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Durand, Anne; Zijlstra, Toon; van Oort, Niels; Hoogendoorn-Lanser, Sascha; Hoogendoorn, Serge

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Access denied? Digital inequality in transport services

Anne Durand [a,b], Toon Zijlstra [a,c], Niels van Oort [b], Sascha Hoogendoorn-Lanser [b] and Serge Hoogendoorn [b]

[a]KiM Netherlands Institute for Transport Policy Analysis, The Hague, Netherlands; [b]Department of Transport & Planning, Faculty of Civil Engineering and Geosciences, Delft University of Technology, Delft, Netherlands; [c]Department of Transport and Regional Economics, University of Antwerp, Antwerp, Belgium

ABSTRACT

Digitalisation in transport services offers many benefits for travellers. However, not everyone is willing or able to follow the new, more or less formal requirements digitalisation has brought along. Existing reviews on the intersection between Information and Communication Technologies (ICTs) and mobility cover a range of vantage points, but the perspective of how various levels of engagement with digital technologies affect access and navigation of transport services has not been addressed yet. In communication science, studying disparities in terms of ICT appropriation and their consequences is known as digital inequality research. This review paper aims at shedding light on what digital inequality in the context of transport services consists of and what its consequences are. To do so, we define and use a conceptual framework for the analysis of digital inequality in transport services. The review of the twenty-five papers, as selected in our systematic literature search, shows that there is a burgeoning interest in this topic. Vulnerability to digitalisation in transport services exists along dimensions of age, income, education, ethnicity, gender and geographical region. We find that motivations and material access get more attention than digital skills and effective usage. Nevertheless, literature acknowledges that having material access to technology does not mean that people benefit from what technology has to offer. Furthermore, the characteristics of ICTs impact one's possibilities to access digital technologies, such as how user-friendly a technology is. Data-driven and algorithm-based decision-making present a particularly pernicious form of digital exclusion from transport services. As digital technologies are progressively becoming indispensable to navigate the world of transport services, low levels of digital engagement may create a new layer of transport disadvantage, possibly on top of existing ones. Although digitalisation can be part of the solution to transport disadvantage, it can also be part of the problem. With network effects at play, what might start as a relative disadvantage may turn into an absolute disadvantage. Given the nascent state of research on digital inequality in transport services, much remains to be understood. Suggested research avenues include mechanisms of digital exclusion from transport services, the contribution of digital

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CONTACT Anne Durand a.l.m.durand@tudelft.nl

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inequality to transport disadvantage, and importantly, solutions to mitigate its impacts.

Introduction

Over the past decades, the adoption of digital technologies into everyday lives of millions has become a major trend. This is known as digitalisation, or digital transformation, "the integration of multiple technologies into all aspects of daily life that can be digitised" (Gray & Rumpe, 2015, p. 1319), i.e. all aspects that can be converted to a digital form. In his book on smart cities, Townsend (2013) contends that the application of digital technologies – or ICTs (Information and Communication Technologies) – has proliferated in transportation systems, notably in cities, more than in any other urban planning disciplines. In transport services in particular – i.e. public transport (PT) and shared mobility modes such as car sharing and ride sourcing (see Shaheen and Cohen (2020)) – digitalisation is pervasive. From smartcards to real-time multimodal planners and platforms such as Mobility-as-a-Service (MaaS), digitalisation promises to simplify mobility and to provide greater control and choice to travellers over how, when and where they travel (Ferreira et al., 2017; Line, Jain, & Lyons, 2011). This is notably possible thanks to mobile phones and especially smartphones, which emerged through the convergence of the internet and personal connected devices (Aguiléra, 2019).

Digitalisation in transport is not limited to smartphones though. It is largely relying on the concept of Intelligent Transport Systems (ITS), defined as "the application of modern ICTs to transport systems" (Leviäkangas, 2016, p. 2). Traditional actors in the transport services' industry such as public transport operators have progressively embraced digitalisation to increase the efficiency and the quality of their services while lowering costs (Ampélas, 2001; Davidsson, Hajinasab, Holmgren, Jevinger, & Persson, 2016). At the same time, new players operating shared mobility modes have emerged in the transport services' arena (Boutueil, 2019; Wong, Hensher, & Mulley, 2017), leveraging on advances in ICTs to scale up these modes (Shibayama & Emberger, 2020).

Digitalisation is changing the way people get access to and navigate the world of transport services. Yet digital transformations are not simply about converting analogue information into bits and bytes, but bring new organisation structures that change society (Benkler, 2006). Digital transformations do not necessarily retain non-digital elements in the same form, as shown in Table 1.

As travellers are increasingly invited to rely on digital technologies in transport services (Aguiléra, 2019; Pangbourne, Stead, Mladenović, & Milakis, 2018), not being willing or able to engage with digital transformations in such services may create a form of transport disadvantage. According to Schwanen et al. (2015), a lack of basic resources, skills and/or autonomy with regards to travel can result in transport disadvantage. Transport and social disadvantage do not necessarily co-exist (Currie & Delbosc, 2010), but when they do, there is a risk of transport-related social exclusion (Jeekel, 2018; Lucas, 2012). This is defined by Kenyon, Lyons, and Rafferty (2002) as:

> the process by which people are prevented from participating in the economic, political and social life of the community, because of reduced accessibility to opportunities, services and

Table 1. Selection of digital transformations, with examples (own framework).

Label	From	To	Examples in transport services
Substitution	analogue	digital	Book with public transport schedules → Websites and applications
Liquid digital	digital	digital	Web-based public transport app → Native public transport app (downloaded from an app store)
Co-existence	analogue	analogue (possibly under a modified version) and digital	Static signage (e.g. in public transport) → Dynamic and static signage Paper tickets → Smartcards/e-tickets and paper tickets (with a premium) Monthly offline public transport subscription → Monthly subscription online, with only yearly subscription available offline
Digital only	-	digital	Ride-sourcing applications such a Uber

Note: The terms co-existence, substitution and digital only are used in media research (O'Neill, 2008; Oggolder, Brügger, Metyková, Salaverría, & Siapera, 2019). We were inspired by Bauman (2006) for the term liquid digital.
Example of the monthly subscription borrowed from OV Ombudsman (2019).

