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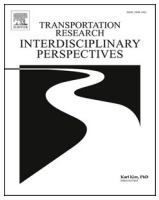

Fostering an inclusive public transport system in the digital era: An interdisciplinary approach

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ABSTRACT

As digitalisation is making its way into public transport (PT) services, policy approaches to ensure that such services remain inclusive are at best fragmented, at worst inexistant. This study pieces together existing initiatives and lessons learnt in the transport sector itself, and takes inspiration from other fields with a more mature understanding of digitalisation. We interviewed twenty-two experts working either in the PT sector or in other sectors such as healthcare and public administration to present an overview of possible measures to foster inclusion in PT in the digital era. We used both triangulation and a two-step respondent validation process to improve results' trustworthiness. We conclude that there is no one-size-fits-all, but a series of complementary strategies to address digital inequality. A focus on an inclusive design from the start, courses, showing the added value of digital tools, specialist products and non-digital alternatives are building blocks to foster a more inclusive PT system in the era of digitalisation. The role of the public transport staff ought not to be underestimated in digital transformations. Importantly, securing the issue of unequal access to public transport due to digitalisation at a decision-making level is essential. Nevertheless, there is only so much that the transport sector can do. Tackling more systemic issues that often underlie digital barriers like poverty and low literacy is crucially relevant. While the present study was conducted in the Netherlands, the presented measures can be applied in other countries by stakeholders working on inclusive digital transformations in (public) transport services.

1. Introduction

In today's society, people are often expected to show self-reliance (Keizer et al., 2019). This means that they are expected to keep up with a fast-paced society and take appropriate action by themselves when needed. This trend has been reinforced by digitalisation, as digital technologies play a key role in shaping societal expectations (Swierstra, 2015). One field where digital technologies have become particularly pervasive is public transport (PT). For instance, smart cards and smartphones have replaced cash and paper tickets in just a few decades (Brakewood et al., 2014; Golub et al., 2022).

Yet some (groups of) citizens are vulnerable to the increasing expectation to take care of everything by themselves digitally (Keizer et al., 2019). This is true for public transport too. In Germany for instance, 24 % of the population reports feeling very limited in their local travels because of a lack of digital skills (Goodman-Deane et al., 2022). Digital skills usually refer to both medium- and content-related digital competences (Van Dijk and Van Deursen, 2014). There is no widely agreed definition of what it means to have "low digital skills" in the context of mobility, but constantly needing assistance or a low performance on basic medium-related tasks like going back to a previous screen are usually seen as signs of low digital skills (Durand et al., 2023; Goodman-Deane et al., 2022).

There are multiple and sometimes overlapping groups of individuals

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Table 1
Policy perspectives on digital inclusion, from Van Dijk (2019).

Perspective	Goal	Focus on
Technological	Creation and distribution of digital technology	Physical access
Economic	Support market, competition and innovation	Physical access Collective usage
Educational	Formal and adult education of information and communication technologies	Digital skills
Social	Inclusion and participation of all	Individual usage
Persuasive	Awareness	Motivation and attitudes

who are more likely to be negatively impacted by pervasive digitalisation in public transport: older adults, people with a lower education level, people with a lower income, migrants and people with learning and communication issues (Durand et al., 2022). Yet public transport may be crucial to some of these individuals, notably due to the reduced access to driver's licence and/or cars among these groups (Bigby et al., 2011; Ryan et al., 2015; Witte et al., 2022).

Interviews with individuals who are more at risk of digital exclusion in transport have revealed that many experience difficulties with digitalisation in public transport to some extent (Durand et al., 2023). They tend to rely heavily on their social network to help them navigate the public transport system. When support is neither available nor sufficient, they may disengage from using public transport altogether. As such, digitalisation can result in an unequal access to public transport; this has been coined *digital inequality in public transport* (Durand et al., 2022). In an inclusive society where public transport is a public service, this is an issue that needs to be addressed.

Tackling difficulties stemming from digitalisation is a relatively new task for transport practitioners and policymakers alike (Macharis and Geurs, 2019), unlike issues linked with physical and sensory accessibility. Nowadays, many public transport professionals are familiar with ways to enable barrier-free travelling for people with a physical or auditory impairment. From lifts at stations to level access and auditory guidance, best practices have been shared within the sector for decades already (European Commission, 1999; European Railway Agency, 2015; United Nations Development Programme, 2010). Examples of improvements can be found in the Netherlands (ProRail, 2021) and in Japan (Dobashi and Ohmori, 2018).

As digital developments in public transport have taken place at a fast pace (Van Dijck et al., 2018), we lack an understanding of solutions to tackle the accessibility issues these developments are causing. At best, fragmented responses are put forward. For example, a large inventory of barriers to plan and deploy inclusive digital mobility services in Europe shows that some services do take into account digital accessibility for people who are visually impaired (Delaere et al., 2021). However, people with different needs, e.g. due to lower digital skills, are seldom considered. At worst, policymakers and practitioners may not respond at all.

Nevertheless, there are other sectors with a somewhat more mature understanding of the ins and outs of pervasive digitalisation. For instance, exclusion due to digitalisation has been on the radar of health and public administration professionals for decades (Ranchordás, 2022; Saeed and Masters, 2021; Sarkar et al., 2011). Besides, communication science researchers have put forward frameworks to mitigate digital inequality and foster digital inclusion (Asmar et al., 2022; Goubin, 2015; Mariën and Van Damme, 2016; Van Dijk, 2019). We suggest that the transport sector should not reinvent the wheel, and learn from these initiatives.

In this paper, we are focusing on actions that can be undertaken to foster inclusion in public transport in the digital era. This means mitigating digital inequality in the present, and making sure that such efforts are sustained in a future where digitalisation will likely keep evolving and playing an important role (Bonnetier et al., 2019; Canzler and Knie, 2016). Such actions therefore also contribute to making public transport more accessible to a larger group of (potential) users, and not only to people who are currently less digitally self-reliant – i.e. people who mostly rely on others to help them navigate digital services, or avoid digital services at all costs.

