Addressing Mobility-as-a-Service Inclusive Design through the Engagement of Vulnerable Users: Future Perspectives for Italian MaaS

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Abstract. Mobility-as-a-Service (MaaS) has been targeted for long for its transformative potential for enhancing accessibility and social inclusion by addressing physical, economic, spatial, and digital barriers faced by vulnerable users, including the elderly, disabled individuals, and those in marginal areas. This paper examines Italy's MaaS4Italy initiative, funded under the Italian National Recovery and Resilience Plan, thus revealing that initial pilots prioritized early adopters (e.g., commuters, younger users) while lacking systematic engagement with vulnerable social groups (VSGs). Drawing on literature review and empirical analysis -including Sardinia-based surveys with NGOs- the authors identify key digital accessibility requirements (WCAG compliance, universal design principles) and engagement barriers (digital divide, mistrust, consultation fatigue). A three-phase governance and deployment framework is therefore proposed: (i) public authorities setting accessibility standards; (ii) co-design via partnerships with NGOs; and (iii) centralized audits with iterative VSG involvement for monitoring. Findings underscore the need for hybrid public-private governance, integrating Artificial Intelligence for bias-mitigated user profiling and tailored services. Policy recommendations advocate tailor-made strategies to ensure equitable MaaS deployment, fostering inclusive national pilots and long-term sustainability.

Keywords: Mobility-as-a-Service · VSGs · NGOs · accessibility standards

1 Introduction

Mobility-as-a-Service (MaaS) has been targeted from the very beginning as a powerful driver for accessibility improvement and social inclusion, shifting the transportation focus from private car ownership to flexible, user-centric, and integrated multimodal

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mobility solutions [1]. By aggregating different transport providers into a single digital platform for planning, booking, and payment, MaaS addresses multiple dimensions of transportation disadvantage [2], stemming from objective factors (such as territorial divide) up to individual conditions.

In details, it may mitigate physical, economic, spatial, and temporal barriers leading to transport poverty, by offering affordable, integrated alternatives to private vehicles [3]. In this context, transport poverty can be conceptualized as a lack of accessibility that prevents individuals from meeting their basic needs and participating in society [4]. It does not only concern the lack of means of transport, but the lack of adequate access to essential activities. In other words, it adopts accessibility as a central operational concept for translating social justice into design practice. In the long term, MaaS gives policymakers the opportunity to shift from broad supply-side subsidies to user-based, person-centered incentive models, directly improving the equity and efficiency of transport subsidies for disadvantaged groups [5]. Territorial inequalities may be addressed, as well.In rural, remote, or island communities, where sprawling geography and low population densities make traditional fixed-route transit financially unviable [6], MaaS systems integrate flexible, crowd-sourced, and Demand-Responsive Transport (DRT) with high-capacity transit, effectively solving "first and last mile" gaps [7].

Within an intersectional perspective, similar context-related disadvantages may also overlap with personal conditions. In this direction, MaaS allows also vulnerable population empowerment through two main lines of action: i. reduction of physical and cognitive effort and ii. improvement of universal accessibility by design [8].

Door-to-door services may indeed be included within MaaS offer, restoring independence for those unable to operate a private vehicle [9]. At the same time, the combination of route planning, booking, and real-time updates into a single interface, should also drastically reduce the logistical effort and anxiety associated with trip chaining, which benefits elderly users and those with intellectual vulnerabilities [10].

Similar goals may indeed be pursued only mainstreaming universal design principles [11] from the initial steps of the process, thus considering the psychological, physical, and cognitive needs of individuals, creating a system usable by everyone without the need for specialized adaptation [12].

In this direction, as highlighted by [13], MaaS potential in terms of social inclusion and universal accessibility may be measured through a multi-dimensional approach focusing on transport service and infrastructures accessibility, as well as on digital platform design. The present contribution aims at applying a similar framework to MaaS4Italy initiative, funded by National Resilience and Recovery Plan (NRRP) and launched in 2021 [14]. Currently in the pilot phase, similar project aimed at defining a national platform for Italian MaaS, supporting data standardization and best-practices sharing among cities and territories involved in the experimentation [15].