> social networks, due in whole or part to insufficient mobility in a society and environment built around the assumption of high mobility. (pp. 210-211)

Furthermore, statistics on internet penetration may mislead professionals and decision-makers who are unfamiliar with the field of digital inequality, i.e. how social groups access ICTs and how various types of engagement with technology lead to offline social (dis)advantages and social exclusion (W. Chen, 2013). For instance, the Netherlands has the highest internet penetration rate in Europe (98%) and is, with Sweden, the European country with the highest use of mobile internet (87%) (Statistics Netherlands, 2018). Yet in this same country, one in six people aged 16 or older have low numeracy and or literacy skills (Netherlands Court of Audit, 2016). This most likely translates into difficulties navigating the digital world (Van Deursen & Van Dijk, 2014). It can impact access to travel information, with negative outcomes on mobility (Hong, Thakuriah, Mason, & Lido, 2020). Furthermore, digital inequality may in fact be increasing in the Netherlands (Van Deursen, Van Dijk, & Ten Klooster, 2015).

Reviews on the intersection between ICTs and mobility have covered a variety of vantage points, from the debate around substitution and complementarity of ICTs and travel, to the experience and use of travel time and space (Aguiléra, 2019; Aguiléra, Guillot, & Rallet, 2012; Andreev, Salomon, & Pliskin, 2010; Gössling, 2017; Hjorthol, 2008; Van Wee, Geurs, & Chorus, 2013). However, the perspective of *how various levels of engagement with digital technologies in a given context affects access and navigation of transport services* – digital inequality in transport services – has not been addressed. This review aims to fill this gap by examining the impacts of digitalisation in transport services on travellers through the lens of digital inequality research. Robinson et al. (2015) argue that such a cross-disciplinary approach is needed, because "digital inequality should not be only the preserve of specialists but should make its way into the work of social scientists concerned with a broad range of outcomes connected to life chances and life trajectories" (p. 570). The three main overarching themes of this review are digitalisation, social exclusion and mobility, with the three main sub-themes being digital inequality, digitalisation in transport services and transport disadvantage. Their nexus forms the position of this study (Figure 1).

Furthermore, this study echoes to recent calls from scholars to acknowledge and investigate challenges posed by digitalisation in transport and the implications of the digital

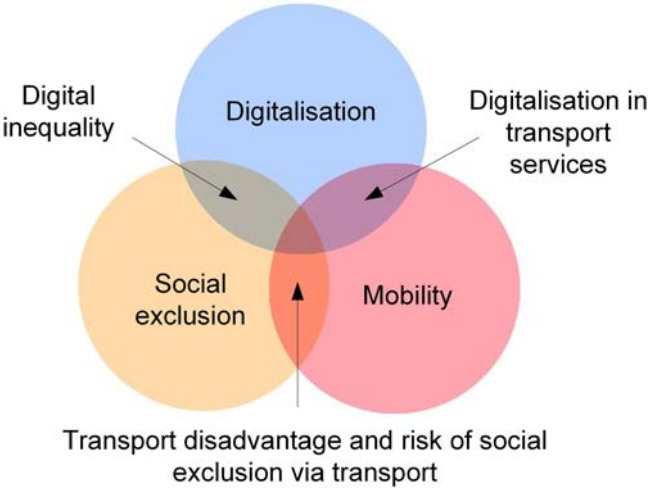

Figure 1. Central concepts of this study with the main themes (circles) and sub-themes (own design).

divide on people's mobility (Banister, 2019; Hensher et al., 2020; Lucas, 2019; Lyons, Mokhtarian, Dijst, & Böcker, 2018; Macharis & Geurs, 2019). The contribution of this review is threefold:

- It provides a conceptual framework that structures the concept of digital inequality in transport services,
- It synthesises the literature on digital inequality in transport services and
- It highlights gaps in literature and topics where further research efforts are needed.

This study is expected to be useful to researchers who would like to investigate the inclusiveness of transport technologies and systems, yet have little background in communication and media science. This paper can also be of value to practitioners who would like to understand the implications of design choices on (potential) travellers and policymakers dealing with a growing political attention to the topic (European Commission, 2020, pp. 99–100).

This paper is organised as follows. Next section introduces the concept of digital inequality and provides a conceptual framework. Then the methodology of the systematic literature review is detailed, followed by the main findings of the review. Finally, future research avenues are suggested, followed by the main conclusions.

Digital inequality

The term *digital divide* became popular in 1990s in the United States, during a decade of staggering growth of the internet and personal computers (Lupač, 2018). This term reflects an initially binary conception of *digital inequality*,[1] between those who had access to technologies versus those who had not. Such a difference in terms of physical access has conceptually evolved over the years into motivational access (Van Dijk, 2005) and material access (Van Deursen & Van Dijk, 2018). In the 2000s, as the internet became

pervasive in Western countries, some scholars started to question the prevalent idea that physical access to technology would provide all its benefits (Selwyn, 2004). Researchers began to investigate differences in terms of usage (Van Dijk, 2005) and skills (Hargittai, 2001). More recently, the realisation that internet users with similar degrees of access and skills do not reap the same benefits of digital technology marked a shift towards a more comprehensive approach to digital inequality, focused on the consequences of internet (non-)use (Scheerder, Van Deursen, & Van Dijk, 2017). Research shows that people with greater offline resources are usually more likely to achieve tangible outcomes from their use of digital technologies and that digital inequality both reinforces and exacerbates social inequality (Scheerder, Van Deursen, & Van Dijk, 2019; Van Deursen & Helsper, 2015; Warren, 2007).

Multiple theories and models of digital inequality co-exist. In this study, we sought a framework for understanding digital inequality in transport services, its causes and consequences. A well-known and established theory of digital inequality is the causal and sequential model of digital media access, originally described by Van Dijk (2005). It focuses on the exclusion of individuals due to the integration of ICTs in all aspects of society. Unlike other theories, it is not restrained to a spatial context or a given field (Mariën, Heyman, Salemink, & Van Audenhove, 2016). For more on digital inequality theories, see Mariën et al. (2016), Pick and Sarkar (2016), Lupač (2018) and Van Dijk (2019).

Van Dijk's model assumes that *personal and positional categories* lead to different *offline resources*. These resources influence the extent to which one accesses or appropriates oneself technology, where access consists of four successive factors: *motivation, material access, digital skills* and *usage*. These factors are influenced by the *characteristics of technologies*. This process of access influences *participation outcomes* and, in turn, offline resources. In spite of the model appearing linear, it can also be read in a circular manner (Van Dijk, 2019). For instance, the fact that gaining skills influences attitudes on technology is included. Van Dijk's model has been tested and validated (Van Deursen & Van Dijk, 2015; Van Deursen, Helsper, Eynon, & Van Dijk, 2017).

