MaaS Personalisation: Making Public Transport More Convenient for Everyone

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Abstract. Mobility as a Service (MaaS) personalisation represents a transformative paradigm for urban mobility, fundamentally reshaping how individuals access and utilize transportation. By integrating diverse transport modes into a unified, user-centric platform, MaaS promises convenience, flexibility, and cost-effectiveness. For MaaS personalisation to truly make public transport more convenient for everyone, it requires a concerted effort from policymakers, transport operators, and technology providers to foster an integrated, intelligent, and equitable mobility ecosystem. This paper outlines the critical components, benefits, challenges, and future trajectory of personalized MaaS, offering a comprehensive understanding of its implications for modern urban environments.

Keywords: Public Transport · MaaS · Accessibility · Inclusivity · Framework

1 Introduction

Mobility as a Service (MaaS) personalisation, fuelled by advancements in machine learning (ML) and artificial intelligence (AI), is revolutionizing customer experiences. Leading digital companies have created high expectations among users for personalised and seamless digital interactions, which has influenced users' perceptions of convenience and relevance. These expectations extend to the mobility sector, requiring MaaS platforms to deliver equally compelling experiences to achieve widespread adoption.

MaaS fundamentally aims to offer users personalized, convenient, flexible, and cost-effective trip options, directly addressing the common pain points associated with traditional public transport (PT), such as fixed routes and schedules [1]. Enhancing convenience in PT is not only a matter of improving service efficiency but also a broader objective of social equity and universal accessibility, as emphasized by the European Union in its Sustainable and Smart Mobility Strategy [2]. Focusing services to individual needs, personalisation makes commuting significantly more convenient, offering flexible, price-worthy, reliable, and sustainable mobility solutions [3] and significantly enhances satisfaction.

Personalisation isn't an additional feature but a core strategic one for PT companies. Personalisation counters the perception of inflexibility often associated with PT,

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empowering users and fostering a shift from obligation to empowerment. This approach increases ridership, improves satisfaction, and contributes to sustainable development goals, making PT a truly competitive alternative to private cars. This research looks at how we can personalise MaaS platforms with a focus on "inclusivity by design" - an approach that puts accessibility at the heart of everything we do. Instead of treating accessibility as a box to check, we need to build systems that work for everyone from day one, regardless of their age, abilities, income level, or background.

Moreover, the inclusion of vulnerable groups (VGs) in the PT system is a fundamental human right that can be realised through the principles of responsive and adaptive measures. PT affects people's quality of life, as it is the only means of transport available to many VGs, such as students, the elderly, people with disabilities etc.

The research question is "How can MaaS platforms incorporate inclusive design principles and personalisation features to ensure accessibility for vulnerable users while maintaining system efficiency and overall user experience?" It can be divided into these sub-questions: (1) How can personalised MaaS features be leveraged to enhance PT convenience and equity across different user groups? (2) How can the principle of 'inclusivity by design' be effectively implemented in MaaS platforms to ensure equitable access and enhanced user experience for all users, particularly vulnerable populations?

The next section includes a review of related work; Sect. 3 presents accessibility challenges for Vulnerable Road Users (VRUs). Section 4 is devoted to Case studies that demonstrate the application of personalised MaaS strategies, focusing on enhancing accessibility for VRUs and possibility to realize inclusivity in MaaS. Section 5 presents Framework for Development Inclusivity by Design in MaaS and then conclusions.

2 Related Work

This section is devoted to a state-of-the-art analysis of inclusivity in MaaS, with a specific focus on personalisation and its role in making PT more convenient and inclusive for diverse users.

MaaS is an evolving concept that fundamentally redefines how users access and consume transportation. MaaS integrates various transport modes and associated services into a single, comprehensive, and on-demand digital platform, and the aim is to simplify travel by offering a "single point of access" to a diverse array of modes, eliminating the need for multiple ticketing and payment operations [4]. The literature on MaaS and inclusivity has evolved significantly from a focus on general accessibility to a more complex understanding of personalisation as a key driver of inclusivity.

MaaS holds significant promise for enhancing accessibility and expanding mobility choices, thereby contributing to social equity. It aims to provide user-friendly, seamless access to a wider range of mobility services, which can directly and indirectly help to decrease the risk of social exclusion stemming from a lack of mobility and transport poverty [5]. This aspect is particularly crucial given that transport poverty is a multi-dimensional issue, influenced by factors such as income, vehicle ownership, distance to public transport, physical or mental disability, and etc [6]. By offering a consolidated platform, MaaS can alleviate the burden of navigating disparate transport options, making mobility more manageable for those who face these challenges.