Targeting effective pilot deployment, particular attention has been paid to the engagement of early adopters (e.g. younger users, commuters, etc.) [16]. Nevertheless, similar approach may translate into poor accessibility of the comprehensive system, both on the physical and digital sides, thus hampering the inclusion potential of a nationwide MaaS proposal for Italy.

In this direction, the present research addresses the identification of accessibility requirements for inclusive MaaS platforms, focusing on the engagement and needs of vulnerable users (Sect. 2). Subsequently, potential barriers to the design and deployment of accessible MaaS will be addressed in Sect. 3, thus identifying potential recommendations that guide policymakers through inclusive and accessible MaaS pilots. Conclusive remarks will be provided in Sect. 5.

2 Background

MaaS inclusive potential mainly relies on the mainstreaming of universal design principles from the very first steps, as well as on the engagement of vulnerable users within a participated co-design process [17].

2.1 Digital Accessibility

The main factors affecting the digital accessibility of mobility apps can be divided into two broad categories: technical and interface design factors (indicating how the app is built) and user-centric factors (depending on the resources and capabilities of the people using the app) [18].

Technical and interface design factors generally align with Web Content Accessibility Guidelines (WCAG) and usability heuristics tailored for mobile interfaces. To be more precise the main factors to consider are as follows:

- Perceivability and Visual Design: an accessible app requires sufficient text size, the ability for users to customize font sizes, and high colour contrast between text and backgrounds [19]. Common accessibility violations in mobile apps include low text colour contrast and the lack of alternative text (alt-text) for images, which prevents screen readers from describing visual content to visually impaired users [20]. Content should also not be placed too tightly on the screen.
- Operability and Navigation: The app must be easy to navigate and control. This includes providing adequate spacing between elements, sufficiently large buttons or icons (touch targets), and consistently placed navigational markers like “back” and “next” buttons [21]. Additionally, elements must have proper technical “focus” enabled; otherwise, they cannot be navigated using external keyboards or recognized by assistive technologies [22].
- Understandability and Clarity: Apps should use plain, everyday language, avoiding technical jargon and complex expressions [23]. Accessibility is also enhanced by intuitive features like autocorrect, clear error messages with constructive recovery solutions, and step-by-step guidance or pop-ups that assist users in completing tasks without confusion [24].
- Robustness and Assistive Technology Compatibility: The app must be technically built to work smoothly with integrated assistive technologies, such as Android’s TalkBack or iOS’s VoiceOver [25]. To achieve this, all interactive elements, input fields, and visual graphics must be correctly labelled in the application’s underlying code [26].

User-centric factors' accessibility is also heavily influenced by the digital inequality gap, which dictates whether a user can actually access and successfully operate the technology according to individual features and resources. Digital literacy and skills are identified as one of the strongest predictors of access to mobility services [27]. Users need "medium-related skills" (knowing how to operate a smartphone or browser) as well as "content-related skills" (knowing how to search for routes, assess the reliability of real-time info, and manage privacy settings) [28]. Material access to the physical technology is a prerequisite. This includes owning a capable smartphone, having a reliable data plan, and managing battery life and operating system updates [28].

From an individual perspective, a lack of trust can severely hinder accessibility. Fear of cybercrime, data leaks, phishing, and general privacy concerns often dissuade users from engaging with digital mobility platforms, especially when online payments or credit cards are required [29]. Digital flexibility is required to adapt to constant changes in the digital landscape. Frequent app updates, shifting to entirely cashless ticketing systems, or navigating sudden platform changes can create significant barriers for users with low digital flexibility [30]. Finally, as far as users' segments are concerned, vulnerability to digital exclusion in mobility frequently correlates with age (e.g., older adults facing cognitive or motor decline), lower income and education levels, physical or cognitive disabilities, language barriers, and lack of social support networks to help them learn the technology [31].