Transport researchers are usually more acquainted with theories using the acceptance of technology perspective, but these are less informative of digital inequality. For instance, the Theory of Planned Behaviour (Ajzen, 1991) or the Diffusion Of Innovation theory (Rogers, 1962, 2003) only cover the first phases of access to a technology, lack a feedback loop and fail to acknowledge the complexity of adoption of a technology (Lupač, 2018; Selwyn, 2004).

Nevertheless, Van Dijk's digital media access model also has drawbacks. A main criticism is motivation as an entry point. As ICTs are becoming increasingly ubiquitous and profoundly entangled in institutions and daily practices, motivation is no longer the precondition to access technology it used to be (Mariën et al., 2016). Indeed, digital has become the default option (*digital by default*) and the individual ability to deal with this digital push may be what increasingly shapes digital inequality, instead of being motivated to use digital technologies. According to Lupač (2018), in order to better investigate digital inequality, it is necessary to assess how *indispensable* ICTs are in a given context, by examining:

- How embedded these technologies are in everyday routines and in institutions of this field,

- How available non-ICT alternatives are, taking into account that an alternative costing extra resources (time, money, etc.) is not necessarily a *real* alternative.

This criticism does not invalidate Van Dijk's model though. Research has shown that it is not necessary to have fully completed one factor to be able to access the next one (Van Deursen, 2018). The notion of indispensability is therefore added to the conceptual framework as presented in Figure 2.

Methodology for the literature review

To identify relevant studies, keywords are assigned to each of these themes shown in Figure 1 and their overlap, with the goal to identify papers that would stand at the centre of Figure 1. The terms in Figure 1 were used as starting points to brainstorm relevant keywords among the authors, examining synonyms, historic terms, antonyms and homonyms. Literature was consulted to find terms used interchangeably, such as Lucas, Mattioli, Verlinghieri, and Guzman (2016) for transport-related social exclusion, Stanley (2011) for social exclusion and Scheerder et al. (2017) for digital inequality. We favoured more general concepts to specific ones, with the expectation that studies that focus on all three main themes will show a certain degree of abstraction. The resulting keywords are displayed in Table 2.

The literature search was conducted in English in Scopus. Five queries were created based on the keywords, each query being the intersection (boolean AND) between two or three sets of keywords (Figure 3).

We used the PRISMA guidelines to select papers (Moher, Liberati, Tetzlaff, & Altman, 2009) (Figure 4). Titles, keywords and abstracts of journal articles, conference proceedings and book chapters were screened using the web application Rayyan (Ouzzani, Hammady, Fedorowicz, & Elmagarmid, 2016). It allows for a smoother and quicker screening process by providing semi-automation features. Furthermore, forward and backward snowball reviews were conducted on the papers found at the Eligibility step. These techniques,

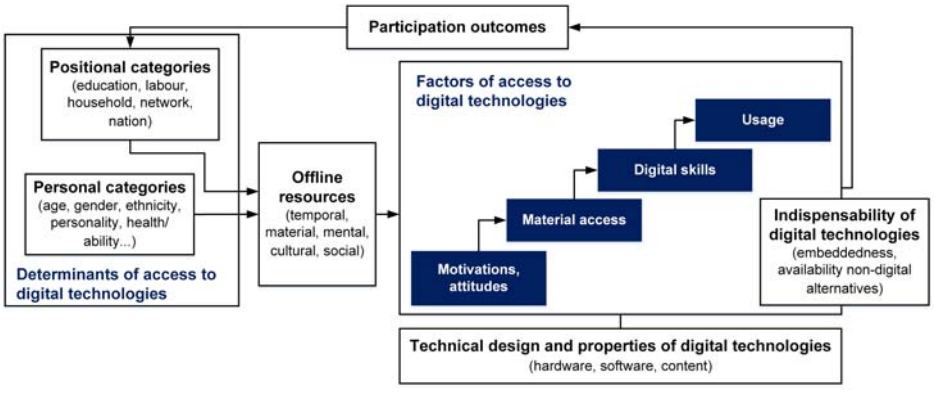

Figure 2. Conceptual framework to investigate digital inequality and its consequences (inspired by Van Dijk's model (Van Dijk, 2005, 2019), complemented with the notion of indispensability (Lupač, 2018)).

Table 2. Sets of keywords for the systematic literature review.

Theme	Keywords
Digitalisation	digital* OR technolog* OR analog* OR telematics OR ICT
Mobility	mobilit* OR transport* OR travel* OR trip*
Social exclusion	"social* inclu*" OR "social* exclu*" OR "social participation" OR "social* sustainab*" OR *equit* OR "social engagement"
Digitalisation in transport services	"digitalisation in transport services" OR "smart mobility" OR "intelligent transport*" OR "interconnected mobility" OR "travel* information" OR "integrated mobility" OR "mobility-as-a-service" OR "mobility innovation" OR "transport innovation" OR "mobility app*" OR "transport technolog*"
Transport disadvantage	"social exclusion via transport" OR "inclusive transport*" OR "transport* accessibility" OR "accessible transport*" OR "social* *clusive transport*" OR "transport-related social *clusion" OR "transport* disadvantage" OR "unmet travel need" OR "transport* poverty" OR "mobility poverty" OR "mobility disadvantage" OR "mobility inequalit*" OR "transport* *equalit*" OR "unfulfilled mobility" OR "participation in mobility" OR "latent travel demand" OR "accessibility poverty"
Digital inequality	"digital inequalit*" OR "digital divide" OR "access to ICT" OR "digital skill" OR "digital litera*" OR "e-inclusi*" OR einclusi* OR "digital *clusion" OR "digital ethics" OR "digital gap" OR "internet skill"

described in Van Wee and Banister (2016), are considered to be useful additions to systematic database searches (Kitchenham & Charters, 2007).[2] We do not claim that this review be exhaustive because of the theoretical impossibility to reach saturation (O'Reilly & Parker, 2012), choices in keywords and queries as well as the dynamic and multifaceted nature of this topic. We focused on studies with a clearly exposed qualitative or quantitative approach, a distinct link with transport services and chose to leave out essays. After reconciliation, a total of 25 articles were included to be analysed. We then examined each paper through a directed content analysis, a deductive process which

