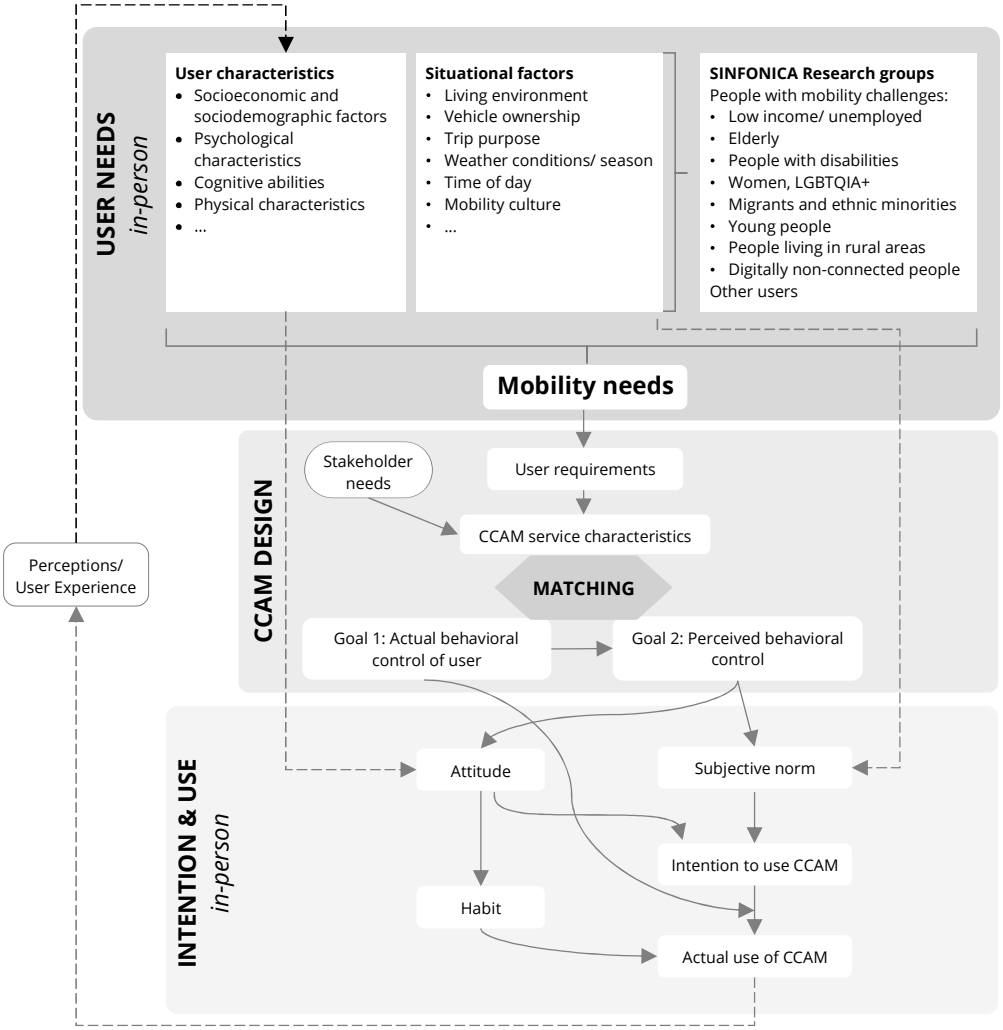

Fig. 1. Framework on mobility needs regarding CCAM having three levels – 'User Needs', 'CCAM Design Requirements', and 'Intention & Use' (Anke & Ringhand, 2023).

Acknowledgements. This study is based on the results of deliverable 1.1, which was produced as part of the SINFONICA project (Anke & Ringhand, 2023). The SINFONICA project (Grant Agreement n° 101064988) was funded by the European Union under the Horizon Europe Research and Innovation Programm. Views and opinions expressed are however those of the authors only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the granting authority can be held responsible. The authors thank

Jens Schade for his contributions to the SINFONICA project proposal, which made this study possible.

Disclosure of Interests. The authors have no competing interests to declare that are relevant to the content of this article.

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