Being individual barriers not valuable aprioristically, a subsequent step would require users' engagement and involvement to address them properly.

2.2 Vulnerable Users' Engagement

In the context of transport digitalization, there is a risk that these systems, rather than helping, may increase the disadvantages of the most vulnerable groups [32]. In this sense, it is vital to involve all potential user groups in the design, testing and evaluation of innovative mobility solutions if inclusivity and accessibility are to be ensured [33].

In order to properly engage VSGs [34] in the planning process, their recruitment requires the adoption of diversified and inclusive strategies. One effective approach consists of creating partnerships with local associations that can operate as facilitators and can act as intermediaries between researchers, policy makers, and target groups [35]. These associations often have a direct relationship with local communities and vulnerable users, allowing them to facilitate communication, build trust and mediate [36].

A series of strategies have been identified from the literature based on direct experience [37]. n particular, studies emphasize the importance of integrating online and offline recruitment channels, especially when involving the elderly since digital-only approaches, such as emails, may exclude people with limited digital skills. Collaboration with organizations and associations, the use of attractive images, visuals and storytelling techniques as well as the employment of snowball sampling methods have been identified as effective instruments for participant recruitment [38]. he provision of incentives, including vouchers, discounts or minor gifts, has been demonstrated to facilitate the recruitment process and enhance the level of interest in participation. Furthermore, the organization of face-to-face events and the dissemination of the research outcomes may

enhance the likelihood and willingness to contribute to subsequent activities and engage in long-term initiatives.

Another effective strategy in reaching vulnerable population groups is through Communities of Practice. This concept has found numerous practical applications in a variety of fields including business, organizational design, public administration, education, professional associations, development projects and civil life [39]. As [40] highlight, the CoP constitutes a functional space in which diverse actors convene with a view to resolving actual problems. This approach constitutes an alternative operational method that can be employed to incorporate vulnerable groups within the planning process.

Finally, to address this challenge effectively, it is essential to adopt a 'tailor-made' approach calibrated to the specific characteristics of the reference population with a thorough understanding of its needs and a particular attention to the social groups at risk of exclusion.

2.3 MaaS4Italy User Profile

MaaS4Italy is a nationwide funded program that was launched in 2021, stemming from Italian NRRP resources (on their turn descending from Next Generation EU financing). It aims both at the design and deployment of a national database and repository supporting shared data standards on a national level, the so-called Data and Service Repository for MaaS (DSRM) [41]; as well as at implementing several pilots across the country. In detail, two subsequent selection rounds were implemented, the former one addressing capital cities and the latter in 2022 addressing regions on a wider scale.

As far as users' profile selection is concerned, MaaS4Italy envisages the engagement mainly of volunteer citizens recruited through information campaigns, mobility habit surveys, and experimental panels, with a minimum target of 1,000 users per pilot project.

During first phase (completed by the end of 2023), the pilot cities engaged users on a voluntary basis and at their own expense, forming panels through ex-ante, ongoing, and ex-post surveys to assess impacts on attitudes and mobility habits. Participation was low but qualitatively positive, as users reported satisfaction, increased travels, and reduced private car use [14]. Average users were recruited from metropolitan or partial populations, profiled by age (>16 years), gender, residence, employment, and transport modes used. Nevertheless, on an individual basis, selected cities and regions identified peculiar target groups to be addressed preferentially.

In details, three pilot cities and one pilot region explicitly refer to vulnerable target segments.

The city of Bari [42] for instance addresses among selected users' groups students, commuters, tourists and disadvantaged residents. Specifically, the latter group includes people with disabilities, pregnant women and families with children under the age of four, refugees and asylum seekers, unemployed people.

Turin, as well, targets two main clusters of users [43]: citizens and corporate users. Among the former group, particular attention has been paid to people with disabilities that benefit from dedicated incentives and support.

Rome, in its turn, addresses commuters, tourists, students and people with mobility impairments [44].

Emilia-Romagna region [45], finally, targets three main categories of resident commuting to larger cities, with particular attention paid to people with disabilities, people living within inner areas using Demand-Responsive-Transport for their daily mobility and tourists.