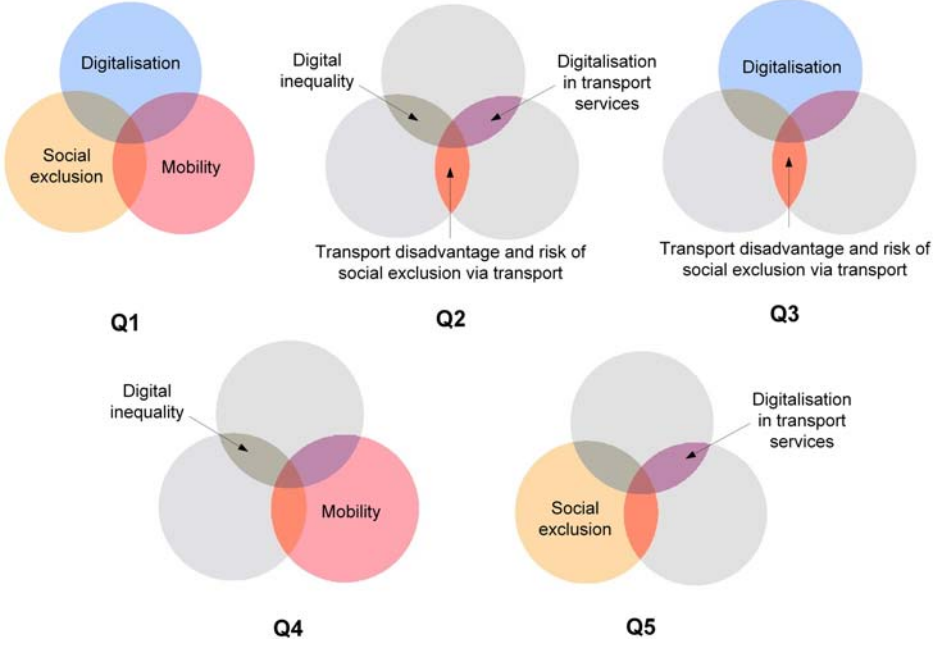

Figure 3. Queries for the systematic literature search.

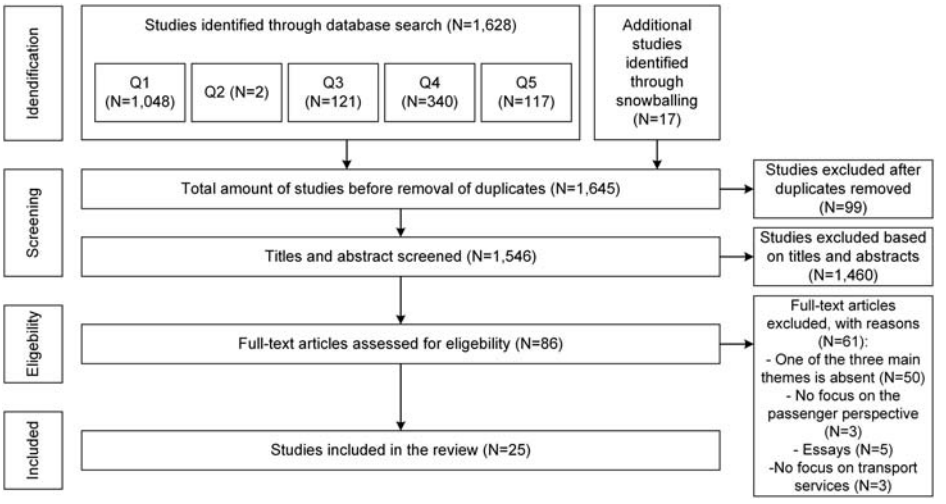

Figure 4. PRISMA flowchart for the systematic literature review done in August 2020.

implies starting the analysis with a theory as guidance (Hsieh & Shannon, 2005), in our case the framework presented in Figure 2. A majority of the selected papers (N=18) are from 2018, 2019 or 2020, demonstrating an increasing interest in this topic.

Findings

In this section, the conceptual framework (Figure 2) is used as a lens to read and organise the literature review's results. As such, this section presents findings from the selected papers (as displayed in Table 3), interwoven with relevant results from digital inequality research. This section successively discusses determinants and factors to access ICTs, technical design, indispensability of digital technologies and participation outcomes. Offline resources are not discussed separately. They are discussed together with factors of access (shown in Figure 2), as suggested in Van Dijk (2019).

Determinants of digital inequality in transport services

Main personal and positional categories of vulnerable groups

According to literature, age, income and education levels, ethnicity, gender and the type of region play a role in digital exclusion from transport services.

Age. Multiple studies agree on the fact that older adults in particular are vulnerable to digitalisation in transport services, providing three main interlinked reasons. First, they are more at risk of being transport disadvantaged, especially for those who are no longer able to drive, as staying active in later life is linked to quality of life (Musselwhite, 2019; Pangbourne, Aditjandra, & Nelson, 2010). Older women who used to be driven by their husband and people who stopped driving are particularly at risk of having their mobility needs unmet (Bertolaccini & Hickman, 2019; Shirgaokar, 2018). Second, older adults are usually more likely to be reluctant to engage with technology in general (Harvey, Guo, & Edwards, 2019; Pangbourne, 2018), which is also verified in transport services

Table 3. Details from selected studies, sorted by date.

Year	Author(s)	Location or sources' language	Method	Type of transport service	Determinants of access	Factors of access				Technical design and properties	Indispensability	Negative participation outcomes
						Motivation	Material access	Digital skills	Usage			
2010	Pangbourne, Aditjandra, Nelson	Scotland, U.K.	Focus groups and questionnaires	PT	X	X	X		X	X	X	
2010	Rizos	Canada & U.S.	Literature review & interviews with PT authorities	PT			X	X			X	
2012	Velaga, Beecroft, Nelson, Corsar, Edwards	Scotland, U.K.	Case study	PT & community transport	X		X					X
2013	Kamga, Yazıcı, Singhal	New York, U.S.	Passenger intercept surveys, usage logs and field observations	PT	X		X				X	
2013	Lamont, Kenyon, Lyons	U.K.	Focus groups	PT	X	X				X		X
2016	Sochor, Nikitas	U.K., Sweden	Semi-structured interviews, focus groups, postal surveys	PT	X	X						X
2017	Snellen, De Hollander	The Netherlands	Expert interviews	PT, shared mobility, autonomous shuttles		X		X		X	X	
2018	Gebresselassie, Sanchez	U.S.	Systematic literature review and analysis of transport apps	PT, shared mobility	X					X	X	X
2018	Jin, Kong, Wu, Sui	Literature in English	Systematic literature review	Ride sourcing	X	X	X					X
2018	Shirgaokar	Canada	Focus groups, interviews	Ride sourcing	X	X				X		
2018	Vecchio, Tricarico	Literature in English and Italian	Literature review	PT, shared mobility		X	X	X		X	X	
2018	Wang, Mu	Atlanta, U.S.	Analysis of Uber data	Ride sourcing						X		
2019	Bertolaccini, Hickman	Queensland, Australia	Online surveys	PT, ride sourcing, community transport	X	X	X		X		X	X

(*Continued*)

Table 3. Continued.

