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# Smartphone apps for mobility access from a social inequality perspective: a systematic literature review

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**Abstract**

In recent years, the growing popularity of smartphone applications has established them as the primary interface for accessing transport services. This has raised concerns among scholars regarding its potentially negative impacts, such as exacerbating barriers to accessing transportation via apps and digital platforms in general. This paper reviews the academic literature on inequalities related to app-based access to transportation. We summarise the vulnerable social groups affected, categorize the types of access barriers they face, and synthesize solutions proposed in existing studies. By applying an intersectional lens, we explore how digital and mobility inequalities overlap, and introduce the concept of digital mobility inequalities. The paper concludes by proposing future research directions and outlining mitigation strategies, with the aim of fostering a critical reflection on the equity implications of the growing reliance on app-based mobility platforms.

**Keywords** Social inequality, Mobility inequality, Digital inequality, Smartphone, Apps, Digital mobility inequalities

## 1 Introduction

Smartphone apps for public transport have become the most popular digital media for accessing travel information in Europe and in the USA in the last decade [1, 2]. As a result, providing access to travel information is increasingly shaped by the assumption that most users have smartphones with mobile internet. However, in Germany only 82% of people older than 16 had their own smartphones in 2025 [3]. This means that transport policy measures relying on high smartphone ownership rates risk overestimating passengers' readiness to use apps. Therefore, nudging measures such as discontinuing printed schedules and reducing the number of physical ticket machines can increase social inequality.

The issue of social inequality in transportation and mobility has received significant attention in the research literature [4–10]. Over the past two decades, this research area has evolved, highlighting various aspects of inequality in both practice and academic discourse [11, 12]. Works focusing on concepts such as transport-related social exclusion, transport poverty, transport disadvantage and mobility justice have a common feature: they highlight the vulnerability of particular social groups to social inequality due to a lack of access to transport.

The introduction of smartphone apps that are not universally accessible raises similar concerns about vulnerable social groups whose access to available transportation can be restricted by digital barriers. The number of publications addressing digital service barriers with a focus on the transport sector is still limited but growing [13–15]. For instance, publications on the adoption of

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mobility-as-a-service (MaaS) and other app-based transport services – which Oviedo et al. [16] defined as "app-based mobility" – contribute to our understanding of existing inequalities [17–19]. Another important contribution is an overarching framework describing the digital divide, developed by Van Dijk [20]. Further, more specific concepts for unpacking these phenomena have also been proposed, such as the "smartphone divide" [21] and "digital inequality in transport services" [22].

Thus, social inequality issues are discussed in the literature from two research domains: digital and mobility. Empirical publications on digital barriers in transport typically focus on specific policies and regional case studies. For example, Pritchard et al. [23] examine the case of London's ban on cash payments on buses, while Liu et al. [24] investigate the influence of the restrictions imposed during the pandemic on the use of smartphone-based services and the perceived transport accessibility in China. However, there is a lack of systematisation regarding vulnerability to social inequality in both the digital and mobility research. It remains unclear how the existing publications address which social groups are vulnerable to both, what exactly determines their vulnerability, and how these can be mitigated.

Our aim is to study the discussion of social groups vulnerable to social inequality in scientific publications, with a focus on transport apps. Our study considers not only mentions of these groups, but also the underlying causes of their vulnerability as barriers. For example, when the non-use of transport apps is related to older age, we explore which more specific factors such as impaired vision or a lack of digital skills are discussed. We aim to summarise and categorise the vulnerable social groups and the barriers they face and the measures described to overcome these barriers in the literature in relation to transport apps. This delivers important insights for researchers and policymakers working on smart mobility as well as digital and mobility inequality. Our findings may also be of interest to app developers and designers, informing their efforts to anticipate vulnerability scenarios in the development process.

This paper is structured as follows. First, we review existing concepts and models that address mobility and digital inequality issues in order to build a framework and specify the research questions. Then, we conduct a systematic literature review of scientific publications available via Scopus and Web of Science (WoS) applying the PRISMA approach. Finally, we summarise the results, discuss their implications, and suggest areas for future research.

## 2 Literature review

### 2.1 Key concepts on mobility and digital inequality

Several concepts in transport studies relate to the inability to access means of transport and, consequently, the associated social opportunities. Lukas [7] highlighted the shift in research focus from accessibility planning, which was previously considered solely from a transport planning perspective, to a social exclusion approach that considers the social and political outcomes of transport policies. In this regard, several terms have been established in the literature discussion. "Transport disadvantage" reflects inequality in accessing transport options available in an area [5, 6]. "Transport-related social exclusion" refers to the inability to participate in social activities, such as work, services, and leisure, due to limited access to transport [11]. Both terms "Transport disadvantage" and "Transport-related social exclusion" presuppose unequal transport accessibility. The former addresses comparative inequality in transportation, whereas the latter characterises social exclusion as an absolute consequence of inequality. "Transport poverty" relates to the transport limitations faced by people with lower incomes, but it still lacks a clear definition [8]. Other terms that offer additional perspectives include "transport justice" [25] and "mobility justice" [26], which have received attention from scholars in recent years [12]. As our aim in this study is to consider all of these aspects, we use the more generic term "mobility inequality" [27–29] in the following. More specifically, we examine the mobility inequality experienced by individuals and not by areas or neighbourhoods.

Velaga et al. [30] were the first to address the interplay between the digital divide and access to transport services. They drew attention to the issue of unequal digital access to flexible transport services in rural areas. The growing interest in researching the ramifications of social inequality shed light on further examples of digitalisation within transportation practices such as the introduction of cashless payment systems for public transport. This technology makes some crucial transport services inaccessible to people without bank accounts or cards [23, 31, 32]. The literature provides three recent concepts developed to generalise such cases of technology-related mobility inequality and evaluate their respective advantages and disadvantages.

**Multimodal divide** [14]. This concept effectively combines the digital and mobility aspects of social inequality: "multimodal" refers to mobility and "divide" refers to the digital divide. However, this term is based only on one dimension of mobility inequality: the number of transport options (mono-optionality versus multi-optionality). Dimensions such as affordability, frequency, reliability, and travel time are not considered.

**Smartness-induced transport inequality** [15]. This concept assumes that digital inequality is projected onto transport-related social exclusion. The authors also provide an example of how it can be applied to access travel information. The "smartness" is understood to be a measure "to what extent a city has become a smart city" [15]. Nevertheless, it is unclear whether "smartness" is the main driving factor of the digital inequalities discussed. We suppose that digitalisation policies and digital technologies themselves should be considered in this context, rather than just the concept of a smart city.

**Digital inequality in transport services** [22]. This concept builds upon the existing theoretical framework of digital inequality [20] and applies it to transport services. The authors consider how digital inequality is produced by the implementation of digital media in the transport sector. While this concept is justified within the domain of digital inequality, it is not directly connected to mobility inequality.

In summary, the concepts discussed above capture specific aspects of the influence of digital technologies on mobility inequality. However, a unified terminology to describe the overlap between digital and mobility inequality has yet to materialise. To support future conceptual developments and systematically summarise relevant publications, we apply an analytical framework, which we outline in the following section.

### 2.2 Analytical framework

We assume that digital technologies can influence existing mobility inequality in either a positive or negative way. Positive effects can be produced, for example by digitally enabled demand responsive transport that alleviates existing mobility inequality by offering flexibility through a digital platform [30, 33]. Digital services such as screen readers in apps and notifications on wearable devices can help people with disabilities overcome the difficulties they face when using transport services. In this study, however, we focus on the negative consequences of using new digital media in transport, specifically transport apps, that may exacerbate existing mobility inequality. This includes smartphone apps and app-based digital services for public transport and shared mobility services, such as Uber, Lyft, bike sharing, car sharing, and scooter sharing, as well as MaaS solutions.

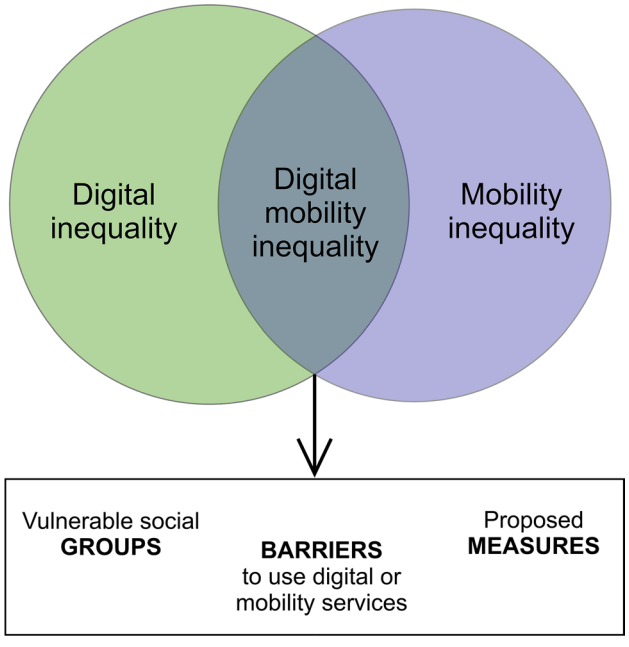


**Fig. 1** Analytical framework

To describe specific cases of digital or mobility inequality encountered in publications, we must address the barriers that lead to inequality among vulnerable social groups. For example, when people with lower income (social group) cannot afford car sharing due to its high costs (barrier). Our goal is therefore to analyse relevant publications and to extract combinations of groups and barriers, whether they belong to the digital or mobility domain, or to both. Additionally, we aim to summarise the measures that the authors proposed to undertake against these cases of inequality. Our analytical approach is presented schematically in Fig. 1.

Following these considerations, this study focuses on the following research questions:

1) What social groups are considered vulnerable to social inequality in the literature?
2) What barriers to using digital and mobility services for these social groups are described in the literature?
3) What measures are proposed to overcome the cases of social inequality discussed in the literature?

We summarise the research literature in its current state in order to answer these research questions. For this, we find a systematic literature review as described in the following chapter is the most appropriate method for answering them.