The present study pieces together existing initiatives and lessons learnt in the transport sector itself, and takes inspiration from research and best practices in other fields. The research took place in the Netherlands, where the public transport sector has been actively leveraging on the opportunities offered by digitalisation (Council for the Environment and Infrastructure, 2021; Government of the Netherlands, 2021). The national rail network is operated by a public limited (or "publicly tradable" in U.S. terms) company (NS), with the state of the Netherlands as the sole shareholder. The government also contracts out various regional and local public transportation services (bus, metro, tram and a few train lines) to other companies. Some of these companies are also public limited companies with a large municipality as sole shareholder, and others are private-sector companies. Despite its limited geographical scope, we argue that this study offers relevant insights for international policymakers and practitioners alike wanting to ensure an inclusive offer of their (public) transport services in the digital era. We aim at answering the following question: *What are possible policy approaches to mitigate digital inequality in public transport in the Netherlands?*

To the best of our knowledge, no publication examining such policy approaches for the field of public transport exists yet. Our main approach to answer this research question consisted of interviewing a diversity of experts, both in the transport sector and outside. We used a framework from communication science research in order to organise both our analysis and our results. This study is also informed by international literature and insights from interviews with people at risk of digital exclusion in public transport, described in Durand et al. (2023); see section 2.3 for a description of our triangulation process.

This paper is organised as follows. In the next section we present our method. Section 3 describes our results. We then present an outlook in section 4. We finish with conclusions in section 5.

2. Methods

2.1. Analytical framework and data collection

Our primary information source to answer our research question consisted of interviews with experts. The first condition that guided our sampling process was that experts should have some affinity with accessibility or inclusivity themes, *and* experience on and knowledge about either digitalisation in public transport, or outside the transport sector. With this condition, we ensured that there was a certain homogeneity within interviewed experts. Homogeneity is important to keep the scope sharp and be able to detect pattern in the data (Guest et al., 2006).

We added a second condition to our sampling process. Indeed, we needed a certain diversity in expertise as we aimed to outline the multidimensionality of perspectives to address digital inequality in public transport. For this reason, we used a framework to guide us, namely Van Dijk's (2019) policy perspectives on how to solve digital inequality (see Table 1). Van Dijk is known for his work around digital inequality, in particular his causal and sequential model of digital media access (Van Dijk, 2005). See Durand et al. (2022) for how this model can be used to understand and study digital inequality in the context of transport services. Ever since Van Dijk described this theory, he has linked policy perspectives to it (Van Dijk and Hacker, 2003). The third column of Table 1 links his policy perspectives to his model. When reaching out for experts, we first estimated which perspective(s) they would most likely put forward based on their previous body of work. This helped us to ensure that we would talk to a diverse pool of experts. For example, our results would have been particularly biased in one direction if we had only talked to experts focusing on an educational

approach to mitigating digital inequality.

The interviews were conducted over the course of multiple months, which left us time to analyse the added value of each new interview and assess whether we had reached a point of saturation, "the point in data collection and analysis when the new information produces little or no change to the codebook" (Guest et al., 2006, p. 65). In total, we interviewed eleven public transport experts with experience on and knowledge about digitalisation in public transport, and with some affinity for accessibility or inclusivity. These experts were from policy, academia, research institutions, transport operators and digital service providers. The amount of PT experts with some affinity for accessibility or inclusivity we interviewed was limited by the amount of suitable candidates in general (Gläser and Laudel, 2010). We also interviewed eleven experts on digitalisation outside the transport sector. These were experts on digital inclusion in general, in the healthcare sector or in public administration services. Two of these experts were working in Belgium and not in the Netherlands, but with previous work experience in the Netherlands and extenstive knowledge of the Dutch context. Besides, interviewing experts who are familiar with practices in another country (here, Belgium) can be enriching for the study. These interviews with experts outside the PT sector aimed at getting insights into and concrete examples on how other sectors are tackling digital inequality. The list of organisations where these experts came from, as well as the roles and experience of these experts, can be found in Appendix A.

We conducted semi-structured interviews for both sets of experts in 2020 and 2021, lasting between 40 min and 1 h 30. The exact questions varied per expert as we approached them with some prior knowledge about their previous work. In general, the interviews revolved around the following three main topics:

- Role of digitalisation in their field (public transport, healthcare, public administration, … depending on the expertise of the interviewed expert) and developments over the past few years (such as public policies).
- Issues around pervasive digitalisation in sector, particularly in relation to a lack of accessibility and exclusion for users.
- (Possible) solutions and lessons learnt from what works and does not work.

Note that the framework of Van Dijk serves as a starting point: since we focus on tackling digital inequality in public transport in particular, our final perspectives are bound to be somewhat different from the ones presented by Van Dijk (2019). For instance, we estimated from the start that the technological perspective as described by Van Dijk (2019) would likely not be relevant for this study. Providing access to a smartphone can be a potentially effective approach to tackle digital inequality, but it is a generic solution that transcends actors in the public transport sector.

2.2. Data analysis

In order to determine measures to mitigate digital inequality from our expert interviews, we analysed them in a structured way. We had the interviews transcribed and we subsequently uploaded them in a qualitative data analysis programme, ATLAS.ti 9. We used qualitative content analysis as described by Kuckartz (2014). Our choice of this type of analysis was motivated by two reasons. First, we were specifically looking for a category-based method, where "the analytical categories are the focus of the analysis process" (Kuckartz, 2014, p. 68). Second, we wanted to select a type of analysis suitable for practice-oriented data such as our expert interviews. In fact, other researchers have used this type of analysis for expert interviews (see e.g. Zerwas (2019)). The first author was the main analyst and shared and discussed findings with co-authors regularly during the analysis period. This was done to ensure confirmability of the results, i.e. the extent to which the study's findings are supported by the data (Shenton, 2004). Note that all interviews were done with two interviewers, the first author with one co-author.

We conducted the analysis as follows. To begin with, we coded text sections where experts were mentioning potential solutions to mitigate digital inequality in public transport. During our second and third coding rounds, we applied respectively deductive and inductive approaches. In the second coding round, we gathered our initial codes into one or multiple of Van Dijk's (2019) proposed policy perspectives. Since not every proposed solution fitted within those perspectives, we developed two new perspectives in the third coding round. Then, in a last coding round, we further refined our coding system. That meant grouping solutions into non-overlapping categories we labelled "measures". We also decided upon one dominant perspective for each measure. We did so for the sake of communication simplicity towards public transport professionals and policymakers.

2.3. Triangulation of results and respondent validation

To ensure that our results were as valid and complete as possible, we used two techniques. Firstly, we used triangulation of data. This means using more than one method to gather insights on the same topic. This is a common practice in qualitative research (Flick, 2009), meant to to enhance both the dependability and the credibility of the study results (Fusch et al., 2018). In addition to expert interviews, we collected insights from literature and interviews with individuals at risk of digital exclusion in public transport. See Durand et al. (2023) for the description and analysis of interviews with individuals at risk of digital exclusion in public transport; note that these were both users and non-users of public transport. Triangulation also allowed us to extend our understanding (Ritchie and Lewis, 2003) of measures to mitigate digital inequality in public transport.