Year	Author(s)	Location or sources' language	Method	Type of transport service	Determinants of access	Factors of access				Technical design and properties	Indispensability	Negative participation outcomes
						Motivation	Material access	Digital skills	Usage			
2019	Bigby, Johnson, O'Halloran, Douglas, West, Bould	Sydney, Australia	Interviews, focus groups	Train	X		X				X	
2019	Golub, Satterfield, Serritella, Singh, Phillips	Portland, U.S.	Case study with focus groups, online and in-person survey	Shared mobility, autonomous shuttles	X	X	X				X	X
2019	Groth	Germany	In-person or postal survey	PT, shared mobility	X	X	X				X	X
2019	Harvey, Guo, Edwards	U.K.	Citizen and expert interviews	PT, shared mobility	X	X	X			X	X	
2019	Malik, Wahaj	Pakistan	Semi-structured interviews	Ride sourcing	X						X	
2019	Musselwhite	U.K.	Focus groups	PT, shared mobility, autonomous shuttles	X	X					X	
2019	Pangbourne, Mladenović, Stead, Milakis	Mostly documents in English	Documentary analysis and case study	PT, shared mobility	X						X	X
2019	Sabie, Ahmed	Canada	Interviews	Public transport	X	X						
2020	Aberle	Hamburg, Germany	GIS analysis	On-demand bus						X		X
2020	Sherriff, Adams, Blazejewski, Davies, Kamerāde,	Manchester, U.K.	Online surveys, interviews	Dockless bike sharing	X	X	X			X		
2020	Sourbati, Behrendt	U.K.	Case study	PT, shared mobility, community transport						X		
2020	Zhang, Zhao & Qiao	Ürümqi & Wuhan, China	Face-to-face surveys	PT, shared mobility	X	X		X	X		X	X
		Totals			19	15	12	4	3	11	15	11

Note: We discuss both positive and negative outcomes in this paper. Nevertheless, due to our selection process, papers included in this review tend to focus more on detrimental outcomes, with positive outcomes frequently mentioned but more superficially addressed.

(Sherriff, Adams, Blazejewski, Davies, & Kamerāde, 2020). This may come from the fact that they have managed their mobility during their whole life without these technologies. It could also be that they adopt technology at a slower pace. Third, as ageing is a natural maturation process, a progressive reduction in cognitive abilities such as processing speeds and a decline in other psychological mechanisms mean that coping with new technologies can be difficult (Harvey et al., 2019). For instance, Pangbourne et al. (2010) highlight that studies show an age-related decrease and difficulty in using public information kiosks and ticket machines.

Income and education levels often go hand in hand. People with lower incomes are vulnerable to digitalisation in transport services because they cannot afford credit cards and even possibly bank accounts, they are less likely to have and use internet at home and at work and they are more likely to have to cancel or reduce data plans (Golub, Satterfield, Serritella, Singh, & Phillips, 2019; Sherriff et al., 2020). Before even considering subscribing to relatively expensive offers from mobility services (Pangbourne, Mladenović, Stead, & Milakis, 2019), entering the ecosystem of digitally-based transport services is problematic. This was also verified by Groth (2019): people with low income and low education levels are more likely to have fewer transport options to choose from, and to have no smartphone.

Ethnicity. According to Golub et al. (2019), Sabie and Ahmed (2019) and Zhang, Zhao, and Qiao (2020), ethnicity is also an important factor. For instance, Golub et al. (2019) found that respondents of colour in Portland (U.S.) were more likely to rely on cash payment in public transport, and less likely to use cashless methods. Together with lower income groups, they were also more likely than average to have cancelled their cell phone service because of costs. The study of Zhang et al. (2020) reveals that minority groups are particularly vulnerable to digitalisation in transport services due to their lack of digital skills. Van Dijk (2019) notes though that differences among ethnic and minority groups are in fact "related more to economic deprivation, discrimination and cultural preferences than to race" (p. 42).

Gender. In China, Zhang et al. (2020) found that women were more likely to be vulnerable to digitalisation in transport services. This is a relatively common observation in developing countries and/or countries where women are less emancipated (Van Dijk, 2019). This might explain why this determinant has not been mentioned by the other studies investigated in this paper, as most focused on an European, North-American or Australian setting.

Type of region. Rural communities are presumably more vulnerable to digitalisation in transport services because of a lack of adequate ICT infrastructure, which can subsequently hinder the possibility to access real-time information for instance (Malik & Wahaj, 2019; Velaga, Beecroft, Nelson, Corsar, & Edwards, 2012).

Some caveats

First, it is unlikely that there is homogeneity within and among all these groups, for instance between people aged 65–75 and people aged 75 and older (Bertolaccini & Hickman, 2019). Second, there is a multiplicity of determinants playing a role in access to digital technologies. For instance, learning disabilities, low literacy/numeracy levels and communication impairments make navigating the digital world of transport services difficult (Bigby et al., 2019; Malik & Wahaj, 2019). In addition, people who are experiencing

issues with digitalisation in transport services may already have had issues when everything was analogue, making low access to ICTs another layer on top of existing layers of transport disadvantage (Bigby et al., 2019; Lamont, Kenyon, & Lyons, 2013). Third, we note that a person might be at a disadvantage to access or use a certain type of service – for instance, online ticketing – while being able to reap the benefits of another type of service – for instance, looking for travel information.

Factors of access to digital technologies in transport services

This section successively addresses the four factors of access to digital technologies, being motivations, material access, digital skills and usage.

Motivations, attitudes

Multiple selected studies mention the importance of attitudes and motivation as an entry point to engage with digital technologies in transport services, notably Groth (2019). He defines the "mental preconditions to use modern ICTs" (p. 63) with five categories: autonomy, excitement, flexibility, privacy and status. Literature reveals two main reasons for non-use of digital technologies applied in transport services that partly overlap with Groth's categories:

- The first main reason mentioned is a *rejection of the technology due to a perceived lack of trust, security, privacy and reliability*. Fears of data misuse with internet banking, scams, identity theft, phishing and fraud can dissuade people from paying online for their transport subscription or for a ride (Harvey et al., 2019; Pangbourne, 2018). This is particularly the case for older adults and people with lower incomes (Musselwhite, 2019; Shirgaokar, 2018). In general, people need to feel safe and in control, which is perceived to go against a heavy reliance on technology (Pangbourne et al., 2010; Shirgaokar, 2018). Privacy is a growing concern because of the ability of digital technologies in transport to track people's journeys (Groth, 2019; Vecchio & Tricarico, 2018). Data leakages at companies may further accentuate this mistrust (Jin, Kong, Wu, & Sui, 2018).
- The second main reason for non-use of digital technologies in transport services is that people *do not want the technology, either because they have a lack of interest in it or because they do not find it useful*. Not everybody knows of the existence of or sees the relevance of technologies such as smartphones, meaning that their application and potential added value remain invisible (Pangbourne et al., 2010).