## 3 Methodology

To address our research questions regarding social inequality on digital access to transport and mobility, we conduct a systematic review of the mobility and digital inequality studies literature, adhering to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 Statement [34]. This approach is commonly used in reviews evaluating the effects of health interventions and has also been adopted in transport studies [35–37]. A key advantage of this methodology is that the reviewing process and results are rigorous and reproducible, as the approach is standardised and well documented. It provides a framework for generalising

common features and inequality mechanisms that help to address expected disparities between the mechanisms of social inequality in the transport and digital dimensions.

Figure 2 shows a flow diagram outlining the systematic process employed to conduct our literature review. In the identification stage, we systematically gathered bibliographic data from published peer-reviewed papers, book chapters and conference proceedings sourced from Scopus and Web of Science (WoS). This method ensures comprehensive coverage of the scientific literature relevant to our research objectives. To initiate this search, we used specific keywords to identify three key aspects: smartphone apps, social inequality, and the transport sector. We used the following search query:

*((smartphone OR app OR apps) AND (transport OR transit OR mobility OR travel) AND (equality OR equity OR inclusion OR inclusive OR exclusion OR exclusive OR disadvantage)).*

Our search conducted in July 2025 yielded 480 publications on Scopus and 468 on WoS. We used the bibliometrix package in R [38] to merge the two raw datasets and remove duplicates. We also used the package for bibliometric analysis later on, including the historical direct citation network. Due to partially missing metadata in the publications, this procedure resulted in 468 publications being included.

The screening phase included both semi-automatic and visual screening. First, we analysed the subject areas described in each publication and excluded those related to pharmacology, pedagogy, geology and other subjects. We also only kept publications written in English. This resulted in 236 publications being included. Next, we screened the titles, abstracts and full texts for relevance to the aims of this study. Publications were marked as irrelevant if they were not related to any form of social inequality or if they addressed smartphone apps solely as a data collection tool. Finally, 74 publications were deemed relevant for answering our research questions.

During the analytical phase, we conducted a bibliometric analysis and a qualitative review based on the full texts of the publications. Our analysis included three distinct groups of categories. First, we looked for mentions of social groups vulnerable to social inequality. Second, where possible, we sought to collect specific barriers related to the particular case of inequality addressed in the publication. Third, we looked for proposed measures to overcome this inequality. For a study to be included in the analysis, it was essential that it mentioned any vulnerable groups, while the last two aspects were optional and

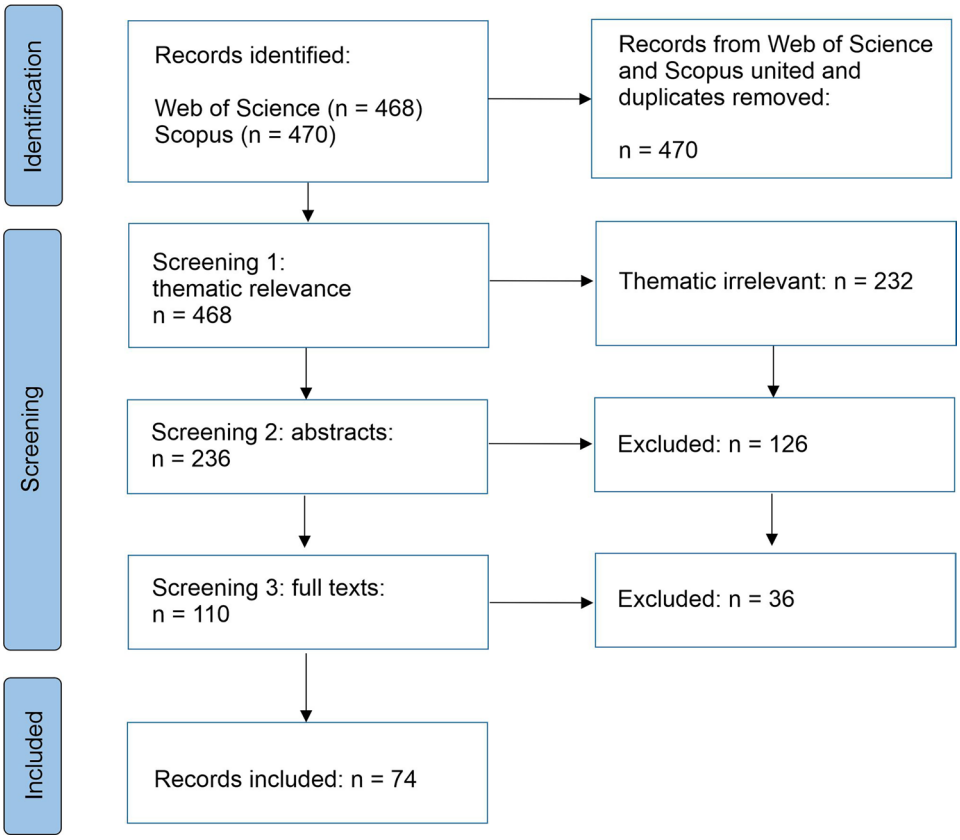


**Fig. 2** PRISMA flow diagram (search results as of 17.07.2025)

could be missing. These categories were extracted from each included publication and organised in a table. Further analysis of the table was then conducted to count the number of publications mentioning each category and its combinations.

## 4 Results

### 4.1 Bibliometric analysis

#### *4.1.1 Descriptive statistics*

The aim of a bibliometric analysis is to describe the basic characteristics and internal relationships within a corpus of selected publications. The corpus consists of 74 documents published in 48 sources between 2012 and 2025. Of these, 51 are research articles and 17 are conference proceedings. The remainder are early access articles and reviews. The number of publications increased from one in 2012 to sixteen in 2024 (see Fig. 3), illustrating the growing interest in this research area.

The three most represented author's countries in our sample are the USA (17 articles), the United Kingdom (11 articles) and Germany (9 articles). The three countries with the most total citations are the USA (545 citations), China (176 citations) and the UK (118 citations). The most cited paper in the sample with over 350 citations on WoS, is written by Alemi et al. [39] and discusses the factors affecting the adoption of Uber in California. Therefore, the geographical distribution of citations and author affiliations seems to be biased towards Western countries with a growing relevance of literature from China.

#### *4.1.2 Historical citation clusters*

Citations provide a means of connecting publications within a chronological citation chain that helps understand the successive development of a research area. Papers are grouped according to common citations through links, and a core historical path is extracted. Only publications with at least one citation linking to another paper in the dataset are included, meaning that isolated papers are excluded. This reduces the set from 74 papers to the core of 35 papers. Publications of the same colour belong to citation communities, or clusters. Figure 4 shows the clusters for the temporal analysis, with publication year on the horizontal axis and normalised citation levels of publications on the vertical axis.

We reviewed the titles and abstracts of the publications within these clusters to identify their common thematic