Secondly, we verified our measures and perspectives 0through respondent validation (Ritchie and Lewis, 2003). That way, we controlled that we had not missed out on measures and that our list of possible measures made sense, thereby enriching the credibility of our results (Birt et al., 2016). Here, we used a two-step approach. The first step consisted of presenting our results to an expert on digital inequality and digital inclusion previously interviewed. This expert was invited to extensively reflect on our suggested perspectives and measures. The second step consisted of a 2-hour online workshop organised in April 2021 with 20 Dutch public transport experts. They represented 10 different organisations in the Netherlands, from policymakers of the Ministry of Infrastructure and Water Management to public transport authorities and operators (see list in Appendix A). After a general introduction, four of the authors of this study led a structured discussion in two separate breakout rooms. A few of these experts or colleagues of these experts had been previously interviewed. Not only did this session allow us to get feedback on our preliminary results, it also enabled us to deepen our understanding of the barriers to apply certain measures.

3. Results

In this section, we present the results of our analysis. We uncovered fourteen measures, categorised into five perspectives. Three perspectives are directly translated from Van Dijk's framework. As expected, our interviews did not reveal that the technological perspective would be directly applicable to the transport sector. For instance, none of the experts, even those outside the transport sector, suggested that giving access to a smartphone to people would be helpful to foster inclusion in public transport in the Netherlands. Similarly, neither the expert or the (non-) PT users, nor literature showed evidence that the economic perspective – solving problems "through a better supply of digital technology" (Van Dijk, 2019, p. 136) – would directly contribute to mitigate digital inequality in public transport. However, experts frequently emphasised the importance of a good design of digital technologies and services. This is why we created a new perspective: the *design perspective*.

Table 2
Summary of the proposed perspectives and measures to foster digital inclusion in public transport.

Proposed perspectives	Suggested measures	Amount of experts who put some version of this measure forward	
		PT experts (11 in total)	Experts outside PT sector (11 in total)
Design perspective	#1 Ensure a usable design and strive for a Universal Design	4	9
	#2 Involve user groups in the design of digital products and services	5	6
	#3 Use assessments and standards	1	6
	#4 Create more awareness among designers and developers	2	1
Educational perspective	#5 Provide courses to improve digital skills with an application in public transport	2	8
	#6 Train public transport staff	1	4
Persuasive perspective	#7 Raise awareness on the positive outcomes of digital tools in public transport	2	3
	#8 Communicate clearly	3	5
Social perspective	#9 Provide non-digital alternatives and safety nets	6	10
	#10 Dedicate special attention to hard-to-reach groups	4	9
	#11 Make use of specialist products	5	2
Governance perspective	#12 Monitor developments and support research	2	8
	#13 Build reflexivity	1	6
	#14 Adopt a proactive long-term approach	2	6

Besides, experts often highlighted solutions on a higher level than the educational, social and persuasive perspectives showed in Table 1. These solutions do not directly impact individuals. Instead, they are focusing on securing the commitment to addressing the unequal access to public transport due to digitalisation now and in the future. We named this a *governance perspective*. Experts outside of transport often put this perspective forward, as we reflect on in section 4.4.

These five perspectives and their corresponding measures are summarised in Table 2. The last column indicates the amount of experts who put forward the various measures; this demonstrates the great complementarity of having interviewed experts both in the public transport sector and outside (see also section 4.4). The remainder of this section describes each measure.

3.1. Design perspective

The design perspective consists of aiming at an accessible design of digital products and services from the start by involving various groups of potential users. Experts also put forward the necessity of embedding an "accessible design thinking" within the transport system itself.

Measure 1: Ensure a usable design and strive for a universal design

Experts all agree that a prerequisite for an inclusive digital product or service is that it should have a usable design. Based on Shneiderman (1980) and Nielsen (1994), Van Dijk (2019) defines the usability of a digital product or service as the combination of multiple characteristics. These characteristics include the ease of accomplishing a basic task, how quickly this task may be performed, how easy it is to remember how to carry out a task, the extent to which mistakes can be corrected, the pleasure of using the digital tool and how intuitive its use is. Ideally, the use of the service or product should not depend on the level of skills of users. Customising which functionalities are visible or hidden in an app is a way to cater to users with a wide range of digital access (Fuglerud, 2014). Although not strictly part of usability, experts stressed the importance of a design that would respect the privacy and personal data of users. In addition, design needs to be adaptable, as the needs of users are not static but change over time (Patrick and Hollenbeck, 2021).

Working with Universal Design (UD) principles was suggested by a few experts. These principles include usability characteristics and go beyond as they are concerned with addressing the needs of "all people, to the greatest extent possible, without the need for adaptation or specialized design." (Connell et al., 1997; Story, 2001). The EU-funded INDIMO project has put forward an extensive UD manual for digital products or services in mobility, applicable in Europe and beyond (Di Ciommo et al., 2021; INDIMO, 2022b). Having a design useful to people with diverse abilities – the equitable use principle – plays a central role in UD.

Measure 2: Involve user groups in the design of digital products and services

In line with UD principles, there is a wide agreement in literature and among experts that involving *diverse* groups of users *as early as possible* in the design process of a product or service is an essential condition to making it inclusive (Bonnetier et al., 2019; Di Ciommo et al., 2021; Goubin, 2015; Henni et al., 2022; Mariën and Van Damme, 2016). For instance, this could mean asking explicitly older adults from 65 to 90 years old and people with lower literacy levels to be involved in the early design stages of a ticket vending machine. Involving these groups is not only about asking them what they want: it is about organising digital tools around how end users make decisions and process information. A design that is accessible for those having the most difficulties, is likely to be inclusive to almost everyone.

When diverse groups of users are not involved early on – or not at all – the design process will often result in specifications for the mainstream user (Bonnetier et al., 2019; Gill et al., 2007). In theory, these specifications can be modified later on. In practice, this often turns out to be expensive, long to carry out, or simply impossible (Bekiaris et al., 2009; Davis and Nathan, 2015). For instance, Van Kuijk et al. (2014) argue that too little attention has been given to users in the development of the Dutch public transport smartcard system. Some adaptations have been carried out since its implementation to make the card more accessible, but at a cost and over multiple years.

Nevertheless, early user involvement also comes with issues. One of them is that people may have internalised stereotypes pertaining to their age, abilities or gender, jeopardising their ability to state their needs (Vermeij and Hamelink, 2021). This is why involving professionals who are in contact with these groups can also be helpful. According to the experts in digital health services we interviewed, involving social workers, nurses and doctors adds value in the design of e-health services. Indeed, they have some understanding of the needs of end users and they need to be able to explain to them how to use the final product. In public transport, this means that public transport staff but also care coordinators and key contact persons representing groups of end users could have a role to play in the design of digital services, as put forward by Bonnetier et al. (2019) in Belgium.