However, inclusivity and accessibility continue to pose significant challenges. According to [7] there are technical barriers, like the reluctance to share data and the pressing need for standardization among data providers. Data fairness remains a serious issue, as studies often ignore inequalities in access to digital technologies among certain user groups. This omission may reinforce existing mobility disparities if data collection relies exclusively on digital means [8].

MaaS must go beyond simply providing choice; it must understand and meet the needs of everyone. This is where ‘inclusivity by design’ comes in - ensuring that everyone, regardless of age, ability, or background, feels welcome and has the opportunity to use the system. It’s not just about making things accessible; it’s about creating truly personalised opportunities for everyone from the outset.

Enhanced flexibility and choice are especially beneficial for individuals who are unable to drive for various reasons, including those below the legal driving age, individuals legally prohibited from driving, persons with disabilities, or those temporarily impaired [9]. Such individuals often face significant barriers to independent mobility, and MaaS can unlock new possibilities for them. MaaS serves as a critical tool for improving accessibility and fostering social inclusion, particularly for underserved population groups. It significantly addresses accessibility challenges for individuals who may not own cars or have driving capabilities [10]. This is achieved by providing various combinations of alternative modes, including carpools, shared mobility options like ridesharing, bikes, scooters, and public transit. MaaS has the potential to drive social inclusion by improving mobility for vulnerable users, such as the elderly and low-income groups, who might otherwise face significant barriers to transportation [11].

For MaaS to advance, it must not only personalise but also embrace “inclusivity by design”. This means integrating accessibility and inclusivity into every stage of development, ensuring that everyone, regardless of age, ability, or background, can easily and comfortably use the system. This is crucial because failure to deliver personalised and inclusive experiences leads to user dissatisfaction and limited uptake. MaaS aims to overcome the limitations of traditional PT (fixed routes and schedules) by offering personalised, flexible, and cost-effective options, directly addressing user needs.

Personalisation, driven by AI and ML, emerges as a key enabler for enhancing inclusivity in MaaS [12]. These technologies facilitate user profiling, dynamic routing, and tailored pricing, allowing MaaS platforms to adapt to individual preferences and real-time conditions [13]. This adaptive capacity not only improves user satisfaction and convenience but also optimizes operational efficiency for transport service providers. Data integration is a key aspect of MaaS. It requires collecting and synthesizing information from various stakeholders in the mobility ecosystem. Utilizing AI algorithms [14] and Data Fusion techniques is crucial for unravelling complex relationships among different datasets, helping to understand macro trends and deliver personalised mobility services.

3 Accessibility Challenges for Vulnerable User Groups in MaaS

3.1 Mobility Barriers for Seniors: Functional Limitations and Digital Divide

Senior citizens represent a significant demographic group facing unique mobility challenges that MaaS platforms must address to ensure true inclusivity. These users frequently experience mobility exclusion and safety risks due to reduced physical mobility and existing deficiencies within traditional public transportation systems. Age-related functional limitations, such as vision impairment, cognitive decline, and physical frailty, can make independent driving increasingly challenging and impact their safety as PT users [15]. Many seniors struggle with digital aspects of modern transportation apps and services, not just physical barriers. While they might be physically able to use buses or trains, complicated apps with tiny text and confusing interfaces can leave seniors feeling lost and excluded. MaaS design for senior citizens must comprehensively address both physical accessibility (e.g., safe walkability, clearly identified accessible routes and stations) and digital usability (e.g., intuitive interfaces, customizable font sizes, offline support options, and alternative access methods). Policymakers should push for transportation technology that's built with seniors in mind, so they don't get left behind. Digital platforms should be specifically tailored to the needs and capabilities of seniors to ensure their participation in future mobility systems.

3.2 Challenges for People with Disabilities

Making PT work for everyone means paying special attention to people with disabilities. MaaS platforms need to do more than just check basic accessibility boxes - they should include features like screen readers, easy-to-use menus, and tools that help visually impaired users get around. When we design these systems right, we make sure nobody gets left behind. When designing MaaS, we need to think about accessibility from the start - not as an afterthought. This means making sure users can easily find wheelchair-accessible routes and stations and automatically showing step-free journey options for people with mobility challenges. While current research touches on physical accessibility, there's little discussion about making these apps work better for people with cognitive disabilities - definitely an area that needs more attention. Different users have different needs, so we need to carefully consider various types of disabilities to make sure everyone can use these transportation services safely and comfortably [16].