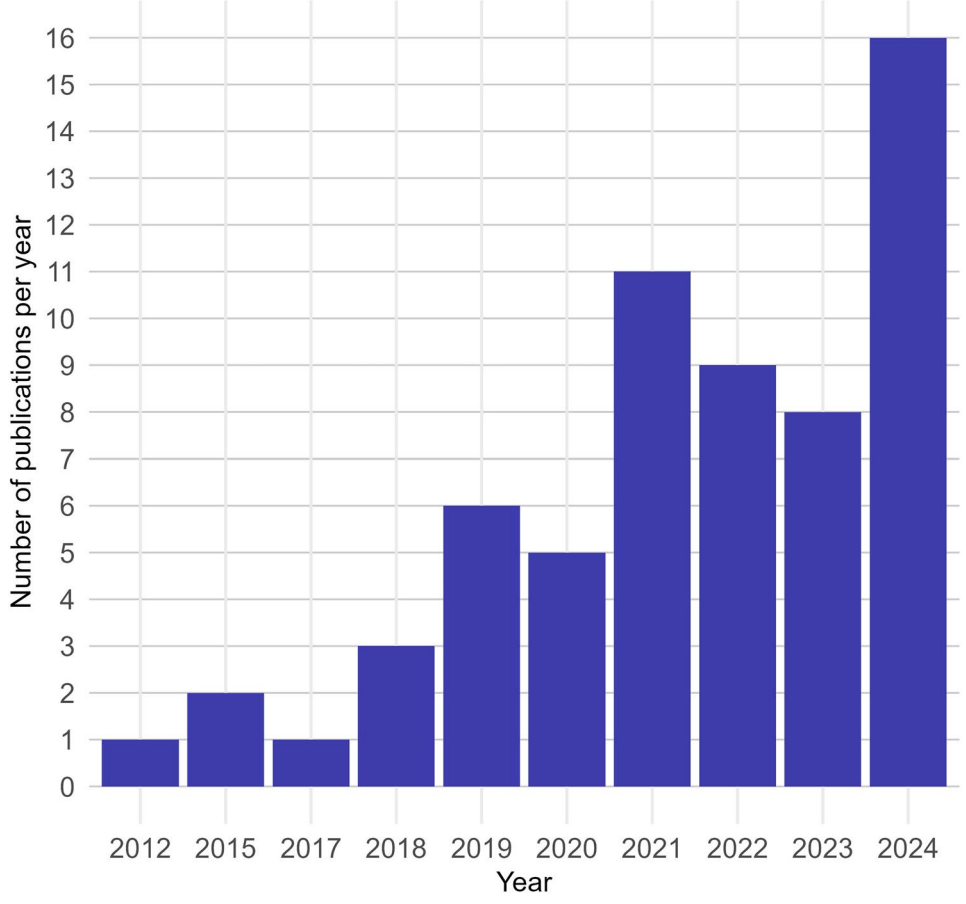


**Fig. 3** Number of publications per year

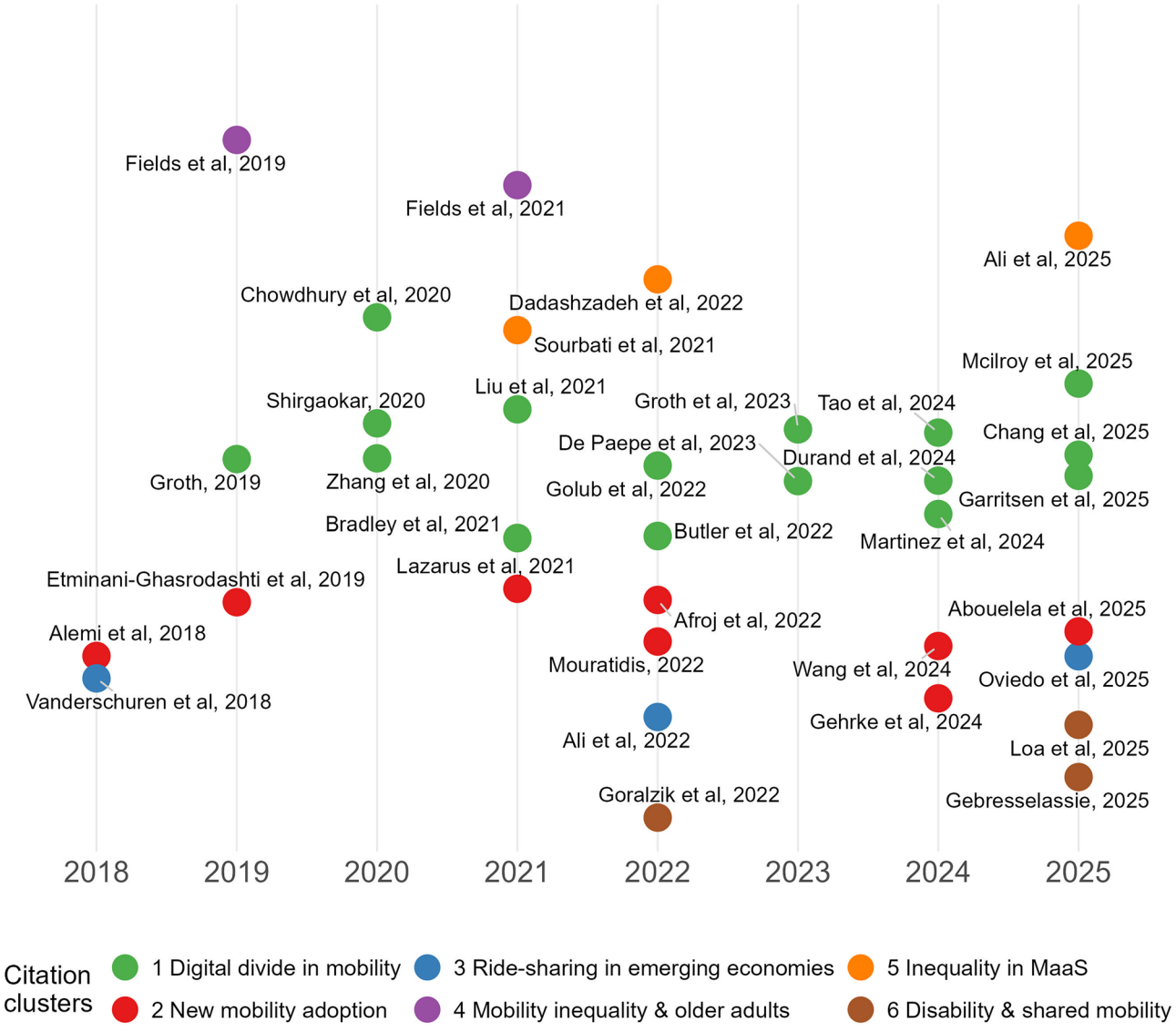


**Fig. 4** Historical citation clusters

features. Cluster 1 (green), with the first paper by Groth [14], highlights the critical inequality issues related to the digital divide in personal mobility. Cluster 2 (red), which started with the aforementioned paper by Alemi et al. [39], investigates the factors influencing the adoption of new mobility services. Cluster 3 (blue) comprises three papers [16, 40, 41], which focus on ride-hailing and ride-sharing services in countries with emerging economies. Cluster 4 (purple), comprising two papers led by Fields [42, 43], focuses on the mobility inequality experienced by older adults. Cluster 5 (orange) presented by three papers [44–46] explores the challenges of justice and inclusion in MaaS. Finally, Cluster 6 (brown) [47, 48] examines the difficulties faced by people with disabilities when using shared mobility services. As shown in Fig. 4, Cluster 1 includes more papers than the other clusters. These clusters are shaped by different vulnerable populations, types of services, levels of specificity, and approaches to inequality.

Although these clusters do not cover the full range of existing studies, they provide information for further summaries of the main research areas. By focusing on these clusters, we can identify four approaches to the topic of social inequality in publications on transport apps: critical approach, focused approach, service adoption approach and technology-oriented approach.

**4.1.2.1** Critical approach This approach is common for publications in Cluster 1. Such publications [14, 15, 22, 49, 50] focus on discovering the inequalities themselves, highlighting vulnerable social groups and the general mechanisms of inequality production. Publications fol-

lowing this approach seek to establish new socio-political perspectives and usually do not propose specific measures, but rather suggest paying more attention to the discovered issues in policy-making. When describing the barriers or mechanisms of inequality, such papers tend to offer a summary or an overview of them.

**4.1.2.2** Focused approach Clusters 3 and 4 are examples of this approach. Publications from this group [31, 42, 48, 51, 52] typically focus on a single vulnerable group and analyse the specific barriers they face. The authors are more likely to utilise qualitative than quantitative methods. The depth of the analysis usually allows for the development of specific policy recommendations to address the type of inequality discussed. The extent of the barriers discussed is limited by the research focus. However, this approach allows for capturing as many details as possible in-depth.

**4.1.2.3** Service adoption approach This approach is common in Cluster 2 publications. These studies [17, 39, 53–57] primarily examine the adoption of specific smart mobility services, such as MaaS, ride-hailing and other sharing options. However, when investigating the factors of adoption, social inequalities in travel practices and digital media use are often discovered. This approach differs from the focused approach, where social inequality is central and known from the outset. The authors are likely to rely on quantitative methods. Conclusions on adoption factors typically provide insights into vulnerable groups, but not into barriers. Practical recommendations may also include measures to address identified social disparities.

**4.1.2.4** Technology-oriented approach The publications of this group [58–63] focus on a specific instance of inequality and create a prototype to address it, such as an app, device or technology. These papers are often published in conference proceedings in the fields of computer science or human-computer interaction. Such publications are almost entirely disconnected from the ongoing theoretical debates, focusing instead on practical solutions. Therefore, this approach is recognised through summarising papers outside of the direct citation network. The most commonly addressed vulnerable groups are people with disabilities and older people, while the most commonly addressed barriers are impairments and a lack of accessible travel information. With regard to social inequality, these works often describe lesser-known, niche cases of digital service inaccessibility.

These approaches highlight some common features in the literature, but do not cover the full variety of studies or imply an exhaustive classification. Instead, they provide researchers with an overview of the potential theoretical and practical approaches that currently address social inequality in the digital mobility sector.

**Table 1** Number of publications mentioning each vulnerable social group

| Social groups | Number of publications |
|---|---|
| People with lower income | 31 |
| People with disabilities | 28 |
| Older adults | 26 |
| Migrants, refugees, ethnic minorities | 20 |
| Women, gender and sexual minorities | 20 |
| Residents of rural and remote areas | 12 |
| Residents of countries with emerging economies | 11 |
| People with lower education | 9 |
| Unemployed adults | 4 |
| Children and adolescents | 2 |

## 4.2 Qualitative review

### *4.2.1 Vulnerable social groups*

We conduct a qualitative review to study what social groups, barriers and proposed measures are addressed in the publications ($n = 74$) we systematically selected. The complete results are presented in Table A1 in the Appendix and our findings are summarised here.

Ten vulnerable social groups were extracted from the publications. Table 1 shows the labels for the social groups and the number of publications that mention each of them. As one publication might mention several social groups, double counting occurred.

As shown in Table 1, people with lower income, people with disabilities and older adults were mentioned most often.

Many publications mention more than one vulnerable group, typically describing them separately. In a few cases, however, different vulnerabilities are combined within the same population. In order to better understand how the groups are discussed in the literature, we examine which social groups are discussed in the same publication. Figure 5 presents a heat map indicating the number of publications that mention each pair of groups.

The data presented in Fig. 5 provides a deeper overview of the intersection of social inequalities. The most common approach is to address people with lower income and older adults simultaneously, as well as adding other vulnerability factors to lower income or older age in general. To analyse this further, Fig. 6 visualises pairs of social groups as a weighted graph, where the weights are based on the number of co-occurrences in publications.

As shown in Fig. 6, the "people with lower income" group has the most connections. Along with groups such as older adults, migrants, refugees, ethnic minorities as well as women, gender and sexual minorities, they form the core of the co-occurrence graph. People with lower education have the same connections in the core as

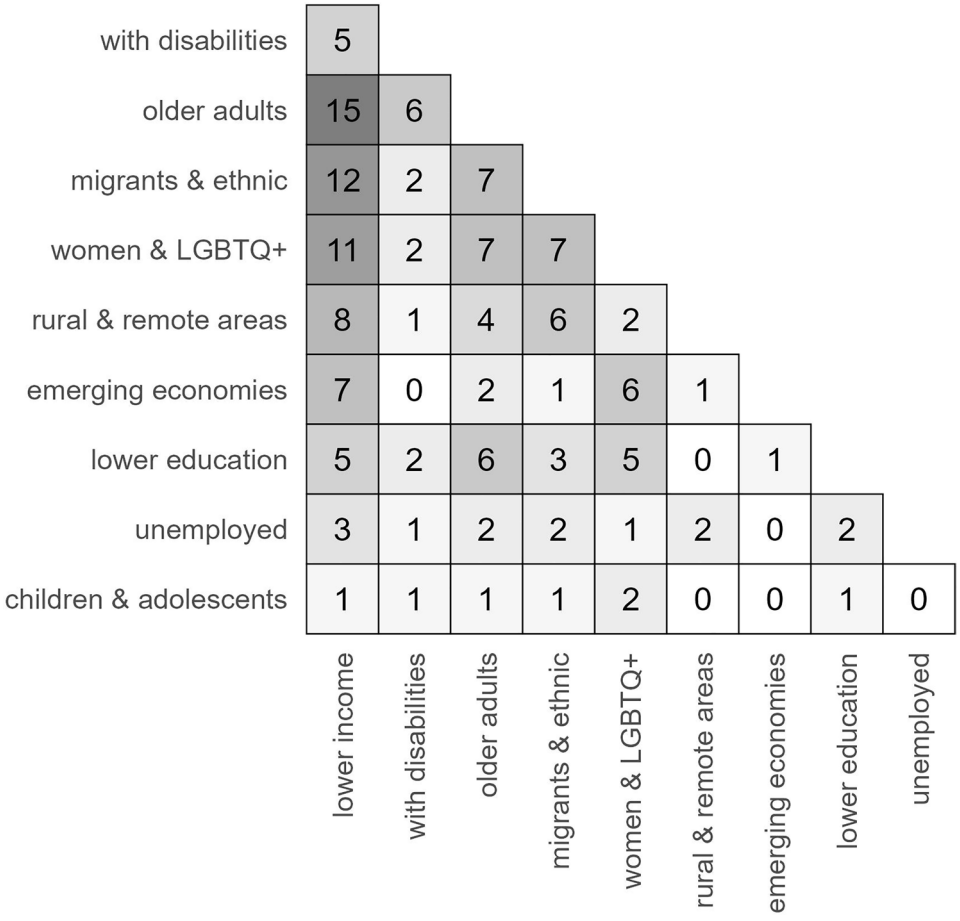


**Fig. 5** Heat map on number of publications mentioning pairs of social groups

people with lower income, suggesting that they are a substitute for this group. People with disabilities tend to be connected in the literature to people with lower income and older adults more often than to migrants, refugees, ethnic minorities, and people with lower education. In addition to being connected to people with a lower income, residents of rural and remote areas are grouped together with migrants, refugees, and ethnic minorities, while residents of countries with emerging economies are grouped together with women, gender minorities, and sexual minorities.