First phase of MaaS4Italy does not show comprehensive and systemic commitment to vulnerable users' engagement. Despite fragmented references to people with disabilities and other fragile categories, an integrated approach towards vulnerable targets is lacking, thus leaving behind relevant users' groups, such as the elderly. In this direction, early adopters –commuters and tourists, above all, appear to be preferable testers of project first round [16].

3 Methodological Approach

Stemming from similar premises, proposed approach targets MaaS accessibility and inclusion potential through three main critical dimensions: i. the assessment of mobile apps features in terms of universal accessibility; ii. ways to engage vulnerable users' associations and NGOs within the co-design process; iii. role of public authorities and actors to foster the implementation of inclusive MaaS. These three steps indeed cover the entire process from the design of interface and functionalities to the deployment of mobility services.

3.1 Accessibility Checking Tool in European Legal Framework

Although WCAG are widely recognized, public authorities and regulators in both the European Union and beyond (e.g. in the USA) do not provide a single, fully automated official tool for assessing the accessibility of mobile mobility apps; instead, they define legal frameworks, standards and monitoring methodologies that combine automated checks with structured human evaluation [46].

In the EU, mobile apps -especially those of public sector bodies, among which MaaS apps may be listed- are covered by the Web Accessibility Directive and are expected to comply with the harmonised standard EN 301 549, which in turn references WCAG 2.1 AA (and is being updated in line with WCAG 2.2), while national monitoring methodologies prescribed by the Directive require in-depth audits and simplified checks carried out by trained evaluators, optionally assisted by automated tools (European Commission, 2016; European Commission, 2018).

In this direction, the European Accessibility Act (Directive (EU) 2019/882), by incorporating international technical standards of the WCAG 2.2 and EN 301 549, transforms accessibility from an accessory requirement to a primary functional requirement. In this sense, it shifts the focus from "assistance services" to an interface that can be used by anyone: if a website or platform such as MaaS is designed for a visually impaired person, it will be easier to use for everyone, including tourists or elderly people in low light or poor readability conditions. However, while the EAA provides the minimum legal framework for introducing minimum standards it must necessarily be accompanied by local policies that guarantee access and address the economic and cognitive barriers faced by the most vulnerable people [47]. The EAA goes beyond the fragmented view

of accessibility by imposing uniform, European-level requirements that are not limited to removing technological barriers but promote the structural adoption of the principles of inclusive design, design for all and universal design. These guidelines are particularly relevant for MaaS platforms, as the directive stipulates that the perception, operability and comprehensibility of digital services must be guaranteed for all users, regardless of their sensory or cognitive abilities. Italy transposes the European Accessibility Act (EAA) with the Legislative Decree n.82 of 2022, which implements the Directive (EU) 2019/882 on the accessibility requirements of products and services.

The adoption of these regulatory standards guarantees an inclusive user-centered digital infrastructure and ensures the same level of accessibility across different channels, reducing barriers for those with cognitive or sensory limitations. Although digital accessibility is an increasingly important issue in the European regulatory landscape, it cannot be separated from accessibility in real contexts. The website is only part of the experience, and having platforms that are truly inclusive and accessible continues into the physical environment.

In this direction, therefore, official practice converges on hybrid, standard-based evaluation -anchored in WCAG and EN 301 549- where automation is used mainly for large-scale or low-level checks (e.g. missing labels, colour contrast), and human judgement remains essential to assess more complex aspects such as operability, understandability, meaningful focus order, gesture complexity and real compatibility with assistive technologies in domain-specific apps like those for urban mobility [22]. Empirical analyses confirm that automated tools identify only partially issues in real mobile apps, underscoring the irreplaceable role of manual and user-involving evaluations [48].

Similar aspects hinder evidently the possibility to implement large-scale monitoring within MaaS4Italy initiative due to the high number of apps that aver been included into the different implemented pilots nation-wide. Despite some of the MaaS providers are present in more than one pilot, general structure of the initiative has the aim to implement an open ecosystem that could include incrementally more and more providers and respective apps.