3.3 Bridging the Gap for Low-Income Populations and Non-Car Owners

MaaS holds significant potential to address accessibility challenges for low-income populations and individuals without personal cars, who often rely heavily on PT. These groups are explicitly identified as vulnerable and underserved, for whom MaaS can provide essential alternative modes of transport [15]. But while MaaS sounds great in theory, it might not work for everyone. Many people don't have bank accounts or smartphones to make digital payments and, in that case, the "seamless payment" aspect of MaaS, while a convenience for many, can inadvertently become a substantial barrier for others, leading to digital financial exclusion.

Achieving inclusivity for low-income populations within MaaS requires a multi-faceted approach that directly addresses these financial barriers. It could include options such as mobility credits through social programs, integrating cash payment alternatives, or providing subsidized subscription models. The aim is to ensure that MaaS serves as an essential lifeline, offering equitable access to transportation, rather than becoming an exclusive luxury service. Literature sources, while acknowledging the vulnerability of low-income groups, do not delve into specific strategies for overcoming these financial and digital payment barriers in detail. As highlighted in the EIT Urban Mobility study [17], researchers should focus on strategies such as age-friendly transport, digital integration and equitable improvement of public spaces.

4 Personalised MaaS Features and Findings from Case Studies

4.1 Case Study 1: Sustainable User-Focused Trip Planner for Decision Making in Case of Multimodal PT

The user-focused trip planner (TP) designed with sustainability in mind can serve as a powerful catalyst for the widespread adoption of MaaS concept and increase the use of PT. This concept should provide users enriched information about mobility services and give maximum personalisation (provide customized route planning) and the possibility of developing a multi-modal safe, and sustainable trip plan [18]. For this, the TP should use the capabilities of a data platform that integrates data sources from various stakeholders (municipality, state, private and others) for the sustainable urban transport approach. In [18] was developed a sustainable and personalised TP concept for the city of Riga (Latvia) (see Fig. 1).

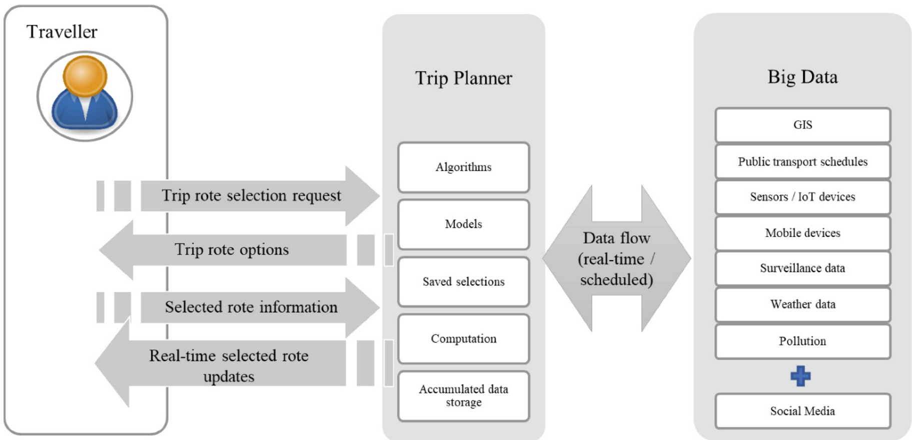

Fig. 1. User-focused Trip Planner Concept with an Expanded Suite of Features.

The concept presented in [18] focuses on the needs and interests of citizens. TP supplements the typical set of functions with information covering reliability, safety, comfort and environmental aspects, as well as provide personalized recommendations to help travelers craft the optimal travel plan. By highlighting faster, safer, more comfortable, and cost-effective routes, the TP aims to draw more users to PT. For key stakeholders like government and city authorities, the TP plays a crucial role in boosting public service efficiency. Research [18] suggests enriching the TP for the Riga case study with 9 characteristics of the journey.

The next 6 key indicators that shape a traveler's journey are evaluated based on the objective data.

Total Travel Time (TTT) measures the overall time spent traveling from the starting point to the destination. It's crucial for planning efficient trips. *Walking Time (WT)* depends on where the traveler starts and ends their journey. It's the time spent walking to and from stops, adding to the total trip duration.