This graph sheds light on compositions that are uncommon or non-existent in our sample, such as those involving children, adolescents, and residents of countries with emerging economies. However, by presenting information on these under-explored combinations, we are not suggesting that these represent significant research gaps. In this study, we do not evaluate the advantages of addressing specific combinations of social groups, but aim to highlight the groups that received the most attention in the literature.

#### *4.2.2 Barriers*

We summarise the barriers to using digital or/and mobility services under 25 categories in Table 2. These categories are organised along three main domains – mobility, digital, and mixed – to highlight the related type of social inequality. As outlined in Sect. 2.2, these domains reflect the type of service access that is limited by a specific barrier.

As shown in Table 2, the main challenges discussed in the selected publications are digital literacy issues, lack of accessible travel information, and impairments. The mixed domain reflects the overlapping factors affecting transport and digital inequalities, including impairments, psychological and cognitive issues, and discrimination.

Furthermore, we examine pairs of vulnerable social groups and the related barriers to using digital and/or mobility services. Having collected 10 types of social group and 43 barriers in previous steps of the analysis, we extracted the three most commonly mentioned barriers for each group (see Table 3).

As shown in Table 3, the selected publications suggest that certain barriers are closely related to specific social groups. Barriers to use transport services are more

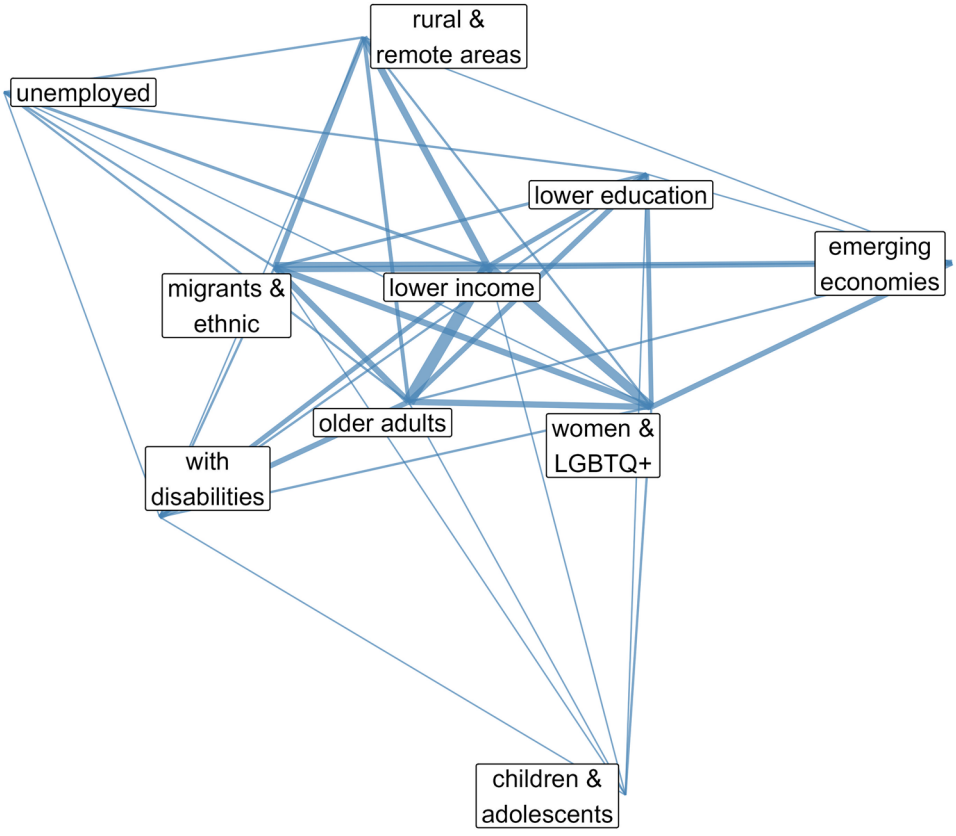


**Fig. 6** Social group co-occurrences

frequently observed than barriers in digital domain. The most common combinations of social groups and related barriers are as follows:

(1) people with lower income facing insufficient affordability and availability of transport services [64];
(2) people with health impairments having limited access to travel information/low accessibility of digital services for people with disabilities [59];
(3) older adults lacking digital skills to use smart mobility services [46];
(4) low physical accessibility of transport infrastructure for older adults [42];
(5) unsafety of transport services for women, gender and sexual minorities [65];
(6) insufficient transport service coverage, connectivity, quality and reliability experienced by residents of rural and remote areas [66];
(7) residents of countries with emerging economies facing discrimination, overcrowding and safety issues in transportation [40].

These combinations represent the most frequently discussed situations of inequality in the selected publications. Notably, most studies focus on overlapping vulnerabilities, addressing multiple social groups or barriers simultaneously rather than isolating the experience of a single group facing a specific barrier. Based on this observation, we examine how these barriers intersect across different service domains, paying particular attention to instances where mobility and digital inequalities occur together within the same study. To analyse the co-occurrence of mobility and digital inequalities within the same publications, we juxtapose the barriers from Table 2 that belong to different domains, looking for publications that address them simultaneously (see Table 4).

As shown in Table 4, the combination of digital and transport (or mobility) barriers gives rise to specific inequalities. Although we only summarise barriers from the same publications, these potentially compound in real life, even if they were studied separately. Consequently, the impact of these barriers on social inequality is likely to be more complex.

#### *4.2.3 Proposed measures*

Further, we analyse the measures discussed by the literature against lack of (digital) transport access. We group the measures to overcome social inequality in 13 categories in Table 5 and provide examples of measures in each category.

**Table 2** Number of publications mentioning barriers underlying social inequality

| Barriers | Examples from texts of the selected publications | Number of publications |
|---|---|---|
| | **Mobility domain** | |
| Transport availability | public transit dependency; no car; lack of transport options; vehicle unavailability | 10 |
| Service coverage and connectivity | historically underserved or public transit-poor neighbourhoods; inadequate public transport links; insufficient service areas; network issues | 8 |
| Physical accessibility | limited access to bus stations; deficient walking facilities; inaccessibility of vehicles | 9 |
| Service quality and reliability | timetable coordination and coverage; insufficient quality of public transport service; service predictability; unattractiveness; toilets | 7 |
| Overcrowding and comfort | overcrowding; lack of convenience and comfort; intoxicated passengers; unwillingness to share a ride with fellow passengers | 6 |
| Traffic congestion | traffic congestion | 1 |
| Travelling constraints | baggage; children; carrying bags; bikes on public transport; mobility limitations | 2 |
| Fares | high travel costs; affordability; costs of ticketing; pricing structure | 12 |
| Safety | fear of crime; risk of violence; safety concerns; high-crime areas; theft; lack of surveillance | 11 |
| Harassment and sexual assault | harassment; sexual assault; verbal abuse | 5 |
| Independent travelling | relying on assistance; challenges in travelling independently; constrained autonomy | 2 |
| Gender gaps | restricted female mobility; social and cultural reasons preventing women to drive a car or to ride a bicycle; gendered walking patterns | 5 |
| Time loss | long wait times for public transport; too long or too short time between journeys; higher level of time spent using transportation | 4 |
| | **Digital domain** | |
| Smartphone | not owning a mobile phone or a smartphone | 8 |
| Mobile internet | having no mobile internet | 1 |
| Privacy concerns | concerns about digitization trends; privacy concerns; anonymity | 7 |
| Information security | data security concerns; personal information leakage; security concerns regarding online payments | |
| Digital literacy | lack of digital skills; low digital affinity; low smartphone skills; not using digital media devices such as computers; not having the ability to use a smartphone; smartphone without mobility applications; lack of awareness about how to use bike share; lack of digital mobility skills; unfamiliarity with the system | 14 |
| Usability and digital accessibility | ease of use of services; error tolerance; inaccessible maps; low accessibility of digital interfaces | 6 |
| | **Mixed domain** | |
| Impairments | people with physical and sensory disabilities; wheelchair; people who are blind and low vision (BLV); deaf people; mental health conditions; persons with Autism Spectrum Disorder (ASD); Down's Syndrome; impaired memory | 13 |
| Bank account | limited access to credit cards; lack of access to banking | 2 |
| Discrimination | racial discrimination; socio-spatial fragmentation; service declines to wheelchair users; racial and gender biases; socio-spatially exclusive supply of new mobility services; underrepresenting historically disadvantaged populations in transport data | 8 |
| Psychological | burden; depression; stress; anxiety; controllability; emotional well-being; lack of trust; loneliness | 8 |
| Cognitive | cognitive efforts in learning mobility apps; cognitive rigidity; complexity of MaaS apps; dealing with uncertainties | 3 |
| Travel information | finding the vehicle when it arrives to an unanticipated location; maps for indoor and outdoor navigation; information for routing while using a wheelchair; information about the on-demand service; unreliable information | 14 |

As can be seen in Table 5, publications pay less attention to the policy implications and recommendations in the context of inequality than to describing the barriers. The most frequently proposed measures relate to specific transport infrastructure, the development of transport apps, and IT training.