These two main reasons are linked with other reasons, such as a lack of money, a perceived lack of (ability to acquire) skills and time and the fear to appear foolish (Sochor & Nikitas, 2016). Furthermore, people's social network is deemed an important resource to foster motivation to use digital technologies in transport services (Harvey et al., 2019; Sabie & Ahmed, 2019).

Material access

The smartphone has taken an increasingly important role in transport services (Gebresselassie & Sanchez, 2018), owing to the wide range of possibilities it offers to users and

operators. Nevertheless, while applications are often free or come at a nominal cost, smartphones (computers, tablets …) are not free and nor is the data plan, the stable internet connection or the printer for the e-ticket (Golub et al., 2019; Rizos, 2010). The older adults interviewed by Harvey et al. (2019), though coming from a panel of "largely well-educated, financially comfortable" people (p. 176), mention the costs of technology as a barrier. The researchers found that the quick obsolescence of devices and the need to replace them regularly annoys people, who feel pushed to adopt newer forms of digital technology. Concretely in transport services, this could mean that some people might be unwilling to purchase a new smartphone so that transport apps can function well on it. Besides, owning a smartphone is not enough: one needs to ensure that there is enough battery, that it is being repaired when broken and that the operating system is up-to-date and able to support applications running on it (Golub et al., 2019; Groth, 2019).

Digital skills

The need for digital skills in transport services tends to be underestimated. Public transport authorities interviewed by Rizos (2010) predicted that smartphone penetration and further developments in transport technologies would make analogue channels obsolete. There was the belief that the digitally disadvantaged would catch up as technology would become cheaper. This reasoning reveals a fundamental misunderstanding of digital inequality: having material access to the physical technology does not mean that people benefit from what the technology has to offer them (Zhang et al., 2020).

Online travel information makes information that was previously unavailable or hard to find, easier to access and potentially understand (Bigby et al., 2019; Gebresselassie & Sanchez, 2018). As such, it can contribute to a decrease in the resistance to use transport services, especially for inexperienced users. Yet Zhang et al. (2020) found that lacking knowledge on how to operate a smartphone and use location-based services was associated with a higher likelihood to have a restricted access to travel information. It is important to distinguish between medium- and content-related skills, both of which are dynamically evolving with technology and people (Pangbourne et al., 2010; Vecchio & Tricarico, 2018):

- Medium-related skills are related to operating a digital medium, like a turning on and off a smartphone and understanding what a browser is. They are necessary to successfully develop content-related skills (Van Dijk & Van Deursen, 2014).
- With the proliferation and fragmentation of online information, knowing how to use location-based services, query travel information, assess its reliability and act upon it become important (Vecchio & Tricarico, 2018). Such content-related skills are called *information and strategic skills*, related to searching, finding, processing and critically assessing information (Van Dijk & Van Deursen, 2014). The difficulty in selecting the right piece of travel information can result in people abandoning their journey (Lamont et al., 2013). Furthermore, skills related to privacy management also become important. In that sense, having some privacy concern can be constructive, as it actively pushes people to take action to protect their data (Zhang et al., 2020).

Usage

Usage follows from motivation, material access and skills (Van Dijk, 2005). People whose material access or digital skills are limited use travel apps less and with less variety, even among public transport captives (Bertolaccini & Hickman, 2019; Zhang et al., 2020). Furthermore, Bertolaccini and Hickman (2019) noted that 84% of the older adults they surveyed use their tablet, laptop or PC at an equal or higher frequency than their smartphone to access travel and navigation information. In spite of new transport technologies often revolving around apps, this shows that the home and seated use of online travel information still has considerable value to some groups. Bertolaccini and Hickman (2019) and Pangbourne et al. (2010) underline that transport planners should not expect everyone to be able to access information on-the-go.

Technical characteristics of digital technologies in transport services

Literature highlights two pathways in which the technical characteristics of digital technologies can impact transport services people have access to: through usability and through an increasingly heavy reliance on data and algorithms.

Usability: the importance of hardware and software design

Usability is an important characteristic of contemporary digital media, affecting the possibility of developing digital skills and therefore to derive benefits from technology. Drawing from Shneiderman (1980) and Nielsen (1994), Van Dijk (2019) defines usability as the combination of intuitiveness and:

> learnability (the ease of accomplishing a basic task), efficiency (how quickly this task may be performed), memorability (remembering how to carry out a certain task), correction of errors (how many errors are made and how they can be recovered) and satisfaction (the pleasure of using the tool). (p. 75)

Selected literature sheds light on issues related to usability that specific groups encounter, such as older adults and people with an impairment. For instance, older adults mention small keypads and pictograms as problematic (Pangbourne et al., 2010), while people with language barriers report issues pertaining to having too much information displayed on a single screen and a lack of forgivingness for spelling mistakes in navigation apps (Lamont et al., 2013). Both hardware and software can create barriers. As digital technologies increasingly allow for customisation, these aspects tend to get more recognition – at least on the software side (Gebresselassie & Sanchez, 2018). However, increasing usability among vulnerable groups is not simply about making amendments to existing systems, but more about organising technology around the way people process information to keep them in control and aware (Harvey et al., 2019; Lamont et al., 2013).

Algorithm-based and data-driven decision-making

A second, more covert and indirect way in which technology characteristics can contribute to digital exclusion from transport services is through algorithms and an intense reliance on digitally collected data. Data collected through sensors, smart cards, applications and surveys increasingly shape and drive transport services and policy decisions

(Sourbati & Behrendt, 2020). However, people who are not present in data are invisible to planners as well as (self-learning) algorithms that assist the dispatching of transport services. Drawing on Kwan (2016), Vecchio and Tricarico (2018) argue that "algorithms offer partial representations of urban phenomena that are prone to omissions and exclusions" (p. 6), with the semblance of objectivity.[3] There is a risk that commercial initiatives that develop their transport services primarily based on digital infrastructure (such as ride-sourcing platforms) shun certain neighbourhoods because they are not profitable enough.