In this sense, going beyond basic technical accessibility checks, could be extremely critical to assure equal access conditions to every app, within every pilot. Moreover, the absence of automated standardized process, may lead to a fragmented framework where traditional accessibility inequalities are transferred to the digital dimension [49].

Being human intervention unavoidable to perform similar evaluations, a potential step to be taken could be to engage vulnerable communities also within the design process to grant statistical representation of the target groups within every pilot, thus bypassing manual technical accessibility checks and corresponding arbitrary risks. In this direction, similar approach could indeed integrate official centralized audit that could support universal accessibility compliance from a more institutional perspective.

Going further with accessibility checks, is should be highlighted how being MaaS a mobility app, user-interface does not represent the only element to be evaluated in this direction. The possibility to include within user profile potential mobility impairment selecting by default universally accessible alternatives should be considered, as well [13]. Effort reduction principle implies indeed the presence of default options supporting seamless selection of journey options by different groups of users.

3.2 NGOs and Associations Role and Criticalities

Engaging associations from the early stages of the planning process is fundamental for ensuring a more inclusive and representative participation of users. These associations can play a key role as intermediaries between researchers, plannersand end users, facilitating communication and helping to reach groups that are often difficult to involve through traditional engagement channels. However, in practice, their involvement does not always occur in a systematicand effective way. Nevertheless, it should be recognised that vulnerable social groups, are frequently designated as "hard-to-reach", signifying groups that are underrepresented and marginalised in public debate [36]:

- Structural barriers: resulting from the use of inadequate communication channels, the so-called "digital divide" and a widespread lack of specific skills within institutions.
- Psychological and social factors: such as scepticism towards authorities, systemic mistrust and the absence of representation that truly reflects the needs of these groups.
- Methodological limitations in engagement: late planning that excludes VSGs from decision-making stages as well as poor inclusivity due to inadequately trained staff, and a lack of incentives to encourage participation [50].

Exploring the nature of these barriers, as highlighted by [33], time constraints often represent a significant challenge, as consultation processes can be long and time-consuming, potentially leading to what is commonly referred to as "consultation fatigue" among participants.

In addition, local authorities and project coordinators may lack the necessary skills to effectively plan and manage participatory processes, while limited financial resources and insufficient personel capacties within public administrations can further constrain the organisation of meaningful engagement activities.

Dissatisfaction among participating organisations may also arise from shortcomings in the management of the participatory process itself.

As noted by [51], associations may feel excluded when they are not consulted with sufficient notice, do not have full visibility of the tasks involved, or are not actively included in the planning stages of the process. Such conditions may weaken trust and reduce the willingness of organisations to participate in future initiative [52].

Another critical issue concerns the risk of bias in the recruitment of participants, which can occur when it only relies on a single communication channel. For instance, the exclusive use of online channels for participant recruitment may primarily reach individuals with higher levels of digital literacy, thus excluding segments of the population with lower digital skills [37]. This limitation is particularly relevant when attempting to involve vulnerable social groups, such as older adults or individuals with limited access to digital technologies.

3.3 Role of the Public and Private Authorities Operator Agreements

Lack of control and monitoring to equal and universal access to MaaS platforms and services may also depend on the role and relevance that private and public actors playwithin the MaaS ecosystem.

MaaS4Italy initiative acts in this direction in a quite ambivalent way: data-sharing standards and platform are provided centrally, so that pilots share a common infrastructure, nevertheless, each of the involved territory is autonomous in defeding their governance mechanisms and models.

Public authorities should indeed define and identify data standards and accessibility mandates, complementing private firms' expertise in app development and real-time integrations [53, 54].

From an operational point-of-view, public-private partnerships in this direction prevail, since only few pilots have the aim to deploy a public-control app (Florence and Tuscany region are working in this direction), thus complicating the framework in which accessibility evaluation and vulnerable users engagement should be planned and implemented.