Measure 3: Use assessments and standards

Under the European Accessibility Act (EAA), service providers such as public transport operators will be required to meet certain standards for digital accessibility from 2025. Websites, mobile services, electronic tickets and information from operators will be covered by this law (European Commission, n.d.). This Act is supposed to cover people with physical or sensory impairments as well as people with autism or dyslexia, mild intellectual impairments and impairments due to old age.

Digital accessibility standards are not new. An EU-wide digital accessibility legislation for websites was adopted in 2016 (European

Commission, 2022). Experts on the accessibility of governmental websites highlighted that a positive approach usually works best when service providers are required to improve the accessibility of their services as a compliance-based approach can be counterproductive – organisations would do the bare minimum. This means using assessments to prepare the transition to an accessible and inclusive service: what are the operators or service providers already doing well? Who is doing best? Such an approach can stimulate the ones lagging behind. Assessments are also deemed particularly useful by interviewed experts because they can challenge providers beyond accessibility standards. Indeed, a service can be accessible yet not inclusive. Accessibility usually focuses on the needs of people with impairments (Emiliani, 2009) and can be objectively measured. Inclusivity goes one step further: it is about taking into account the whole diversity of end users (Fuglerud, 2014; Waller et al., 2015), and providing a range of features that the end user can choose from to fit their needs in their context (Patrick and Hollenbeck, 2021).

Although legal instruments that enforce or encourage digital accessibility are emerging, most of the rules do not actually specify the elements expected in the accessibility (Di Ciommo et al., 2021). Nevertheless, multiple tools for assessing the accessibility and inclusivity of digital products and services in mobility have been published in recent years as part of EU-funded projects (INDIMO, 2022a; Nesterova et al., 2020; Repetto and Bagnasco, 2021) and outside these projects (Dadashzadeh et al., 2022; Richardson et al., 2022). They ask questions such as the possibility to use non-digital alternatives, text-to-speech technology support, the possibility for user feedback, etc.

Measure 4: Create more awareness among designers and developers

Raising awareness among designers and developers about the specificities of people that fall outside a certain "standard user range" can encourage a more inclusive design. Trainings or games exist for this purpose at all levels, starting with design and engineering students as Tüker and Çatak (2020) propose in Türkiye. Furthermore, an interviewed expert explained how accompagnying someone during their journey can be eye-openeing. Such an experience had shown her the challenges people may face in public transport.

Diversifying the profiles of designers and developers can also increase the inclusivity of digital technologies. No technology is ever value-neutral (Van den Hoven, 2012); it is laden with (implicit) assumptions from its creators. For instance, Rosales and Fernández-Ardèvol (2020) showed that digital platforms often embed ageist values, i.e. values that discriminate based on age. This is due to a lack of (age) diversity in innovation teams, as also recognised by a few interviewed public transport experts. Design decisions tend to follow homophilic patterns, arising from a shared background, such as education, language and socialisation practices (Rosales and Fernández-Ardèvol, 2020). Such a lack of diversity enhances the need to involve (potential) user groups early on (measure 2) (Bonnetier et al., 2019) and to compensate them fairly for their expert knowledge.

3.2. Educational perspective

The educational perspective focuses on people with lower digital skills and how they can be best assissted when needed.

Measure 5: Provide courses to improve digital skills with an application in public transport

This measure focuses on training individuals' digital skills with an application in public transport. Olausson and Kamel (2020) give the example of a Swedish regional public transport authority and operator organising training events for older adults every year. According to a representative interviewed by Olausson and Kamel (2020), these events are highly appreciated by both participants and operators. In France, the public transport administration in Paris (RATP) is provinding mobility workshops for various target groups, which usually include a digital component (RATP, 2016). Nevertheless, such initiatives have been discontinued in the past in the Netherlands. According to experts, quantifying the effectiveness of such trainings and finding the right target group were the two main issues. Regarding the latter, an interviewed public administration expert made a suggestion: in the Netherlands, some public administration services may offer individuals calling these services the possibility for a referral to free courses to improve their digital skills. According to this expert, about 11 % of such calls result in a referral. Staff training to discern relevant individuals is important (see measures 6 and 7).

Ultimately, literacy and basic digital skills play an important role in being able to develop new digital skills (Van Dijk and Van Deursen, 2014). Ideally, trainings to improve digital skills with an application in public transport should be linked to existing initiatives, for instance in the field of adult education or broader digital skills trainings. In the Netherlands, some general digital skills courses have started including a part on planning a public transport trip in their standard offer (see Digisterker (2020) for instance). Importantly, such trainings need to have a practical component (Harvey et al., 2019). A few individuals interviewed in Durand et al. (2023) reported having taken part in general courses to improve their digital skills. Those who could benefit from on-hands support from family or friends to help them apply their new knowledge had seen a positive impact of the course on their ability to plan trips independently, while the others had not.

Measure 6: Train public transport staff

Digitalisation also affects staff. Workers play a key role in making digital transformations more inclusive. This has been documented in the healthcare sector for decades (Kruszyńska-Fischbach et al., 2022). Interviewed experts in healthcare argue that the public transport sector is no exception as public transport staff are in contact with travellers. As such, they play an important role in shaping travellers' experience with digital technologies, particularly for those who are less digitally self-reliant (Bigby et al., 2019; Van Holstein et al., 2021). The interviews conducted in our previous study show that PT staff can have a significant impact on travellers who are less comfortable with digitalisation. For instance, they can facilitate travel by helping with seemingly small but impactful actions, such as requesting a smartcard or activating an option on a travel app (Durand et al., 2023).

Public transport workers could be trained to recognise the barriers that certain groups of travellers face when using digital tools, as well as the possibilities to overcome these barriers. This is currently not the case in the Netherlands. Some interviewed PT users reported instances when staff had refused to help them, wrongly assuming that they had access to digital travel information (Durand et al., 2023). Increasing the digital skills of public transport workers themselves may also be needed, but there needs to be a clear scope of what falls under their competences or not (Voss and Vitols, 2020).

3.3. Persuasive perspective

The persuasive perspective is about enticing people to use digital products and services by making them more appealing. An inclusive design is important here (Rathenau Institute, 2017), as well as a couple of additional measures.

Measure 7: Raise awareness on the positive outcomes of digital tools in public transport

Campaigns and awareness programmes can trigger interest in using digital products and services in public transport. The interviews conducted in Durand et al. (2023) reveal that people with a lower digital self-reliance can also reap benefits of digitalisation. By highlighting the advantages of using such digital tools, such interventions can motivate individuals who do not usually turn to digital services and products to give them a try.