In multiple publications, technologies, apps and virtual assistants are seen as solutions to existing inequalities. It highlights the "bidirectional" negative or positive influence of transport apps on social inequality [64]. On one hand, transport apps are often inaccessible for people with disabilities and difficult to operate for older adults, thereby increasing the level of inequality. Furthermore, smart transport services that are accessible only via apps can be unavailable in marginalised neighbourhoods or on the urban periphery [72]. On the other hand, transport apps enable shared mobility services, such as ride hailing, on-demand options and mobility-as-a-service. These

**Table 3** The most common barriers in using digital or/and mobility services for vulnerable social groups

| Social groups | Barriers | Number of publications | Share of publications on this group |
|---|---|---|---|
| People with lower income | fares | 10 | 0,36 |
| | transport availability | 8 | 0,29 |
| | physical accessibility | 7 | 0,25 |
| People with disabilities | travel information | 13 | 0,57 |
| | impairments | 12 | 0,52 |
| | usability and digital accessibility | 4 | 0,17 |
| Older adults | digital literacy | 9 | 0,47 |
| | physical accessibility | 6 | 0,32 |
| | fares | 5 | 0,26 |
| Migrants, refugees, ethnic minorities | digital literacy | 8 | 0,44 |
| | fares | 6 | 0,33 |
| | discrimination | 5 | 0,28 |
| Women, gender and sexual minorities | digital literacy | 7 | 0,39 |
| | safety | 7 | 0,39 |
| | fares | 6 | 0,33 |
| Residents of rural and remote areas | fares | 4 | 0,36 |
| | service coverage and connectivity | 4 | 0,36 |
| | service quality and reliability | 3 | 0,27 |
| Residents of countries with emerging economies | discrimination | 3 | 0,33 |
| | overcrowding and comfort | 3 | 0,33 |
| | safety | 3 | 0,33 |
| People with lower education | digital literacy | 4 | 0,67 |
| | fares | 3 | 0,5 |
| | smartphone | 3 | 0,5 |
| Unemployed adults | digital literacy | 1 | 0,33 |
| | discrimination | 1 | 0,33 |
| | fares | 1 | 0,33 |
| Children and adolescents | cognitive | 1 | 0,5 |
| | digital literacy | 1 | 0,5 |
| | fares | 1 | 0,5 |

services can enhance spatial accessibility and decrease the level of inequality [33]. Additionally, newer apps tend to overcome some issues of low digital accessibility that were present in previous apps. As anticipated, apps have a positive and negative impact on inequality in both mobility and digital domains.

## 5 Discussion

### 5.1 Intersectionality and layered inequality

Through our literature analysis, we find that many publications we reviewed addressed several inequalities simultaneously that overlap for the same populations. For example, poorer provision of transport services in less populated rural areas compared to metropolitan centres is associated with lower accessibility of services and may cause transport poverty and transport-related social exclusion [8]. Smartphone-based flexible services have been developed to reduce the existing mobility inequality experienced by rural residents [30]. At the same time, older people with a lower level of digital literacy may find it harder to access these new services than younger people [13, 51]. Consequently, older people living in rural areas with poor transport connection can experience two layers of inequality simultaneously: low availability of transport services and an inability to access apps to use smart mobility services that could otherwise help to mitigate these barriers.

This overlap relates to the concept of intersectionality, which was first proposed by Crenshaw [73]. She highlights the compounded form of inequality experienced by Black women. Rather than experiencing racism and sexism as separate or additive, Black women encounter a distinct form of exclusion shaped by the interaction of both. This framework helps to explain why addressing one type of inequality in isolation may be insufficient, since people's lived experiences are shaped by the interplay of multiple factors. Intersectionality thus provides a valuable lens for studying the complexity and multidimensionality of social inequalities.

The layered inequalities observed in the reviewed publications can be categorised further. For example, Goralzik et al. [48] detail the various challenges faced by people with disabilities when using shared mobility services. These include vehicle inaccessibility, safety concerns, information scarcity, and limited error tolerance. While these challenges are partly related to mobility inequality and partly to digital inequality, they are experienced simultaneously by the same social group. The intersection of these mobility and digital barriers reflects how these two groups of inequality factors can reinforce each other. By contrast, Garritsen et al. [74] consider disparities in digital skills, highlighting the vulnerability of several social groups, such as older adults, people with lower education level, and unemployed adults. Here, a single domain of inequality (digital) affects different social groups. Recognising these two patterns helps us to understand the various ways in which layered inequalities manifest in the context of digital mobility. Future research needs to further investigate the specific type of inequalities shaped by the overlap of digital and mobility layers – digital mobility inequalities.

### 5.2 Digital mobility inequalities

Our results highlight several areas where digital and mobility inequalities intersect. We propose addressing the intersections of digital and mobility inequalities as digital mobility inequalities. Digital mobility inequalities are plural, representing "bundles" of intersecting

**Table 4** Co-occurrence of transport and digital barriers in the same publications

| Inequality description | Mobility domain | Digital domain | References |
|---|---|---|---|
| Unavailability of smart mobility services due to a lack of digital access or concerns about data privacy | transport availability | smartphone; digital literacy; privacy concerns | [14] |
| Lack of smartphone and internet access, lack of digital skills, privacy concerns, anxiety and discomfort with digital devices experienced by older adults and people with lower income when using public transport | service coverage and connectivity; physical accessibility; service quality and reliability; fares; overcrowding and comfort | smartphone; mobile internet; digital literacy; privacy concerns; psychological | [67] |
| Difficulties faced by older adults when accessing services such as Lyft and Uber | transport availability; safety | smartphone; digital literacy; usability and digital accessibility; information security; privacy concerns; psychological | [51] |
| Lack of access to banking, internet or smartphone limiting cashless fare payments for public transport | transport availability | smartphone; bank account; mobile internet | [31] |
| Low accessibility of shared mobility services for people with disabilities | transport availability; travel information; safety; service quality and reliability; overcrowding and comfort | usability and digital accessibility | [48] |
| Challenges by digital access to shared bikes | transport availability; fares | smartphone; digital literacy; bank account; usability and digital accessibility | [68] |
| Low digital accessibility of travel information for people with visual impairments | physical accessibility; travel information | usability and digital accessibility | [69] |
| Challenges women face when accessing MaaS | safety; harassment and sexual assault; psychological | digital literacy; cognitive | [70] |
| Challenges older people, women and people with disabilities face when taking multi-modal journeys and using MaaS apps | travelling constraints; time loss; service quality and reliability; safety; fares; impairments | travel information; impairments; cognitive | [56] |
| Equity bias in transport data: underrepresentation of marginalised groups in data used for transport planning and policy-making | service quality and reliability; fares; time loss | discrimination | [71] |
| Spatially selective supply structures of new mobility services | service coverage and connectivity | discrimination | [72] |

inequalities experienced by populations belonging to multiple vulnerable social groups. We illustrate this concept in Fig. 7.

The scheme in Fig. 7 depicts the nexus between digital inequality and mobility inequality emerging through the co-occurrence of two types of barriers. In light of this concept, the empirical examples gathered in Table 4 can be discussed further. These examples differ by the role played by digital media in producing inequalities. For smart mobility services, such as Uber or bike sharing, apps are often the only means of accessing the service. As Durand et al. [22] have highlighted, such digital-only services are characterised by the indispensability of digital media. Those incapable of using apps are unable to access certain transport options and have fewer options available to them. Groth [14] describes this as a multimodal divide. This type of digital mobility inequality is characterised by unequal access to digital technology, which is essential for accessing the respective mobility services.

Another situation arises when a transport service, such as a public transport, is accessible, but the quality and comfort of using it is hindered by a lack of travel information. As using public transport apps that provide real-time travel information reduces waiting time and stress levels [75, 76], app non-users are disadvantaged in comparison to app users. This is particularly important for people with disabilities, whose travel information needs and preferred formats for receiving information are often overlooked in practice. This type of digital mobility inequality is characterised by unequal access to travel information.

Since transport services are unequally available spatially, app-based mobility is also susceptible to socio-spatial inequalities. For example, Aberle [77] and Groth et al. [72] highlight the limited service area coverage of MaaS and car, bike and e-scooter sharing, which often depends on the density of solvent travellers. In this case, even those who possess a smartphone and are digitally savvy cannot use these services, as they are constrained by geofenced service areas. Before these services existed, they did not contribute to the landscape of mobility inequality. However, once this option exists but is only offered to certain populations, it creates social inequality and reproduces existing transport inequalities [78]. The defining feature of this type of digital mobility inequality is the unequal service coverage.

Providing an overview of these cases of inequality serves to illustrate the concept of digital mobility inequalities, which might encourage further theoretical and empirical developments.