Similar approach positions users as active co-creators, particularly in rural settings, to enhance feedback-driven inclusivity [53]. This division bridges operational silos for broader service coverage [55].

It is therefore self-evident that similar hybrid approach leaves some relevant issues unsolved, not only in terms of governance and business effectiveness [56] but also in terms of social sustainability of the proposal.

In this direction, within a diverse society, public entities and policy-makers are required to act on multiple levels [57]:

- Set accessibility standards both in terms of physical and digital infrastructures, thus playing the fully public role of assuring equitable and universal access to new urban mobility services;
- Define public-private agreements with providers and actors involved within the ecosystem that include standards define at step 1. thus including universal accessibility criteria related to MaaS apps, mobility services and vehicles, equitable fares taking into account different mobility profiles. In this direction, similar elements would represent a pre-requisite and/or a rewarding element guiding providers selection;
- A third step of the enabling/monitoring role played by public promoter of the initiative should deal with the deployment of centralized audit and evaluations of universal accessibility conditions offered to users within the various pilots, thus engaging also vulnerable groups in the assessment process to feed an iterative approach.

Similar three steps' process aims at building a structured path for co-design and deployment of inclusive MaaS, to ensure proper involvement and empowerment of vulnerable categories that could benefit from MaaS paradigm, but that have been partially left behind from the initial pilots. An institutional and demanding workflow that aims at representing diverse mobility needs and behaviors, thus requiring at the same time a shared responsibility during the entire process.

4 Discussion

Identifying the workflow could therefore be crucial in supporting the progressive implementation and deployment of an inclusive MaaS approach during the pilot and subsequent phases.

In this direction, three different steps of recommendations have been identified:

- Empowerment and strategic framework: Public Authorities should play the role as primary coordinator who sets requirements and rules for societal equity and the compliance with accessibility standards. PA should also set the strategies for properly involving VSGs;
- Co-design process: a second step in which to translate the standards set in step 1 in operational requirements for a collaborative engagement. It translate standards in official agreement. In this step association play a key role as parties of interest by defining requirements with the PA;
- Institutionalisation and accountability: monitoring and long-term governance with association actively designated since the initial phases.

Adopting a structured, multi-step approach ensures that inclusivity is incorporated across all stages of MaaS development, from strategic planning to long-term governance. The ensuing sections of this paragraph will explore how these principles can be operationalised to create requirements for inclusive travel planning. These criteria are then enhanced through the use of AI-driven solutions for profiling users' needs and delivering tailored, on-demand services.

Similar tool may support in the long run the transition from the preliminary pilots based on early-adopters experiences to wider public applications, thus including vulnerable users. The analysis of massive data concerning mobility behaviours performed by AI tools could indeed support policy makers and MaaS providers to identify relevant factors and variables related to specific potential barriers for vulnerable groups (such as physical effort; presence of slopes; safer routes, etc.).

An AI-based transition roadmap from early testbeds to regular and inclusive MaaS proposal could indeed feed and speed-up participatory workflow, through the capitalization of the collection and processing of massive behavioural data and preferences.

At urban level AI-based solutions could also impact physically on users' experience of multi-modal journeys. The co-design process could indeed benefit from massive data collection and processing to improve both available transport services and platform universal accessibility, through a crowd-sourced approach.

4.1 Participatory Approach for Defining Criteria Oriented to Vulnerable Users' Needs

In the context of the design of inclusive transport systems, the establishment of a multi-step process has been identified as a fundamental prerequisite. A subsequent investigation into the mobility needs of vulnerable groups is recommended, with the objective of defining criteria for the development of tailored travel alternatives. In this context, co-creation processes represent a key strategic approach, enabling the active involvement of end-users throughout the design phases [37].

As [58] stated, these processes are typically operationalised through a combination of participatory methods, including interviews, focus groups, interactive workshops, and living labs, which allow for the collection of both qualitative and contextualised insights [37, 40, 51]. Such approaches facilitate a deeper understanding of users' experiences, constraints and preferences.