Reliability (3) indicates how likely it is that the chosen transportation modes in the selected route will operate in a specified environment without delay. The higher value of the criteria shows that the PT mode will be on time with the highest probability compared to other(s) PT modes. *(4) Public Transport Modes and (5) Connectivity Ratio.* These indicators assess the journey's multimodality. *PT modes* are measured as a total number of PT modes per route option (single mode is the best option). *Connectivity ratio* is measured by the transfer time from one vehicle to another against the total journey time. (6) *Trip Fee* is the total cost of the journey, an essential factor for budget-conscious travelers.

The subsequent three indicators are derived from the user' subjective evaluations.

The *comfort level* of a trip is characterised by three sub-characteristics: occupancy, accessibility, and cleanliness, which are quantifiable through data collected from traveler interviews. Occupancy of PT mode is estimated in 25% increments: <25%, 25%–50%, 50%–75%, and >75%. When a route involves multiple PT modes, the least favorable occupancy value is selected. Accessibility, defined as the feasibility for a wheelchair user or a person with a pram to board the PT, is measured on a binary scale (0 or 1). A score of '1' indicates accessibility, while '0' signifies no such option. For trips with multiple PT modes, the scores are aggregated. Cleanliness is assessed on a 1–5 scale, where '1' denotes "very dirty" and '5' signifies "exceptionally clean". The maximum value on this scale corresponds to the most desirable outcome.

The *level of security and safety* during the trip is evaluated subjectively, with data sourced from historical traveler feedback on social networks. This measure uses a 1-to-5 scale, where a higher score indicates greater security.

The last indicator is the *environmental impact* of PT, which is directly tied to air quality. This is assessed based on the transport mode: trams and trolleybuses receive a '0' for their impact on air quality, while buses are assigned a '1'. When a route includes multiple PT modes with varying environmental effects, their impacts are aggregated.

The main idea is to create a user-focused TP, which will allow travellers to set up their preferences for the indicators and define weigh to each indicator based on its importance for them personally during the profile setup. TOPSIS was used for scenario ranking. The approach was approbated for Riga City Case Study.

4.2 Case Study 2: PT Accessibility for People with Motor Disabilities

This study, conducted in Riga, focuses on modelling accessible transportation networks using graph-based approaches and Recurrent Neural Networks (RNNs). The researchers [16] examine sidewalk walkability and PT data integration, providing insights into optimizing routes for individuals with mobility challenges. This approach not only highlights the existing barriers but also suggests practical solutions to enhance urban mobility for wheelchair users. The study incorporates data sources: sidewalk condition data from OpenStreetMap, which evaluates surface types, smoothness, and lighting conditions; PT schedules following the General Transit Feed Specification (GTFS), obtained from Riga PT Operator; and electronic ticket validation data, which facilitates passenger congestion predictions on trolleybus routes. By merging these datasets, the research establishes an accessibility assessment model that accounts for both physical infrastructure and PT constraints.

First, sidewalk accessibility across Riga is examined, with a focus on the pedestrian infrastructure connecting major PT stops. A walkability score is introduced to capture core factors: surface type, referring to the material composition and degree of navigability for wheelchair users; smoothness, which reflects the evenness of surfaces; and lighting conditions, indicating streetlight density that ensures safety and visibility, especially at night. Each sidewalk segment is assigned a colour - red for poor, yellow for moderate, and green for high accessibility. Findings (see Fig. 2) reveal that sidewalks near central transport hubs are classified as red, underscoring significant barriers for users with mobility impairments. In contrast, sidewalks in parks and newly developed neighborhoods are predominantly green, indicating comparatively better accessibility.

Then GTFS data are integrated to identify accessible PT routes and stops, focusing on trolleybus routes, which typically provide better wheelchair access due to low-floor entry designs. The methodology involves mapping PT stops within a 250-m radius of key destinations, filtering trolleybus routes by analysing the GTFS route type variable and constructing a directed graph representation of the PT network. In the graph nodes represent transit stops, and edges denote direct connections between them, enriched with route IDs and scheduled departure and arrival times. For each transit connection, travel time is computed by subtracting the departure time at the origin stop from the arrival time at the destination stop. Transfer hubs are identified using centrality metrics such as degree centrality, which highlights stops that serve as major intermodal nodes; betweenness centrality, which pinpoints transit points that facilitate high interconnectivity; and direct route intersections, ensuring that users can minimize walking distances when switching between transit lines. The accessibility-focused graph model allows the system to dynamically recommend routes that prioritize minimal walking distances, ensuring that users with mobility impairments can navigate the urban transport network with greater ease.