**Table 5** Categories of proposed measures in the reviewed publications

| Categories | Examples of measures | Number of publications |
|---|---|---|
| Strategic | - Consider unequal abilities when planning smart mobility services<br>- Prioritize user experience (e.g., ease of transfers)<br>- Redesign shared mobility with accessibility needs in mind<br>- Integrate smartphones/apps carefully in policymaking to avoid exclusion | 7 |
| Financial | - Subsidised public transport<br>- Subsidies for pooled rides for low-income users<br>- Affordable grocery delivery in underserved areas<br>- Surcharge on ride-hailing to fund wheelchair-accessible services<br>- Subsidized rides for seniors<br>- Partnerships providing smartphones/internet access<br>- Transport vouchers and equity programs | 9 |
| Transport infrastructure | - Maintain bus stops and improve public transport quality<br>- Subsidise or partner with ride-hailing/microtransit providers<br>- Mandate minimum vehicle availability standards<br>- Create dedicated bus and micro-mobility lanes<br>- Provide women-only services<br>- Provide accessible taxis, paratransit, rehabilitation buses<br>- Include accessibility experts in vehicle development<br>- Install ramps | 10 |
| Digital mobility services | - App-based private shuttles<br>- Better integration of shared modes<br>- Improve on-demand ride services | 4 |
| Safety | - Install security cameras and lighting; clear safety signage<br>- Deploy trained personnel on buses<br>- Provide late-night transport options for women and non-binary people<br>- Enhance app safety features (alerts, tracking, verification) | 1 |
| Alternative technologies | - Provide non-smartphone options<br>- Allow cash payments<br>- Maintain paper-trail systems | 3 |
| Usability and digital accessibility | - Reduce cognitive effort in apps<br>- Improve contrast, increase font sizes, reduce icons<br>- Provide standardised, multilingual apps<br>- Apply inclusive design with diverse user groups | 8 |
| Communication | - Promote positive perceptions of accessible mobility<br>- Conduct campaigns on concessionary fares<br>- Communicate clearly using accessible language<br>- Engage community champions<br>- Promote SMS-based mobility services for older adults | 5 |
| Technology | - Use augmented reality (AR) and virtual Reality (VR)<br>- Install digital kiosks<br>- Provide wearable assistive devices | 6 |
| App | - Co-design mobile apps with users<br>- Provide navigation apps for users with disabilities<br>- Offer apps for deaf passengers<br>- Recommend accessible routes via mobile apps | 10 |
| Information provision | - Provide real-time information<br>- Offer service and capacity updates<br>- Include information on luggage facilities<br>- Display estimated travel times and costs | 3 |
| Virtual assistant | - Gamified travel assistants for older adults<br>- Conversational agents<br>- Digital inclusive mobility guides | 4 |
| IT training | - Basic IT and digital literacy training<br>- Tutorials for using transport apps<br>- Outreach for new payment systems<br>- Face-to-face training and on-site assistance | 9 |

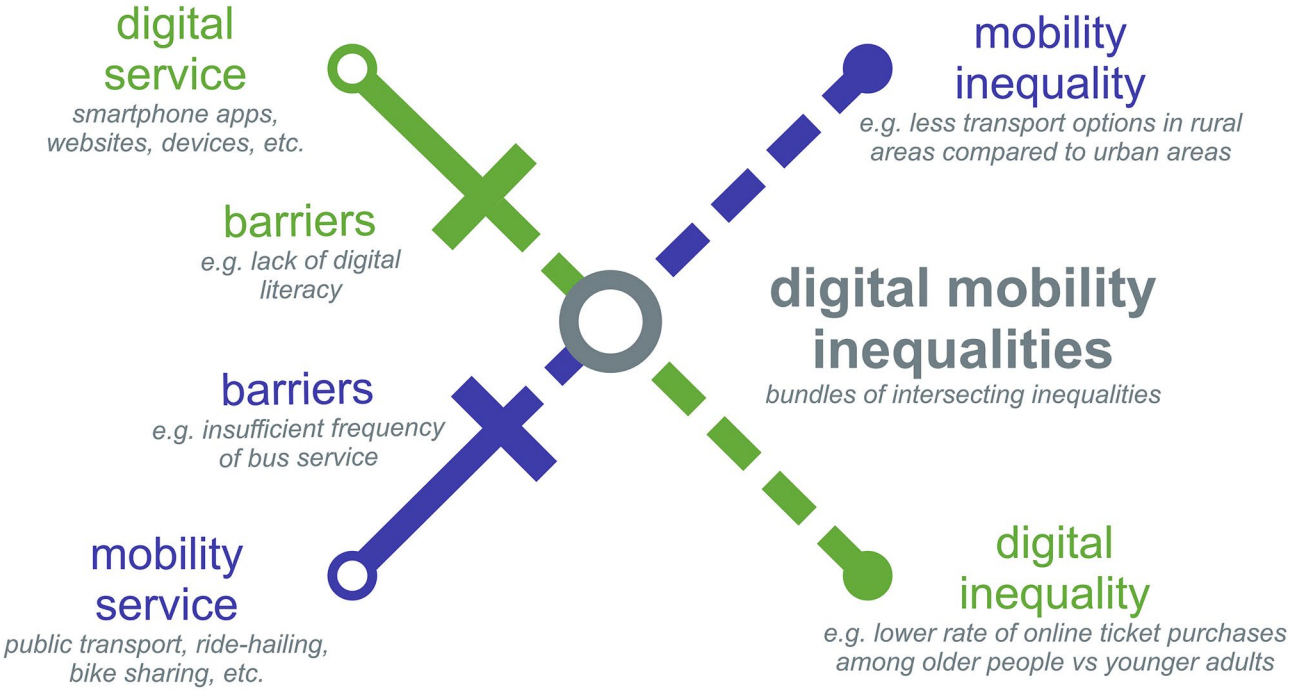


**Fig. 7** Digital mobility inequalities as an intersection

### 5.3 Privacy concerns and voluntary social exclusion

Data privacy concerns has been highlighted as a factor that prevents particular social groups from using smartphone apps for public transport [15]. This is in line with the inequality in digital access we describe in Sect. 5.2. However, data privacy concerns differ in many ways from other factors of social inequality. While not owning a smartphone, lacking digital literacy or having insufficient app accessibility produce social inequality beyond a person's control, data privacy concerns cause deliberate, internally driven decisions not to use apps. This aspect therefore requires additional discussion.

The role of data privacy concerns in relation to transport apps shows signs of what Barry [79] called "voluntary social exclusion". This implies that a person does not participate in a social activity because of a free decision when an equal opportunity to participate is provided. App non-use as a seemingly deliberate act of digital non-participation can be a coping strategy for dealing with information insecurity, particularly among less digitally affine users. For example, older adults are simultaneously challenged by a lack of knowledge and self-reliance [32]. Owing to administrative regulations [15] and changes in social norms [22], the number of available alternatives is decreasing. Therefore, not the privacy concerns themselves, but the digital nudging policies and the social digital push determine the conversion of digital media non-use into a factor of social exclusion.

In a broader sense, people actively select which digital services to use and avoid, irrespective of the social groups they represent and how digitally affine they are. Groth [14] considers the deliberate avoidance of smart mobility as an action of resistance to state surveillance. Not participating in social practices can constitute a form of political action that supports the application of a digital non-participation framework [80]. Beyond data privacy, conscious non-users may be more concerned about the broader implications of digital surveillance and the potential misuse of their mobility data. Avoiding transport apps may be seen not only as a coping strategy against data insecurity, but also as an exercise of the right to protect one's privacy. Therefore, the voluntary

character of digital inequality driven by information security and privacy concerns offers different interpretations, which should be addressed in future research.

## 6 Conclusion

This systematic literature review focuses on publications simultaneously related to smartphones or apps, transport and inequality. It aims to expand our understanding of how both mobility and digital dimensions of inequality are researched by highlighting vulnerable social groups, existing barriers and proposed measures. Our findings contribute to a more detailed understanding of social inequality issues in relation to transport apps. Additionally, we discover four approaches to social inequality in the literature on transport apps: critical, focused, service adoption, and technology-oriented. Exploring these categories helps to improve our understanding of the inequality research landscape. Further, we find that applying the intersectionality concept proposed by Crenshaw [73] helps to unravel the overlap between digital and mobility inequality layers – digital mobility inequalities. Lastly, we emphasise the underexplored potential voluntary character of inequality driven by data privacy concerns as barriers to the usage of digital mobility services. Therefore, this study summarises recent advances in research on transport apps in relation to social inequality, suggesting overarching conceptions that unite digital and mobility aspects.

Based on our findings, we propose two main directions for future research to deepen the understanding of digital mobility inequality:

(1) Investigations into intersectional social inequalities in the context of smart mobility services (digital mobility inequalities);
(2) Analysis of the relationship between the experienced or perceived inequality consequences and the voluntary avoidance of transport apps, particularly among those who are able to use them.

This review is not free from limitations. First, it is based solely on publications in English, which makes it biased toward Western scientific approaches and practical cases. For example, the inequality scenarios related to having no smartphone or no access to internet are hardly visible in the reviewed publications. Second, we only use a specific set of keywords to select publications, and we do not use snowballing for the benefit of scientific rigour and reproducibility. This limits the scope of the review, as does the relevance screening, which is not free from subjective perceptions. Third, our analysis may have not comprehensively captured all the relevant groups, for example, children and young people. Despite these limitations, our analysis provides valuable insights for future research and policy development.

Our findings are particularly relevant in the context of European transport policy. Firstly, the European Union legislation aims to guarantee travellers' rights. This includes equal access to transport infrastructure while also maintaining the right to refuse the use of digital services or provide personal information [81]. Here our study provides insights through the discussion of multiple digitalisation-related issues and in particular privacy concerns and voluntary social exclusion. Secondly, the high level of smartphone adoption in the EU [82] makes way for a fast progression of digitalisation of transport services that relies majorly on smartphone-savvy travellers. Despite the economic benefits of implementing app-based mobility solutions, European decision-makers should consider the needs of vulnerable social groups and be aware of inequality risks. This study summarises the latest literature on these various risks and informs the implementation of inclusive digitalisation policies.

Practically, our findings suggest three actionable strategies to support more inclusive and equitable digital mobility systems for transport service operators, app developers, smart mobility entrepreneurs and policy-makers:

(1) Ensure the availability of accessible, non-digital alternatives for individuals who cannot or choose not to use smartphone-based services.
(2) Enhance the inclusivity and usability of digital mobility platforms by adapting their design and functionality to meet the needs of diverse user groups, including those with disabilities or limited digital literacy.
(3) Provide tailored training and support services for users willing to adopt digital mobility tools but facing barriers, such as unfamiliarity, language difficulties or technical limitations.