These campaigns can also target people who are more digitally self-reliant, by encouraging them to be more open to assist others when needed (Bigby et al., 2019; Sabie and Ahmed, 2019). A more personalised approach consists of mobilising public transport ambassadors (usually peers) (Janse, 2012; Leliveld, 2022) or coaches for people with

Table A1
Summary of the interviewed public transport experts. Five of them identified as female, six of them identified as male.

#	Name of organisation	Position of interviewed expert	Experience of expert in this position or similar one (only if linked with public transport and accessibility)
1	Dutch Ministry of Infrastructure and Water Management	Senior policymaker in public transport accessibility	5–10 years
2		Senior policymaker in smart mobility	10–15 years
3	PBL Netherlands Environmental Assessment Agency	Senior researcher in urbanisation and transport	15–20 years
4		Senior researcher in urbanisation and transport	5–10 years
5	NS (Dutch national railway company)	Channel management manager	10–15 years
6	9292 (national multimodal trip planner)	Specialist in relations with PT travellers	10–15 years
7	Public transport ombudsman		1–5 years
8	Rover (public	Director	5–10 years
9	transport travellers' organisation)	Policymaker	1–5 year
10	Radboud University	Researcher in transport and justice	15–20 years
11	Delft University of Technology	Researcher in design of mobility services	5–10 years

Table A2
Summary of the interviewed experts outside the public transport sector. Four of them identified as female, seven of them identified as male.

#	Name of organisation	Position of interviewed expert	Experience of expert in this position or similar one
1	Ministry of the Interior and Kingdom Relations	Senior policymaker in digital accessibility	20–25 years
2	Stichting Digisterker (organisation helping people with low digital skills)	Project leader educational programmes	5–10 years
3	Low-Tech magazine	Journalist	15–20 years
4	CAK (Central Administration Office)	Programme manager digital inclusion	15–20 years
5	Pharos (Dutch Centre of Expertise on Health Disparities)	Programme manager eHealth	5–10 years
6	National Ombudsman	Digitalisation expert	5–10 years
7		Digitalisation expert	10–15 years
8	Vrije Universiteit Brussel, Belgium	Researcher in adult education and social inclusion	10–15 years
9		Researcher in digital inclusion	10–15 years
10	Utrecht University	Researcher in media and governance	20–25 years
11	Tilburg University	Researcher in health accessibility and technology	30–35 years

Organisations represented during the workshop with Dutch public transport experts:
- CROW (Dutch knowledge platform for transport and infrastructure).
- RET ((sub)urban operator, region Rotterdam).
- GVB ((sub)urban operator, region Amsterdam).
- Arriva (regional operator).
- NS (Dutch national railway company).
- Vervoerregio Amsterdam (public transport authority, region Amsterdam).
- OV-bureau Groningen-Drenthe (public transport authority, north of the Netherlands).
- Translink (Dutch public transport data administrator).
- 9292 (national multimodal trip planner).
- Dutch Ministry of Infrastructure and Water Management.

an impairment. Both have the opportunity to raise awareness about the benefits of digital technologies in a tangible way and boost confidence of people with a lower digital self-reliance. Experts noted the need for subsidies for both of such interventions; see the Outlook section below.

Staff can also play a role in raising awareness. They can entice travellers who use service desks or who call to use online services by explaining and showing them the added value of online channels (Goubin, 2015). However, this needs to be done carefully, or it can have the opposite effect as a few experts cautioned. For example, many PT users with a lower digital self-reliance interviewed in Durand et al. (2023) mistakenly believed that some analogue services and products had disappeared. The art is to ensure that people do not feel pressured to use digital services (Pieterson, 2009).

Measure 8: Communicate clearly

Communicating clearly in accessible language is an absolute precondition to allow people to engage with digital products and services (Mariën and Van Damme, 2016). In general, the use of plain and everyday language, icons and a clear layout are all recommended (Goubin, 2015; Hueting et al., 2021). In non-English speaking countries, English technology jargon may not suit an accessible text; even in the UK, Harvey et al. (2019) reported that a term like 'smartphone' is often unsuitable for an older demographic. In the Netherlands, language ambassadors help public administration services write more accessible and clearer texts on their websites (Pander Maat and van der Geest, 2021). Using the langage level B1[1] is often advised in some countries (DELF-DALF, n.d.; Government of the Netherlands, n.d.). Experts outside the public transport sector also emphasised that alignment between sectoral stakeholders regarding communication and terms used via digital channels is crucial to entice people into using these channels.

3.4. Social perspective

The social perspective aims at a full access of public services – such as public transport – for everyone.

Measure 9: Provide non-digital alternatives and safety nets

Non-digital alternatives may be precisely what allows people to travel independently, as showed in Durand et al. (2023) in the Netherlands and Van Holstein et al. (2021) in Australia. As part of a social perspective, maintaining them makes sense. For the operator, this measure often means retaining analogue options such as paper tickets or service desks, but also public transport staff. Interviews with non-PT users with low digital skills show that they find it hard to imagine using public transport without having PT staff available to answer their questions (Durand et al., 2023). Interviewed public transport experts also supported the fact that help from PT staff can be instrumental for small, one-off actions as mentioned in measure 6.

When non-digital alternatives are retained, it is essential to ensure their quality. Otherwise, they lose much of their usefulness (Mariën and Van Damme, 2016). Neverthless, public transport experts are not always in agreement about how this translates in real life. Some deem that retaining a customer service phone number for which individuals have to pay extra charges is questionable. Others justify such a fee by emphasising the high maintenance costs of non-digital alternatives.

Experts and literature mentioned ways to ensure quality non-digital alternatives under the constraint of costs. We list them below (this list is

[1] The B1 language level refers to the Common European Framework of Reference for Languages (CEFR) level B1, an intermediate level of language proficiency (Council of Europe, n.d.).

not exhaustive and is in no particular order):

- Classifying tasks in terms of urgency, complexity and audience to decide on the usefulness of analogue alternatives (Goubin, 2015). Research on digital transformations in public administration services shows that older adults, people with cognitive impairments and people with financial difficulties tend to value human contact more (Ebbers et al., 2016). Pieterson and Ebbers (2020) have also demonstrated that people usually feel best served through non-digital channels when complex questions are involved or quick responses to important matters are needed. A public transport expert confirmed this: in times of disruptions or strikes, up to three times more individuals than normal call the information service line of a large Dutch multimodal travel app/website. Besides, these individuals tend to be more diverse in terms of demographics than usual.
- *When appropriate,* directing people to digital options (see measure 8).
- Using low-tech tools such as help buttons on ticket vending machines to assist users remotely. Visual contact with an assistant, via a screen on vending machines, can give people reassurance.
- Bundling non-digital services of various parties. This approach lies at the core of the Digital Inclusion programme launched in 2018 by the Dutch Ministry of the Interior and Kingdom Relations (Ministry of the Interior and Kingdom Relations, n.d.). Citizens can visit the Digital Government Information Points present in almost all Dutch libraries if they have difficulties with any digital public administration service.