The third phase addresses the real-time challenge of passenger congestion, which can significantly impact transport accessibility for wheelchair users. Overcrowded PT, even if physically designed for accessibility, may be difficult to board due to space constraints. The study incorporates predictive modelling to estimate passenger congestion levels, employing deep learning techniques such as LSTM networks and Gated Recurrent Units. Passenger count data is aggregated in ten-minute intervals to create a continuous time

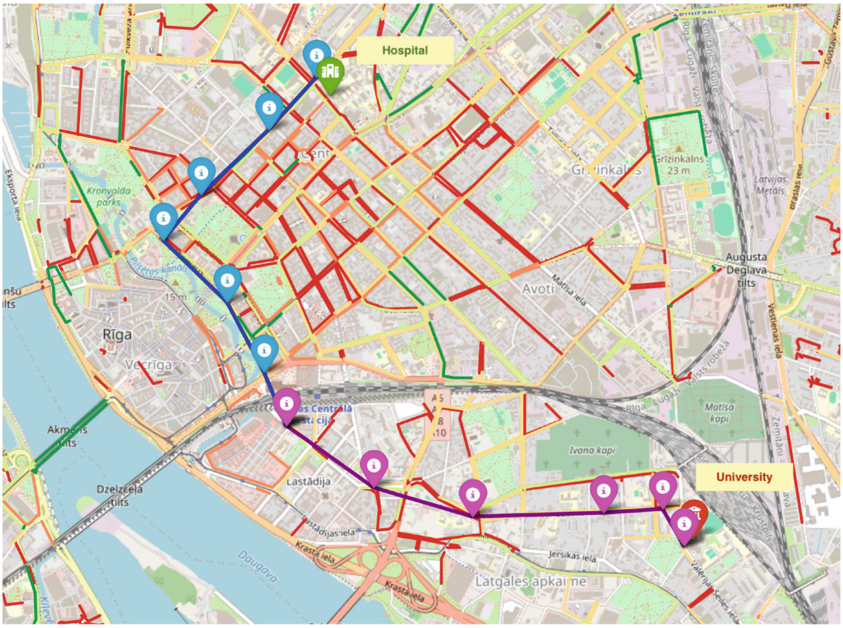

Fig. 2. Integration of optimal PT routes from hospital to university.

series, with lagged features engineered to capture temporal dependencies in congestion trends. The algorithm integrates the Exponential Moving Average-based congestion forecasting model to provide real-time accessibility predictions, allowing users to select routes that are less crowded and thus more accessible.

This procedure allows to construct the semantic graph that combines PT network structure and passenger predictions into a unified transport accessibility graph. PT stops with consistently low predicted passenger counts are classified as highly accessible, while transfer hubs are optimized to ensure minimal walking distances between different PT modes. Sidewalks with poor accessibility scores are flagged for potential infrastructure improvements, providing urban planners with data-driven insights for future city-wide enhancements.

To complement the accessibility graph and predictive congestion modelling, the framework integrates an algorithm for the generation of personalised route suggestions. This ensures that recommended journeys are not only structurally accessible but also attuned to the mobility characteristics of individual users. The process begins with the assessment of segment distances between consecutive points in the network, providing the basis for route measurement. To support intuitive wayfinding, it incorporates directional guidance derived from the bearing of each segment and expressed as clear, compass-based instructions. Travel pace is then adjusted according to the selected mode of movement. Older pedestrians may sustain an average pace of 15–20 min per kilometre, while the pace of wheelchair users is shaped by factors such as surface quality and gradient. By integrating these parameters, the algorithm produces personalised travel time estimations, thereby enriching the accessibility model with practical, context-aware routing information. This approach strengthens the system's capacity to recommend routes that are informative, responsive to the user's needs, and accompanied by instructions that are both actionable and reliable within real-world urban environments.

4.3 Personalised MaaS Features

The personalised MaaS system should improve convenience by offering an extended set of features that go beyond standard time and cost metrics. The features include:

- Customized route planning. MaaS can use multi-attribute decision-making methodology to rank routes based on user-defined weights for different attributes. Users can prioritize factors to find the route that best suits their preferences. For example, a traveler who values a quick journey may prioritize total travel time, while another may prefer a route with the fewest transfers.
- Reliability. MaaS can provide information about PT reliability, which indicates punctuality. This allows users to make informed choices.
- Subjective indicators of quality. MaaS can incorporate subjective criteria (comfort, safety, security, etc.), which are often overlooked in traditional trip planners. Data can be collected from sources like historical feedback and social networks. This allows users to choose routes that align with their personal sense of well-being and comfort.
- Sustainability. MaaS can provide information about the environmental impact of a route (e.g., air quality). This allows users to make informed choices that are not only convenient but also align with their personal values, such as environmental friendliness.