## Appendix

**Table A1** Results of the qualitative review

| References | Social groups | Barriers | Categories of barriers | Measures | Categories of measures |
|---|---|---|---|---|---|
| [64] | people with lower income | lack of transport options | transport availability | smartphones and smart apps should be carefully integrated in policymaking to reduce the risk for people of being socially excluded due to a lack of transport options | strategic |
| [83] | older adults; migrants, refugees, ethnic minorities | - | - | SMS use has the potential to mitigate transport disadvantage, particularly for migrant elderly groups; efforts should prioritize promoting the usage of SMS among the elderly population rather than focusing only on increasing smartphone access | communication |
| [24] | older adults; people with lower income | accessibility loss during the COVID-19 pandemic; food deprivation, loneliness, and depression due to containment measures | physical accessibility; psychological | - | - |
| [45] | older adults; people with disabilities; people with lower income | inaccessible transport infrastructure, non-affordable costs, availability of information on infrastructure accessibility | physical accessibility; fares; travel information | the ability of a MaaS app to address inequity | - |
| [84] | older adults; people with lower income; women, gender and sexual minorities | low (perceived) digital skills | digital literacy | - | - |
| [14] | people with lower income; migrants, refugees, ethnic minorities; women, gender and sexual minorities | unavailability of transport options, no smartphone, smartphone without mobility applications, low digital affinity, concerns about digitization trends | transport availability; smartphone; digital literacy; privacy concerns | - | - |
| [85] | women, gender and sexual minorities; residents of countries with emerging economies; people with lower income | limited affordability, social and cultural reasons preventing women to drive a car or to ride a bicycle, deficient walking facilities, fear of crime, sexual harassment and verbal abuse while walking or travelling by bus, overcrowding, long wait times for public transport, traffic congestion | fares; discrimination; physical accessibility; safety; harassment and sexual assault; overcrowding and comfort; time loss; traffic congestion | The most preferred policy options were 'walk with the organized vendor,' 'living further away with better living standard,''subsidized public transport,' 'app-based private shuttle,' and then Bus Rapid Transit (BRT) | financial; digital mobility services; transport infrastructure |
| [86] | people with lower income; migrants, refugees, ethnic minorities | inadequate public transport links, high cost of public transport, traffic congestion, particularly during morning peak times, and the lack of crossconnectivity and direct public transport routes to desirable locations | service coverage and connectivity; fares | face-to-face transport app training, a transport to supermarkets shuttle service, and an information campaign about concessionary bus passes; providing translations of materials into the most commonly spoken languages within the community; approaching members of under-represented groups to become community champions | transport infrastructure; communication; IT training; usability and digital accessibility |

**Table A1** (continued)

| References | Social groups | Barriers | Categories of barriers | Measures | Categories of measures |
|---|---|---|---|---|---|
| [15] | older adults; women, gender and sexual minorities; migrants, refugees, ethnic minorities | privacy concern and the lack of knowledge in smartphone use | privacy concerns; digital literacy | First, the local governments must consider the unequal ability in using smart mobility services among social groups when promoting smart mobility services. Second, the legal system that criminalizes the leakage, steal, and exchange of the big data … must be improved. | strategic |
| [70] | women, gender and sexual minorities; migrants, refugees, ethnic minorities; people with disabilities; children and adolescents | safety concerns while using transport, fear of crime, harassment, overcrowding, privacy concerns, lack of digital skills, cognitive efforts in learning mobility apps, complexity of MaaS apps, smartphone battery limits | safety; harassment and sexual assault; privacy concerns; digital literacy; cognitive | (1) address issues connected with infrastructure and culture, possibly shaped through communications; (2) address the perceived and real risks of access to MaaS; (3) increase the flexibility of the service; (4) reduce the cognitive effort required by accessing the service, for example through user-friendly and standardized apps; (5) associate access with positive perceptions by means of communications | communication; usability and digital accessibility |
| [55] | migrants, refugees, ethnic minorities; people with lower education | lack of digital literacy, not owning a smartphone | smartphone; digital literacy | Digital kiosks might prove to be a solution, as they can facilitate the use of the services found at mobility hubs | technology |
| [87] | older adults; migrants, refugees, ethnic minorities; residents of rural and remote areas; people with lower income | lack of access to personal vehicles, high travel costs, safety concerns | transport availability; fares; safety | transit agencies should investigate ways to better design and deploy Transit Incorporating Mobility on Demand (TIMOD) so that the newly provided services can better fill in the gaps of existing bus transit | strategic |
| [46] | older adults | not using digital media devices such as computers, tablets and smartphones, limited digital skills | smartphone; digital literacy | commissioning bodies to develop a strategic approach to structured data gathering and analysis that addresses issues of exclusion from smart public service infrastructure | - |
| [53] | residents of countries with emerging economies; older adults | no smartphone, low smartphone skills | smartphone; digital literacy | educating residents and improving the existing on-demand ride services | IT training; digital mobility services |
| [42] | older adults; people with lower income; people with disabilities | constrained autononmy and flexibility, safety concerns, dimished emotional well-being, barriers to community engagement, and burdensome | independent travelling; safety; psychological | transportation vouchers, which would reduce the economic burden; expanding ride-sharing services for older adults; program for older adults to help them transition to new services, many of which require using app technologies | financial; IT training |
| [88] | older adults; women, gender and sexual minorities; people with lower income; people with lower education | no owning a mobile phone or a smartphone, having no mobile internet, lack of skills to download and install apps, | smartphone; digital literacy | this represents an opportunity for service providers to support potential users in the downloading of apps with which to access their service | IT training |

**Table A1** (continued)

| References | Social groups | Barriers | Categories of barriers | Measures | Categories of measures |
|---|---|---|---|---|---|
| [56] | older adults; women, gender and sexual minorities | bikes on public transport, bike parking and theft, too long or too short time between journeys, timetable coordination and coverage, reliability, network issues, safety, security and comfort at connections, toilets, complexity and costs of ticketing, car parking, access to public transport stations, children, baggage, impairments, unreliable information, difficulties with route selection from many options, missing connections | travelling constraints; time loss; service quality and reliability; safety; fares; travel information; impairments; cognitive | In-app safety and comfort info could help women and older travellers. Careful marketing is required to engage the latter.; A MaaS app could provide information on luggage facilities, ramps, service busyness and capacity, and the presence of food and drink outlets and toilets | communication; information provision |
| [31] | older adults; people with lower income | lack of access to banking, internet or smartphone | smartphone; bank account; mobile internet | Outreach and education could help transition riders to new payment systems; Cash acceptance through retail networks or on TVMs [ticket vending machines] may still be necessary for the medium term as a large share of transit riders report that they plan to pay fares in cash even if not on board vehicles | IT training; alternative technologies |
| [44] | older adults; people with disabilities | - | - | better integration of shared modes, provision of accessible taxis and rehabilitation buses, and stepwise bundling system | digital mobility services; transport infrastructure |
| [89] | older adults; women, gender and sexual minorities; people with lower income; children and adolescents; people with lower education | 4As: availability, accessibility, affordability, and attractability | transport availability; service coverage and connectivity; physical accessibility; service quality and reliability; fares | - | - |
| [90] | residents of rural and remote areas; people with lower income; migrants, refugees, ethnic minorities; unemployed adults | higher transportation costs, insufficient quality of public transport service | fares; service quality and reliability | programs and interventions that safeguard and improve access to affordable high-quality mobility options for transportation disadvantaged neighborhoods | strategic |
| [91] | older adults; people with lower income; people with disabilities; migrants, refugees, ethnic minorities; residents of rural and remote areas | low digital literacy, low accessibility of digital interfaces [apps] | digital literacy; usability and digital accessibility | (1) improving digital literacy through education and (2) providing an easily accessible digital interface | IT training; usability and digital accessibility |

**Table A1** (continued)

| References | Social groups | Barriers | Categories of barriers | Measures | Categories of measures |
|---|---|---|---|---|---|
| [92] | residents of rural and remote areas | car use, positive attitudes towards cars use | - | where intermodal and shared options are encouraged, the operator should focus on user experience by optimizing the efficiency of transfers, routes, frequencies, and comfort of passengers; in lower density suburban areas where coverage, use and attitudes towards PT are significantly lower, improving commuters experience with PT may be the most viable long-term strategy | strategic |
| [93] | people with disabilities; people with lower income | having no car, inaccessibility of vehicles | transport availability | introducing a surcharge on ride-hailing trips that is used to help fund wheelchair-accessible services; offering paratransit services on an on-demand basis through partnerships with TNCs [transportation network companies] and taxi companies that have access to a fleet of WAVs | financial; transport infrastructure |
| [48] | people with disabilities | inaccessibility of vehicles, lack of information about the on-demand service, safety concerns, service predictability, controllability, error tolerance and security, unwillingness to share a ride with fellow passengers | transport availability; travel information; safety; service quality and reliability; overcrowding and comfort; usability and digital accessibility | - Redesign shared mobility services based on the access needs of users facing mobility barriers.; - Invest in the accessibility of the transport infrastructure, like dedicated lanes for micromobility solutions.; - Include accessibility experts and users with disabilities in the development of vehicles, mobility infrastructure, and mobility services. | strategic; transport infrastructure; usability and digital accessibility |
| [74] | older adults; people with lower education; unemployed adults | not having the ability to use a smartphone, lack of digital mobility skills | digital literacy | the accessible design of digital products and services from the start by involving various groups of potential users; Communicating clearly in accessible language; on-site assistance and digital training to encourage and help first-time users | usability and digital accessibility; communication |
| [16] | residents of countries with emerging economies; people with lower income; women, gender and sexual minorities | - | - | - | - |
| [66] | people with lower income; residents of rural and remote areas; migrants, refugees, ethnic minorities | unequal use of micromobility services (dockless e-scooters and docked bike-share systems) | service coverage and connectivity | increasing vehicle supply alone would probably not lead to higher micromobility use in disadvantaged neighborhoods; enrollment of equity programs and reducing access barriers (e.g., smartphone and banking requirements) to micromobility services | transport infrastructure |
| [49] | women, gender and sexual minorities; residents of rural and remote areas | gendered walking patterns | gender gaps | - | - |
| [94] | residents of countries with emerging economies; women, gender and sexual minorities; people with lower income | low transport accessibility | transport availability | Pooled-rides should be subsidized to low-income groups | financial |