Some experts also highlighted that digital technologies are not infaillible. Analogue alternatives can also be important for digitally self-reliant travellers in case of technical failures. Besides, smartphones can also run out of battery or have network issues; free and public internet as well as public charge points act as safety nets in such cases (Golub et al., 2019).

Measure 10: Dedicate special attention to hard-to-reach groups

Dedicating special attention to hard-to-reach groups means investing in coordinated actions to support the needs of particular groups that other measures may not reach. This measure explicitly acknowledges the need for partnerships, for instance between local policymakers, libraries, community centres, non-profit organisations and social workers. Mariën and Van Damme (2016) emphasise that creating partnerships between parties is an essential building block to foster inclusion in an increasingly digital world. Parties that are closest to particular groups will understand their specificities better, such as social workers and community centre coordinators (Durand et al., 2023). These parties will also be more easily able to reach them (Van Dijk, 2019). Outside the transport sector, an example of such measure would be the Digital Government Information Points (see measure 9) as described by an interviewed expert. In the field of public transport, an example of such measure would be a neighbourhood event advertised in the local newspaper and targeting a specific group (e.g. older adults). Such an event could aim at making this group more familiar with their transport options and answer questions they might have about e.g. how a smartcard works, which app to choose to look for travel information, etc. A more concrete example is that of *maisons des mobilités* (literally "mobility houses") in France: these are places being developed in rural and *peri*-urban areas particularly, offering support to travellers when needed (Losego, 2018).

Measure 11: Make use of specialist products

In some cases, specialist products – traditionally referred to as assistive technologies[2] – might be needed for individuals to be able to fully use and reap the benefits of digital technologies. Indeed, the goal of the Universal Design approach (see measures 1 and 2) that design should be such that no adaptation and specialised design is needed, is often not realistic (Emiliani, 2009). Instead, design professionals and researchers alike have been making the case for *inclusive* design (Fuglerud, 2014; Waller et al., 2015). Inclusive design considers the full range of human diversity such as ages, abilities and cultural background, and acknowledges this diversity as a starting point in the design strategy. This is where specialist products can play a role. They can range from pieces of equipment to services or product systems including software (European Disability Forum, 2020). In the case of public transport, specialist products can be apps that focus on people with cognitive difficulties or with visual difficulties. The Dutch GoOV (GoOV, n.d.) and NS Platform Guide (NS, n.d.) apps are respective examples of such tools. Specialist products can also be non-digital, such as a helpline. According to Kok and Koopmans (2017), the need for specialist products even justifies the need to keep non-digital alternatives in public transport (see measure 9).

Interviewed experts highlighted the importance of two aspects when introducing specialist products. First, design and involvement of end users is key (see section 3.1) to ensure the success of specialist products. Otherwise, the product may be useless. This is what some transport experts reported, based on their experiences developing tools that ended up unused, namely a reading tool in a travel app and a Braille map. Second, these specialist products should be developed with a long-term perspective, they should be future-proof. In particular, one should be able to maintain them. Experience with the digitalisation of public administration services has shown that websites developed for people with specific accessibility needs (like eyesight issues) have often been poorly maintained. They were not regularly updated and became substandard and outdated versions of the original websites.

3.5. Governance perspective

Last but not least, we found a call among experts for (semi-)public organisations governing public transport to reappropriate themselves the governance of digitalisation in the sector. Literature also echoes this call (see e.g. Bonnetier et al. (2019) and Herzogenrath-Amelung et al. (2015)). Governance is essentially about steering the actions of a large group of people to achieve specific goals, and minimise risks and undesired outcomes (Hoppe, 2010). For this specific perspective, the involvement of experts on (the governance of) digitalisation from outside the transport sector was of particular added value. Indeed, they offered a middle road between technological fatalism on the one hand ("good or bad, technology is coming and resistance is futile") (Cohen and Jones, 2020, p. 81) and technological optimism on the other hand. The latter is rooted in the belief that everything is getting better for everyone thanks to digital technologies, and is usually driven by technology manufacturers and marketing discourses (Herzogenrath-Amelung et al., 2015; Steer, 2022). The measures presented in this perspective aim at securing the issue of unequal access to (public) transport due to digitalisation now and in the future at a decision-making level.

Measure 12: Monitor developments and support research

Experts in the healthcare sector and in public administration services agreed that monitoring is an important building block in the governance of digitalisation. Knowing what is going on in terms of digital developments, how (potential) users are affected and how existing policy goals are impacted is necessary to be able to contribute to steering digital transformations in the sector. Investing in inclusive monitoring

[2] Waller et al. (2015) suggest using the term *specialist products* instead of *assistive technologies*, for the latter is usually embedded within a disability-centric approach. Besides, they argue that nearly all technology can be considered as assistive anyway.

becomes capital to capture the experiences of people who are less digitally self-reliant. Therefore, relying exclusively on web-based panels and barometers is not enough.

Besides monitoring, research projects are also needed to better understand the ins and outs of digital transformations in the sector. A few interviewed experts highlighted the need for both quantitative and qualitative research on this topic (see also Mariën and Van Damme (2016)). When one focuses solely on quantifiable aspects, more subtle yet significant impacts might be overlooked. Swierstra (2015) call these "soft impacts". They are qualitative, co-produced by users and are invited, and not strictly speaking caused by, technologies. Soft impacts are about changing practices, such as the expectation from public transport staff that passengers have access to a smartphone (Durand et al., 2023) or new forms of work for passengers and drivers caused by a cash ban on buses as Pritchard et al. (2015) investigated in the U.K. By contrast, quantifiable impacts unequivocally caused by technology are "hard impacts", such as economic impacts. In Swierstra's view, the ubiquitous and occasionally exclusionary nature of soft impacts means it is no longer acceptable to disregard them.