If left unsupervised, algorithms may exclude – intentionally or not – groups of people that are already disadvantaged in some way (Snellen & de Hollander, 2017). Nevertheless, evidence on that point is still contradictory. Wang and Mu (2018) found that there was no evidence yet that Uber was related to an aggravation or an alleviation of the existing socio-spatial disparities in Atlanta. In contrast, Aberle (2020) uncovered that peripheral districts do not seem to hold sufficient potential to profitably run ride-pooling services in Hamburg. Only one out of the four analysed on-demand bus services was found to deliver utility for low-income and socially excluded groups, while the three others were mainly operating in affluent districts. The difference was that that first scheme had been obliged by public administration to operate in a more remote area. Still, selected studies agree on the fact that digital technologies can directly impact the physical offer of transport services available to a specific person, potentially creating a spatial selectivity. This selectivity can dynamically evolve as the provider wishes through geofencing, as Sherriff et al. (2020) shows with dockless bike sharing in Manchester. For more on the socio-spatial equity of shared mobility, see the notion of splintering urbanism (Graham & Marvin, 2001) as put forward in the review by Z. Chen, Van Lierop, and Ettema (2020) on dockless bikes.

Indispensability of digital technologies in transport services

The indispensability of ICTs can be found at different levels in public transport and shared mobility, as explained below.

Public transport: increasingly digital by default, with concerns

In the case of public transport, literature highlights how travellers are increasingly expected to conduct tasks via digital channels by default, to have their own means to buy tickets or look for travel information (Rizos, 2010; Snellen & de Hollander, 2017). Although digital and analogue media may still often coexist, the latter may take a modified form, requiring more money (a premium), more energy and/or more time (see Table 1), potentially discouraging its use (Snellen & de Hollander, 2017). Furthermore, while digital technologies may be helping staff to better assist travellers, literature notes that these technologies are also substituting for employees. This is a cause for concern among groups that feel vulnerable (Musselwhite, 2019), particularly when it comes to responding to irregularities or last-minute changes (Bigby et al., 2019). A station kiosk can be an alternative to staff and still relatively low-tech; however, it may still present challenges for those who have little experience with computers and smartphones (Kamga, Yazıcı, & Singhal, 2013). Overall, Sourbati and Behrendt (2020), Pangbourne et al. (2010)

and Jin et al. (2018) caution that a digital push is particularly questionable in the case of a public service.

Shared mobility: more than digital by default, digital only

In shared mobility such as ride sourcing, car and bike sharing, not only is digital the default option, it is also nowadays frequently the only option (Pangbourne et al., 2019). Without digital technologies such as smartphones and/or credit cards, there is often no way to unlock these digitally-based transport modes (Groth, 2019; Vecchio & Tricarico, 2018). Mobility-as-a-Service (MaaS) is also premised on such technology use (Pangbourne et al., 2019).

Furthermore, Golub et al. (2019) mention the "banking divide" as a significant barrier to access these services, affecting low-income and minority households especially. Such a divide is arguably more of a problem in developing economies (Pangbourne et al., 2019), although the ban on cash in buses in countries such as the UK and the Netherlands also raises questions.

One may argue that commercial shared mobility providers can target the population they want, namely people with smartphones and bank accounts. However, if these modes are to be further scaled up with the objective to encourage more environmentally sustainable travel practices as often put forward, the question of exclusion due to *digital only* becomes more significant (Pangbourne et al., 2019). This is especially true as the production of multimodal travel behaviour – a central element of the sustainable modal shift suggestion – is conditioned by access to digital technologies (Groth, 2019).

Participation outcomes

Almost all selected studies mention positive outcomes linked to digitalisation in transport services. Real-time information has brought clear benefits to travellers (Velaga et al., 2012). Personalised assistance allowed through ICT advances, such as features that address impairment and language barriers, can support more inclusiveness and participation (Bigby et al., 2019; Pangbourne et al., 2010). Furthermore, shared mobility modes are often presented as opportunities to meet the needs of groups with a low range of transport options available, because they could safeguard and afford mobility without the need for private vehicles (Golub et al., 2019; Malik & Wahaj, 2019).

As such, digitalisation can be part of the solution to transport disadvantage, but it can also be part of the problem (Lamont et al., 2013). Gebresselassie and Sanchez (2018) warn that "[a lack of] access to emerging technologies affects the same demographics whose transport disadvantage could be alleviated using advancement in ICTs" (p. 8). In Australia, Bertolaccini and Hickman (2019) found that many older non-drivers do not own smartphones and make fewer trips to friends and family, even with a sample biased towards urbanised areas. This led them to conclude that transport services requiring smartphone apps use would almost certainly exclude many older Australians and not solve the transport-related social exclusion they face. A correlation between mode options and smartphone distribution has also been observed by Groth (2019).

Similarly to recent conclusions in digital inequality research (Van Dijk, 2019), literature acknowledges that digital inequality in transport services is likely to follow and

possibly reinforce patterns of social inequality (Groth, 2019; Pangbourne et al., 2019; Zhang et al., 2020). Furthermore, there are often economic and commercial stakes in the introduction of ICTs in transport services. When left unchecked, these stakes may fuel a technological push that downplays consequences on society (Pangbourne et al., 2019; Sochor & Nikitas, 2016). Through a critical analysis of the MaaS rhetoric (where shared mobility modes are to play a central role), Pangbourne et al. (2019) caution that MaaS's "promise of freedom cannot be delivered with respect to well-being and inclusion" (p. 44).

Not only is the risk for exclusion pointed out in literature, but also the risk for (further) polarisation (Jin et al., 2018) and a "technological gentrification" of transport services (Pangbourne et al., 2019, p. 43). Yet cumulative advantage is a mechanism for inequality (DiMaggio & Garip, 2012; DiPrete & Eirich, 2006). In network behaviour theory, this is known as the flip side of Metcalfe's law (Tongia & Wilson, 2011) and was applied in transport by Dupuy (1999, 2011) to explain automobile dependency. The reasoning as applied in the case of digitalisation in transport services is explained in Figure 5. What is first considered to be a *relative* disadvantage can turn into an *absolute* disadvantage and exclusion from the network. In that sense, digital inequality in transport services is not just about exclusionary effects but also about a potentially changing accessibility distribution among social groups.

Future research directions

Given the relatively nascent state of research on digital inequality in transport services, much remains to be understood. It is our hope that our cross-disciplinary perspective will inspire other researchers to investigate this topic from different angles. We present here a few main research avenues relevant to scholars and professionals interested in the inclusiveness of digital transformations in transport services.