**Table A1** (continued)

| References | Social groups | Barriers | Categories of barriers | Measures | Categories of measures |
|---|---|---|---|---|---|
| [95] | people with disabilities | apps do not include the specificity of people with reduced mobility, temporarily or permanently | usability and digital accessibility | app that recommends optimized routes … for people with reduced mobility | virtual assistant |
| [96] | people with disabilities | challenges in travelling independently for people with Down's Syndrome (DS) | independent travelling; impairments; physical accessibility | app that can support people with DS in performing daily life activities | app |
| [97] | women, gender and sexual minorities; residents of countries with emerging economies | risk of violence, sexual assault and harassment while taking urban public transportation, limited security systems | safety; harassment and sexual assault | - | - |
| [52] | women, gender and sexual minorities | gender gaps in travel and activity participation | gender gaps | tailoring transportation solutions that accommodate late-night travel to address safety concerns for women and non-binary people; flexible work policies to support women's work-life balance since women, especially those with kids, have less personal time after work due to household responsibilities | transport infrastructure; strategic |
| [67] | migrants, refugees, ethnic minorities; people with lower income; residents of rural and remote areas; women, gender and sexual minorities; older adults | challenges related to public transport service availability and accessibility, limited access to bus stations, low reliability, safety concerns, privacy concerns, overcrowding, trust issues, unfamiliarity with the system, negative experiences, | service coverage and connectivity; physical accessibility; service quality and reliability; fares; overcrowding and comfort; privacy concerns; psychological; digital literacy | dedicated bus lanes, well-maintained bus stops, better lighting, emergency call boxes, and security cameras, bus routes into underserved neighborhoods and integrate real-time information systems; a Safety Ambassador program with trained personnel riding buses to assist passengers and provide immediate help if safety concerns arise; user-friendly apps and digital literacy programs, partnerships with local organizations that provide smartphones and internet access to low-income users | transport infrastructure; financial; IT training; usability and digital accessibility |
| [98] | people with disabilities | inaccessible maps for indoor and outdoor navigation | usability and digital accessibility | - | - |
| [99] | migrants, refugees, ethnic minorities; people with lower income; older adults | historically underserved or public transit-poor neighborhoods | service coverage and connectivity | ensuring spatial equity by mandating minimum vehicle availability standards | transport infrastructure |
| [57] | older adults; women, gender and sexual minorities; people with lower income; people with disabilities; people with lower education; unemployed adults | - | - | - | - |
| [100] | people with disabilities | lack of information for routing while using a wheelchair | travel information | a model to help mobility-impaired persons and people around them to represent a road network as a graph | technology |

**Table A1** (continued)

| References | Social groups | Barriers | Categories of barriers | Measures | Categories of measures |
|---|---|---|---|---|---|
| [71] | migrants, refugees, ethnic minorities; people with lower income | underrepresenting historically disadvantaged populations in transport data; data biases in transportation; higher cost burden for transportation for those of lower income; a high level of public transit dependency for low-income and minority populations; higher level of time spent using transportation | discrimination; fares; time loss | - | - |
| [101] | residents of rural and remote areas | high fares | fares | the new ticket (D-Ticket) | financial |
| [69] | people with disabilities | visually impaired people still face several problems while attempting to access into the public transport system | physical accessibility; travel information | android mobile application called TransmiGuía | app |
| [72] | people with lower income; migrants, refugees, ethnic minorities; residents of rural and remote areas; unemployed adults | socio-spatially exclusive supply of new mobility services | discrimination | - | - |
| [61] | people with disabilities | deaf people | impairments; travel information | the MyCarMobile application, a travel assistance android mobile application for deaf people | app |
| [60] | people with disabilities | blind people | impairments; travel information | a set of complementary electronic devices: an improved long cane (MobiFree Cane) that has the ability to detect holes and drop-offs at the floor- level; the concept of a pair of sunglasses (MobiFree Sunglasses) mainly focus in the detection of head-level obstacles and a directional speaker (MobiFree Echo) to obtain echo information of surrounding elements | technology |
| [102] | people with disabilities | people with visual impairments | impairments; travel information | inclusive mobility guide as assistive technology to help the visually impaired through auditory navigation | virtual assistant |
| [51] | older adults | lack of perceived usefulness of services, lack of trust, safety concerns, ease of use of services, security concerns regarding online payments, having no smartphone, low digital skills | safety; usability and digital accessibility; information security; privacy concerns; psychological; smartphone; digital literacy | Providing more information on the app for estimated trip time and out-of-pocket costs for other alternatives; Offering tutorials on the use of technology to access services; having a paper trail was important; subsidized rides for seniors; having a separate credit card with a smaller credit limit just for TNC service booking as a way to reduce risk of consumer fraud; larger fonts, fewer icons, better contrast, and other accessible features; the possibility of paying cash on completion of the ride; maintaining a complaints hotline or increasing the supply of vehicle-for-hire licenses during extreme weather | information provision; IT training; alternative technologies; financial; usability and digital accessibility |

**Table A1** (continued)

| References | Social groups | Barriers | Categories of barriers | Measures | Categories of measures |
|---|---|---|---|---|---|
| [54] | residents of rural and remote areas | car use, distrust in specific apps, insufficient service areas, vehicle unavailability, data security concerns, unattractiveness of transit or sharing modes | psychological; transport availability; service coverage and connectivity; service quality and reliability; information security | real-time information, increased sharing options, assisted parking | information provision; digital mobility services |
| [103] | people with disabilities | people with physical and sensory disabilities | impairments | design concepts for accessible smartphone control of an AV trip | app |
| [104] | residents of countries with emerging economies; people with lower income; residents of rural and remote areas | socio-spatial fragmentation | discrimination | - | - |
| [43] | older adults; people with lower income; residents of rural and remote areas | mobility limitations, unfeasibility of travelling by bus from a grocery store while carrying bags, food deserts and places with transportation scarcity | physical accessibility; transport availability; service coverage and connectivity; travelling constraints | Public partnerships and/or subsidization of ride-hailing or micro transit services; increasing affordability and availability of online grocery delivery in under resourced areas | financial |
| [47] | people with disabilities | service declines to wheelchair users | discrimination | Compensate extra labor and time; Use app technology to support driver incentive | financial |
| [58] | people with disabilities | people with intellectual disabilities | - | Viamigo: A digital travel assistant | app |
| [105] | older adults; people with disabilities; people with lower education | lack of digital skills, concerns on system information insecurity, personal information leakage | - | basic IT trainings and education | IT training |
| [65] | women, gender and sexual minorities; migrants, refugees, ethnic minorities | anxiety while waiting for a vehicle at stops/stations | safety; harassment and sexual assault; psychological | - | - |
| [50] | people with disabilities | mental health conditions, such impaired memory and difficulty in making decisions; having anxiety in a challenging situation | psychological; impairments | - | - |
| [59] | people with disabilities | people who are blind and low vision (BLV), finding the vehicle when it arrives to an unanticipated location | impairments; travel information | a multisensory smartphone-based map system designed to enable non-visual tracking of summoned vehicles | app |
| [106] | people with disabilities | no pathways or information available to help visually impaired people | impairments; travel information | smartphone-sensing for accessible wayfinding | app |
| [107] | people with disabilities | people with visual impairments | impairments; travel information | virtual reality glasses for orientation and mobility training | technology |
| [62] | older adults | - | - | a gamified virtual assistant to the elderly during a walking tourist visit | virtual assistant |
| [39] | older adults; migrants, refugees, ethnic minorities; people with lower education | - | - | - | - |
| [41] | people with lower income; residents of countries with emerging economies | no car | transport availability | - | - |

**Table A1** (continued)

| References | Social groups | Barriers | Categories of barriers | Measures | Categories of measures |
|---|---|---|---|---|---|
| [63] | people with disabilities | The navigation of indoor spaces poses difficult challenges for individuals with visual impairments, as it requires processing of sensory information, dealing with uncertainties, and relying on assistance | impairments; travel information | an indoor navigation app that prioritizes accessibility, integrating enhanced features to meet the needs of visually impaired users | app |
| [108] | people with disabilities | visually impaired people | - | a wearable assistive device, mounted on a pair of eyeglasses | technology |
| [109] | people with disabilities | visual impairments | impairments; travel information | a co-designed mobile app | app |
| [40] | residents of countries with emerging economies; people with lower income; women, gender and sexual minorities; people with lower education | high fares, lack of privacy and security, restricted female mobility, lack of convenience and comfort | fares; safety; privacy concerns; gender gaps; overcrowding and comfort | - | - |
| [110] | women, gender and sexual minorities; residents of countries with emerging economies | low quality of bus transport services, the COVID-19 pandemic | service quality and reliability; overcrowding and comfort; gender gaps; time loss | Since the waiting time is critical, the more the number of buses available and the more the bus schedule is technically adjusted and operated, the more is the bus frequency and the minor is the waiting time and the passenger loading | transport infrastructure |
| [111] | migrants, refugees, ethnic minorities; people with lower income | racial discrimination | discrimination | | - |
| [68] | women, gender and sexual minorities; migrants, refugees, ethnic minorities; people with lower income; people with lower education | cost and pricing structure, lack of awareness about how to use bikeshare, and limited access to credit cards or smartphones, | fares; digital literacy; smartphone; bank account; usability and digital accessibility | cash payment options for the unbanked,; non-smartphone options, provision of multilingual services | alternative technologies; usability and digital accessibility |
| [112] | migrants, refugees, ethnic minorities; residents of countries with emerging economies | seasonal migrant workers in India face significant challenges in accessing social security schemes due to their high mobility, inadequate documentation, low digital literacy, regional policy variations, and a general lack of awareness. | digital literacy; discrimination | the Jan Saathi app, an innovative mobile application, and a scheme discovery and eligibility check platform | app |
| [113] | older adults; people with lower income | closures of bank branches, poor public transport accessibility of other branches | service coverage and connectivity; physical accessibility | - | - |
| [114] | residents of countries with emerging economies; older adults; people with lower income | - | - | - | - |

**Table A1** (continued)

| References | Social groups | Barriers | Categories of barriers | Measures | Categories of measures |
|---|---|---|---|---|---|
| [115] | women, gender and sexual minorities; migrants, refugees, ethnic minorities | nighttime operations, intoxicated passengers, high-crime areas, lack of surveillance, racial and gender biases, anonymity, inadequate training, and high-stress environments | gender gaps; overcrowding and comfort; safety; discrimination; harassment and sexual assault; privacy concerns; psychological | installing video and audio recording systems, enhancing app features (e.g. emergency alerts, real-time tracking, verification systems), offering women-only services, keeping interior lights on during dark hours, displaying signage about surveillance, training programmes focused on preventing sexual harassment and improving communication | safety |
| [116] | people with disabilities | persons with Autism Spectrum Disorder (ASD) experience, in general, cognitive rigidity and behavioral and communication problems | impairments; cognitive; travel information | the combination of Virtual Reality (VR), Augmented Reality (AR), and Conversational Agents (CA) | technology; virtual assistant |

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**Authors contributions**
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**Data availability**
Data supporting the findings of this study are available from the corresponding author upon request.

## Declarations

**Competing interests**
The authors report there are no competing interests to declare.

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