5 Framework for Developing Inclusivity by Design in MaaS

'Inclusivity by Design' means creating MaaS platforms where accessibility and inclusivity are not afterthoughts but are integrated into every stage of the design and development process. It's about ensuring that everyone, regardless of age, ability, socioeconomic status, or other factors, can easily and comfortably use the system.

Key Principles of 'Inclusivity by Design' MaaS:

- Accessibility from the Start. Accessibility considerations are not added after the system is built, but are fundamental to the initial design concepts. MaaS must follow accessibility guides, including features for users with visual, auditory, motor, or cognitive impairments (e.g., screen readers, large fonts, audio cues, simplified language).
- Multilingual Support.
- User-Centred Development: The entire process is driven by the needs and preferences of all users, including all VGs. This requires thorough user research and iterative design cycles. Involve users in the design and development of the MaaS system through feedback mechanisms and participatory design sessions, ensuring inclusivity for VGs.

- Equitable Access: The system aims to provide equal access to transportation options for everyone, regardless of their location, financial resources, or mobility limitations. This may involve integrating various transport modes and offering affordable fare structures.
- Simplified User Experience: The platform should be intuitive and easy to use for all, requiring minimal technical skills or knowledge. It means clear navigation, simple booking processes, and multiple ways to access information (visual, audio, etc.).
- Personalised Experiences: The system should adapt to individual needs and preferences, providing personalised journey suggestions, accessibility options, and support services. MaaS are becoming more sophisticated in their ability to provide personalised routing for people with disabilities. A key example is the integration of real-time accessibility data.
- Implement robust data privacy and security measures to protect user information and build trust within VGs.

Figure 3 presents framework for deployment 'Inclusivity by Design' in MaaS. This framework provides a scientific basis for measuring how MaaS platforms are doing in creating an environment where everyone can "feel a part of the system".

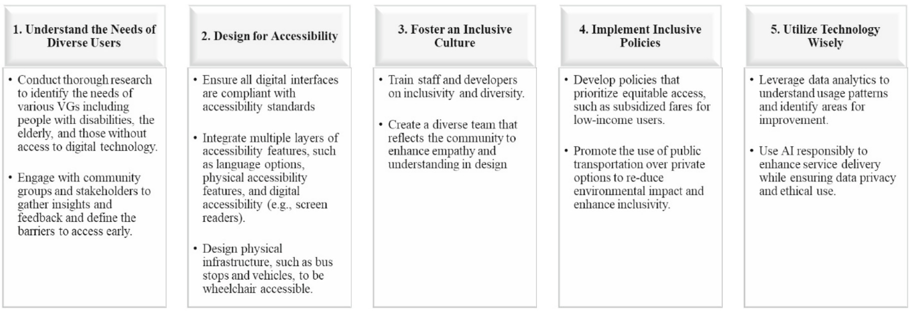

Fig. 3. Framework for deployment 'Inclusivity by Design' in MaaS.

To move beyond evidence, researchers in [19] have developed indicators to systematically evaluate MaaS inclusivity. The most promising example is the MaaS Inclusion Index, which breaks down inclusivity into three key pillars:

(1) Accessible Transport Index for the accessibility of the physical transport infrastructure measurement (e.g., wheelchair ramps, lifts).
(2) Accessible Data Index for the quality and personalisation of the data available to the user (e.g., real-time updates, multi-language support, clear information) assessment.
(3) Accessible Platform Index for the user-friendliness and inclusivity of the MaaS interface itself (e.g., voice commands, non-digital access options, personalised settings) evaluation.

6 Conclusion

Personalised MaaS features can enhance PT convenience and equity by offering tailored solutions that address the varied needs of different user groups. By moving beyond a one-size-fits-all approach, MaaS platforms can attract a wider audience to PT, making it a genuinely competitive alternative to private cars.

State of the art in MaaS inclusivity is defined by its embrace of personalisation as a tool for creating a sense of belonging, respect, and empowerment. While significant progress is being made in areas like accessible routing, gender-sensitive features, and personalised subsidies, critical challenges remain in addressing the digital divide and mitigating the potential for algorithmic bias. The future of MaaS inclusivity will depend on the continued development of platforms that are not only technologically advanced but also ethically sound and socially just. This personalised approach within MaaS platforms transforms mobility into an inclusive service that respects and addresses the distinct needs of VGs, promoting equitable and human-centred urban transport.

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