In this perspective, interviews and focus groups can be regarded as qualitative tools which are considered essential for the purpose of gathering first-hand experiences and gaining an in-depth understanding of individuals' capabilities, limitations and requirements [40, 59, 60]. The utilisation of these methods facilitates the identification of needs that are frequently eluded by quantitative surveys [61]. Specifically, focus groups are frequently considered as a functional approach for discussing and validating previously collected data through the interaction among participants, while also facilitating discussions within a selected small group [47].

The recommendations resulting from participatory methods and user engagement activities provide the empirical basis for defining a set of criteria designed to guide the design of inclusive MaaS travel options. In this regard, the potential of artificial intelligence to dynamically profile users' needs and enable adaptive, on-demand mobility services is significant.

The issues highlighted in the literature are also reflected in the empirical activities conducted as part of this research. As part of the PNRR-funded project to develop a MaaS platform for Sardinia, a survey was conducted to analyse the mobility habits of vulnerable people and their propensity to use digital tools for this purpose.

The questionnaire was developed and designed in collaboration with the Italian Multiple Sclerosis Association (AISM) whose contribution helped refine both the structure and the language of the survey in order to improve accessibility and comprehension for participants with different cognitive and physical. The survey was disseminated both at local and national level, using a multi-channel strategy integrating both online, via digital platforms and official social media channels and face-to-face administration methods to ensure wide dissemination and facilitate participation among users with varying levels of digital literacy.

AISM played a particularly important role in this phase, helping to reach people with disabilities and other vulnerable groups through its local branches and communication channels. The University of the Third Age (UTE) of the city of Alghero (Sardinia, Italy), played a significant role in facilitating communication with elderly people at a local level. For their involvement a face-to-face event as being organised in order to present the research project and distribute the questionnaire.

Despite the involvement of associations that acted as intermediaries between researchers and potential end users, as well as the use of both online and offline dissemination channels, the sample actually reached was limited. In the case of the questionnaire on mobility habits, 31 responses were collected, while the second questionnaire recorded 23 participants. The limited sample size can also be partially ascribed to the temporal constraint, as the involvement of vulnerable groups requires long-term engagement process capable of establishing trust between the different parties involved [37]. Therefore, the empirical phase was not intended to achieve statistical representation but rather to gather preliminary insights into mobility habits and attitudes towards assistive technologies among vulnerable users thorough the involvement of key informants.

Future research should involve a larger sample of vulnerable users to ensure statistical validity.

4.2 AI for Profiling Users' Needs and Managing on-Demand, Tailored Services

Artificial Intelligence (AI) may play a crucial role in profiling vulnerable users' behaviours and needs more precisely, thus enabling a more tailored, effortless and seamless travel experience. AI-driven profiling in MaaS extends indeed far beyond basic demographic data to capture the dynamic, context-dependent nature of individual mobility necessities.

From a methodological point-of-view, the mainstreaming of similar algorithms into the centralized repository of MaaS4Italy initiative – one of the distinctive features of the project- may support increased levels of accessibility and inclusiveness, thus relying on public action, only.

By leveraging Machine Learning (ML), for instance, AI synthesizes massive volumes of heterogeneous data -including historical travel patterns, real-time traffic, passive smartphone sensors, and socio-economic characteristics [62]. Through unsupervised learning and Natural Language Processing (NLP), AI can mine unstructured, crowdsourced data like app reviews to extract latent behavioral patterns and psychological traits [63].

By processing this detailed data, AI enables a more effortless and seamless experience specifically tailored for vulnerable groups in several critical ways. In this direction, AI deployment could effectively support the three-phase pathway towards a more inclusive MaaS proposal, especially referring to the two latter steps. Both within the co-design and institutionalization phases AI could contribute to detect and mitigate potential biases in service allocation and bundle proposal.