Measure 13: Build reflexivity

Digitalisation puts pressure on public values (Royakkers et al., 2018). This observation also applies in the transport system, where commercial interests can conflict with the societal interest in an inclusive mobility system (Council for the Environment and Infrastructure, 2021; Physical Environment Consultative Council, 2021). Just as measure 4 requires designers and developers to question their own assumptions, this measure asks institutions to be reflexive. Institutional reflexivity means that the organisation holds up a mirror to itself regarding its own activities, assumptions, how it deals with underrepresented voices (Young et al., 2019) and how it deals with public values (Stilgoe et al., 2013).

A way to build reflexivity is to give a permanent place to ethical reflections in organisations. This is precisely the message addressed by the Dutch Physical Environment Consultative Council to the Ministry of Infrastructure and Water Management after experimenting with ethical reflections on a few topics (Physical Environment Consultative Council, 2021). Ethical reflections, also called moral deliberations, originally come from healthcare (see e.g. Hermsen and ten Have (2005)). During such a reflection, participants share their perspectives and values, explore the implications of different courses of action, and consider the potential impacts for various stakeholders. The goal is to reach a deeper understanding of the ethical dimensions of a situation and to identify a course of action that is consistent with the participants' shared values and principles. A concrete example for an ethical reflection could be on whether it is desirable to add a premium on analogue alternatives like paper tickets.

Measure 14: Adopt a proactive long-term approach

This measure consists of establishing a long-term approach to managing digital transformations in public transport services. Some experts suggested working with tools associated with anticipatory governance, as Cohen and Jones (2020) also put forward. Anticipatory governance seeks to anticipate and respond proactively to potential future challenges and opportunities, rather than simply reacting to them after they have occurred. It involves using foresight, scenario planning techniques (see Snellen et al. (2019)) and 'what if' analyses (see Ravetz (1997)) to identify emerging trends and issues, and then designing policies and strategies to address them. Such tools can be used before technology is being developed, but anticipation processes can also be applied when technology is at the threshold of society. Although scenario planning does not provide a definitive blueprint for the future or prescribe specific actions, it does compel policymakers to approach evolving situations in a deliberate and systematic way, weighing their available responses (Cohen and Jones, 2020). In the United States, Kuzio (2019) showed how a few metropolitan planning organisations are taking into account social equity impacts of emerging technologies in their long-term plans. Recently, Kollosche and Uhl (2022) provided specific examples of scenario building for digital and inclusive mobility systems in four European cities.

4. Outlook: What to do now?

4.1. Commitments

The measures presented in this study are intended to be used as initial steps for stakeholders working on inclusive digital transformations in public transport services. For instance, designers of innovative payment methods in public transport can take advantage of checking the resources we mentioned in measure 3. Policymakers working on facilitating the emergence of Mobility-as-a-Service (MaaS) could benefit from the tools mentioned in the governance perspective.

However, commitment is needed in order for any of these measures to have an effect. Such a commitment could be at the level of a company, like an operator deciding to train their staff or develop more awareness among their app developers. Some operators explained that they were willing to invest in a more inclusive public transport offer to some extent, as they were aware that there are wider benefits than "just" people with a lower digital self-reliance: more ease of use for occasional users, safety net when battery phone is dead, etc.

Yet professionals involved during the workshop argued that operators in particular were unlikely to have (enough) budget to properly address issues around digital inequality. A public transport system strongly oriented towards financial and economic efficiency offers little incentive to focus on people who are less digitally self-reliant. In general, experts contended that achieving changes to improve inclusion in public transport in the digital era may require a stronger, more fundamental commitment. Such a commitment could be a direct financial support (e.g. through subsidies) or could be directly built within concessions for a more structural engagement. For instance, authorities could include incentives and/or requirements in contracts for concessions regarding standards for the provision of non-digital services. Note that this is already happening in the context of recent contracts for demand-responsive public transport services in the Netherlands and the UK (Potter et al., 2022; Reizen door Zeeland, 2023).

Such a commitment for an inclusive transport system could also be decided and legally anchored at a nation-wide level. For instance, the Dutch Ministry of Infrastructure and Water Management – responsible for transport issues – is now considering legally incorporating both the involvement of consumer organisations with expertise in PT accessibility in advisory processes as well as the use of the B1 language level for travel information (State Secretary of the Ministry of Infrastructure and Water Management, 2023). All in all, the measures described in this paper can be used as valuable starting points when considering commitments for a more inclusive public transport system.

4.2. From accessibility to inclusivity

A way to ensure such a commitment to keeping public transport inclusive in the digital era would be to broaden the ongoing conversation around accessibility. In the Netherlands, public transport accessibility for people with physical or sensory impairments has been on the agenda of policymakers for decades (Spittje and Witbreuk, 2005). There is no denying that these groups deserve attention. Besides, they sometimes face problems due to digitalisation in public transport too (Vicente and López, 2010). Digital accessibility for these groups of people is increasingly taken into account, for instance via spoken instructions on ticket machines and the NS Platform Guide app (see measure 11) (ProRail, 2021). At the same time, if policymakers are striving for a fully accessible public transport system (see for instance action 17 of the Memorandum on the Future of Public Transport 2040 (Ministry of Infrastructure and Water Management, 2021) and the Agreement on Accessibility to Public Transport 2022–2032 (Ministry of Infrastructure and Water Management, 2022)), broadening the discussion around accessibility to one on inclusivity would be a step forward. As previsouly

mentioned in measure 3, accessibility usually focuses on the needs of people with impairments and can be objectively measured while inclusivity is about taking into account the whole diversity of end users. Such an observation about a narrow focus on (sensory and especially physical) accessibility is not exclusive to the Netherlands; see for instance the review of Levine and Karner (2023) about the narrow focus on mobility disability among transport planners in the U.S..

What makes such a shift challenging is that people with a physical or sensory impairment are usually easier to identify than people experiencing problems with digitalisation, and so are their needs. For instance, organisations for people with a visual impairment have become increasingly involved in the development of products and services in the public transport sector in the Netherlands. At the same time, there is no single organisation representing people experiencing difficulties with digitalisation and articulating their concerns. People facing issues with digitalisation in public transport consitute a heterogenous group and their needs are multifacted. For example, not all older adults face barriers due to digitalisation. As a result, individuals struggling with digitalisation in public transport might become invisibilised, as Bonnetier et al. (2019) already warned in Belgium. This risk highlights once more the need for diverse user groups to be involved in the design of services and products, as presented in measure 2.

4.3. Complementarity of perspectives

Many of the measures we describe often refer to another one as a precondition. In fact, these perspectives arguably complement each other. We conclude, as Van Dijk (2019) does for digital inequality in a broder sense, that "all of these perspectives are necessary and valid; the digital divide problem is much too complicated to be approached with a single or limited strategy" (Van Dijk, 2019, p. 134).