Knowledge-based AI frameworks use logic rules to combine a user's specific profile with contextual data (such as weather or traffic disruptions) to automatically filter out unsuitable transport modes and recommend personalized alternatives [64]. For elderly users or those with disabilities, AI can learn routine behaviors and autofill travel parameters or pre-select options, significantly reducing the cognitive burden and digital literacy required to navigate complex apps [65]. Furthermore, potential integration with wearable sensors deploying ML can monitor stress levels in frail older individuals, providing data that could be used to suggest more comfortable, less congested, and safer routes. During field operations -both during pilot as well as further upscaling steps- AI could also contribute positively in the perspective of MaaS providers to optimize service supply and bundle, deploying effectively anonymized mobility behavioral data and preferences, through dynamic and site-specific pricing mechanisms.

AI optimization reduces operational waste for MaaS providers, potentially lowering service prices to levels that attract users from economically disadvantaged regions [62]. AI-driven dynamic pricing models can analyze a user's price sensitivity and offer tailored mobility bundles, monthly allowances, or targeted subsidies, ensuring that shared transportation remains a financially viable alternative to private car ownership for low-income households [66].

For vulnerable users living in suburban communities or transit deserts with poor public transport access, AI models can identify unmet demand and optimize the placement of shared mobility options [67]. AI dynamically deploys services like ride-hailing or micro-mobility to provide essential first- and last-mile connectivity.

Notwithstanding, to guarantee that deep profiling benefits vulnerable groups without reinforcing existing inequalities, AI systems must be carefully designed to mitigate algorithmic bias [68]. If a dispatch algorithm is trained predominantly on data from affluent neighbourhoods, it may inadvertently learn to offer fewer services or longer wait times to marginalized areas, exacerbating social inequality. By embedding fairness constraints -such as equalized odds or demographic parity- into machine learning pipelines, MaaS platforms can ensure that resources and vehicles are fairly allocated, preventing the system from disproportionately denying services based on a user's demographic or socio-economic background [69].

5 Conclusion Remarks

In light of the experience gained from the MaaS4Italy and Sardinian MaaS projects in transport planning, the involvement of associations and organisations representing vulnerable users emerges as a key element in bridging the communication gap between policymakers and end users for the deployment of a universally inclusive Italian way to MaaS. In particular, the collaboration with AISM and UTE highlighted the importance of combining digital and non-digital engagement methods, involving trusted intermediaries and promoting long-term participatory process capable of fostering trust and participation over time.

These actors fulfil a pivotal intermediary function, aiding in the overcoming of mistrust, language barriers, and physical or cognitive limitations that frequently compromise the efficacy of conventional participation channels for the vulnerable social groups. At the same time, a critical issue has been identified. Despite the presence of regulatory frameworks addressing accessibility, particularly in relation to digital systems, the lack of effective enforcement mechanisms still limits the practical implementation. In this perspective, public authorities should assume a central coordinating role in the development of inclusive MaaS initiatives, as demonstrated by selected case studies. Their responsibility should extend beyond mere regulatory compliance, encompassing the active facilitation of stakeholders' engagement and integration of accessibility requirements from early design stages.

This is particularly relevant when addressing the needs of vulnerable users who require a tailor-made approach based on the target group involved in the process. In this regard, analysing vulnerable users' needs is essential for developing criteria for designing travel alternatives tailored to their actual needs [70].

Finally, the development of inclusive MaaS is best achieved by a structured and coordinated approach combining institutional leadership, stakeholders' facilitation and user-centered design to deliver tailored mobility solutions. It is therefore important to understand inclusive MaaS not merely as a technological innovation but as a governance challenge requiring coordinated, multi-actor and user-centered approaches.

Despite representing a preliminary study on potential inclusion and accessibility improvement for Italian MaaS proposal, the present research provides a comprehensive framework for future phases of MaaS4Italy. Limitations of the work are represented by the consideration of grey official literature from MaaS4Italy project, without the possibility to access pilot field data. Moreover, territorial focus has been represented by one case-study only.

Further steps would concern the analysis of pilot field data from the different territories, as well as the mapping of primary stakeholders to be addressed within the different territorial contexts, as well as the deepening of potential policy implications.

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