Since difficulties around digitalisation in public transport are often measured in terms of digital skills of (subgroups of) the population, it can be tempting to focus solely on an *educational perspective*. However, such an approach reflects an overly narrow view of the issue of digital inequality (see Durand et al. (2022)). Besides, it is not viable to rely solely on courses without thinking about design, as technology keeps advancing. However, an *inclusive design* may never reach certain people without some degree or enticement and special attention to some groups (*persuasive perspective*). Since one functional design for everyone is likely irrealistic, specialist products, non-digital alternatives and staff training are probably needed (*social perspective*). And given that technology keeps evolving, securing the issue of unequal access to (public) transport due to digitalisation at a decision-making level makes sense (*governance perspective*). The "optimal combination" of measures will likely strongly depend on the situation and the target groups. There is no one-size-fits-all to mitigate digital inequality, as Yeboah et al. (2018) and Zhang et al. (2020) already highlighted.

4.4. Beyond the public transport sector

The measures presented in this study come at a cost and striving for the inclusion of every single person may be unrealistic. Since multiple sectors face similar issues around digitalisation, the (public) transport sector might benefit from joining nation-wide initiatives around digital inclusion, when they exist as they do in the Netherlands.

Importantly, there is only so much that the transport sector can address. If there is one point on which all experts agreed, it was that the transport sector cannot tackle digital inequality alone. Addressing more systemic issues that often underlie digital barriers like poverty and low literacy (see Durand et al. (2023)) is also needed. This conclusion aligns with discussions on the need to view matters such as accessibility poverty and transport-related social exclusion – where digital inequality plays a role (Luz and Portugal, 2021) – through a wider lens of social and economic disadvantage (Lucas, 2012; Ward and Walsh, 2023).

At the level of our study, looking beyond the public transport sector itself proved beneficial. This study demonstrates the scientific and policy relevance of an interdisciplinary approach. A clear added value of involving experts from other fields is that they often had a more overarching view of ways to mitigate digital inequality. They usually approach issues around (the risk of) digital exclusion from a more systems thinking perspective, with attention to feedback loops (unintended consequences), delays, the use of methodologies and by seeking collaborations. Notably, they generally explained the need for a governance perspective and possible actions to take in a more articulate way, reflecting a somewhat more mature understanding of the ins and outs of pervasive digitalisation. These experts usually had more work experience than the PT experts (see Appendix A). However, we do not believe that it is a coincidence or a bias, for the intersection of accessibility/inclusivity and digitalisation in PT remains a fairly recent field. Experts in digitalisation in the healthcare and public administration sectors also highlighted a valuable takeaway for this study, namely the need to take into account the role of staff in digital transformations. Still, public transport experts obviously had an important role to play in this study too. In particular, they had more understanding of barriers to fostering inclusion in public transport.

5. Conclusions and further research

This study presents an overview of approaches to foster inclusion in public transport in the digital era, motivated by a fragmented or sometimes inexistent understanding of how to address the social impacts of digitalisation in PT. Based on 22 interviews with experts, we conclude that there is no one-size-fits-all to foster an inclusive public transport system in the digital era. Nevertheless, this study showcases important building blocks to achieve a PT system that keeps welcoming even the least digitally self-reliant users. A focus on an inclusive design from the start, showing the added value of digital products and services, providing courses, specialist products and non-digital alternatives are all components that contribute to fostering a more inclusive PT system in the era of digitalisation. Importantly, the role of the public transport staff ought not to be underestimated by public transport authorities and operators. Workers at the interface between the system and users of the system play a key role in the digital transition. Last but not least, securing the issue of unequal access to public transport due to digitalisation at a decision-making level is essential: (semi-)public organisations need to reappropriate themselves the governance of digitalisation in the sector. Nevertheless, there is only so much that the transport sector can do. Tackling more systemic issues that often underlie digital barriers like poverty and low literacy is crucially relevant.

Despite its geographical scope, this study offers relevant insights for international policymakers and practitioners alike wanting to ensure an inclusive offer of their (public) transport services in the digital era. Indeed, digital inequality in transport services goes beyond the Netherlands (Durand et al., 2022) and the leading position of the Netherlands in terms of digitalisation in general and in public transport makes it an interesting case. This study also shows that triangulating a source of information (here interviews with experts) with other sources of information (interviews with users and literature) can lead to the production of rich insights into a specific topic.

We note two main limitations to our study. Firstly, we were not able to detail all of the ins and outs of every single measure in one paper. Yet the crux of the matter often lies in the finer particulars. For instance, Levine and Karner (2023) showed that a compliance-based approach – which forms a part of measure 3 – may be insufficient, misleading and even fail to understand the lived experiences of people. This pitfall was already mentioned by an expert. Simiarly, Levine and Karner (2023) warn that public engagement opportunities (measure 2) may be used more as a way to check a box than to allow people to have a meaningful impact on outcomes. Therefore, the implementation details of each of the measures need to be carefully examined before proceeding to applying them. Secondly, even though we have involved a diversity of

experts, reached a saturation point and read studies across multiple disciplines, we cannot claim that our list of measures is exhaustive.

In this study, we have chosen to exclusively focus on public transport and have left out modes such as shared mobility modes. Nevertheless, multiple measures can be applied to a much broader set of transport modes. For example, monitoring the evolution and impact of technological developments (measure 12) is not limited to traditional public transport services; it is arguably particularly relevant for emerging transport modes such as shared cars, shared scooters and shared bicycles. Our study can inspire researchers and professionals working on the potential deployment of these modes to examine ways to foster an inclusive access to these modes too.

While a strong point of this study lies in showcasing the breadth of actions that can be can undertaken to foster an inclusive public transport system in the digital era, the lack of knowledge on the efficiency of these measures can hinder their application. As underlined in measure 12, knowledge is essential to contribute to steering digital developments; further research could therefore focus on evaluating the impacts of measures that aim at mitigating digital inequality in transport services.

CRediT authorship contribution statement

Anne Durand: Conceptualization, Methodology, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Project administration. **Toon Zijlstra:** Conceptualization, Formal analysis, Data curation, Writing – original draft, Writing – review & editing. **Marije Hamersma:** Formal analysis, Data curation, Writing – original draft, Writing – review & editing. **Arjen 't Hoen:** Conceptualization, Writing – original draft, Writing – review & editing. **Niels van Oort:** Conceptualization, Writing – review & editing. **Serge Hoogendoorn:** Conceptualization, Writing – review & editing. **Sascha Hoogendoorn-Lanser:** Conceptualization.

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Data availability

The authors do not have permission to share data.

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Appendix A

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