Mechanisms of digital inequality in transport services

More empirical evidence on the determinants and factors of access to technology (and how they relate to each other) is needed to better understand the mechanisms of

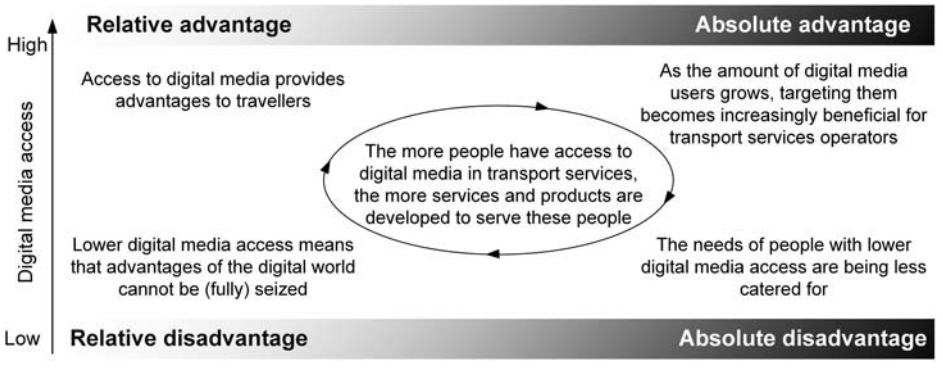

Figure 5. Schematic of the relationship between relative and absolute (dis)advantage and digitalisation in transport services (own design).

digital inequality in transport services, i.e. who is impacted and in which way. Because studying impacts on mobility in general is too broad, focusing on one particular pattern could be useful. This is what Zhang et al. (2020) did, by investigating the pattern of obtaining transport information.

In terms of determinants, further research could confirm the dimensions of vulnerability as presented in this paper and uncover additional ones, inspired from digital inequality research (Scheerder et al., 2017). Distinguishing between various groups could allow to better identify specific barriers and needs.

In terms of factors, ICT usage and digital skills required in transport services and how they are linked to determinants are particularly underexplored. More research is needed, as these two factors are deemed even more important than determinants in shaping outcomes of digital technologies' use (Van Deursen & Helsper, 2018). Investigating the intricate relationships that link factors together (with determinants) could also prove valuable.

Overall, we encourage researchers to refine the framework suggested in this paper, thereby tailoring it better to the specific context of transportation. This implies a closer look at the role of spatial determinants. For instance, not being able to access travel information will not have the same outcome in a high-frequency metro system as in a low-frequency rural bus service.

Relative (dis)advantage

Relative (dis)advantage is highly contextual. We encourage researchers to develop a local understanding of what indispensability means. Here, we see two complementary paths.

The first one would require a careful examination of how relatively vulnerable populations cope with the pervasiveness of digitalisation in transport services. People may have different priorities, meaning that indispensability may vary individually. Here, the Capability Approach would offer a suitable framework, as it explicitly recognises the diversity of human needs and preferences (Sen, 2009). One of the selected papers in this review, Sherriff et al. (2020), applied this approach. It can be used to investigate how mobility contributes or not to the achievement of individual freedoms and aspirations (see e.g. Ryan, Wretstrand, and Schmidt (2019) and Nordbakke (2013)), but it can also be used to consider issues of transport justice (see e.g. Vecchio (2020)). Additionally, the concept of motility which includes notions of access, skills and appropriation (Kaufmann, Bergman, & Joye, 2004), may be useful to advance our understanding of how digitalisation in transport services interacts with the potential to be mobile. Besides these two approaches, a perspective of distributive justice could also be helpful to determine the extent to which access to digital tools in transport services matters in terms of accessibility (Pereira, Schwanen, & Banister, 2017).

The second path would focus on the tangible benefits that people reap from having access to digital technologies to plan and manage their daily mobility. Who is able to reap such benefits, why, in which context and how? How do they shape the meaning of indispensability? Scholars interested in this avenue could get inspiration from third-level digital divide research (Van Deursen & Helsper, 2015). In any case, such research would require an exploration that goes further than simply "ICTs in transport services provide convenience".

The contribution of digital inequality to transport disadvantage and transport-related social exclusion

Although some literature acknowledges the *association* between digital inequality/exclusion and transport disadvantage/transport-related social exclusion, empirical evidence remains limited on the *contribution* of the former to the latter. Is digital inequality in transport services creating a new form of transport disadvantage, thereby contributing to exclusionary processes on its own, or is it adding to or even changing existing disadvantages?

Furthermore, scholars could seize digital transformations occurring in transport systems as opportunities for investigation, such as Pritchard, Vines, and Olivier (2015) with the ban on cash in London buses. As the COVID19 crisis intensifies digitalisation in all fields (Robinson et al., 2020), examining these processes of digital transformation in transport services and their potentially exclusionary effects would be valuable.

Solutions to mitigate or prevent digital inequality in transport services

Identifying and examining strategies to mitigate or prevent digital inequality in transport services is important to bring this issue to policymakers' or practitioners' attention. No clear overview and discussion on this exists yet. For instance, although training is frequently mentioned by the selected papers, the different ways to teach people, their pros, cons and most importantly, the underpinnings of such an educational perspective, are seldom discussed.

Mitigating digital inequalities in transport services also requires a broader reflection on technology governance, as initiated by Pangbourne et al. (2019). Here, research could focus on power imbalances (Royakkers, Timmer, Kool, & van Est, 2018), how to be responsive to changing values and circumstances (De Reuver, Van Wynsberghe, Janssen, & Van de Poel, 2020), the anticipation of technological impacts and processes of inclusion in technology governance (see e.g. Stilgoe, Owen, and Macnaghten (2013) for methods). The latter point on inclusion echoes to the call for a shift from a state- to a more society-centric way to achieve transportation equity and justice (Karner, London, Rowangould, & Manaugh, 2020; Sheller, 2018). The approach of Sourbati and Behrendt (2020), linking data justice with Sheller's mobility justice, could be an interesting avenue to explore.

Conclusions

This paper investigated digital inequality in transport services by examining the impacts of digitalisation in transport services on (potential) travellers through the lens of digital inequality research. Motivated by a lack of attention to this particular perspective in the research on ICT and mobility, we searched for relevant literature and reviewed twenty-five papers addressing digital exclusion from transport services. Our goal was to shed light on what digital inequality in the context of transport services consists of and what its implications are. Literature on this topic is in a nascent state, but interest has grown sharply over the past two years. In general, reviewed studies focus on a few aspects of digital inequality and do not necessarily have in mind the bigger picture, or at least they do not make it explicit. This is where the conceptual framework presented in this paper, embedded in our cross-disciplinary approach, adds value. In turn, this

framework allowed us to synthesise the main findings on digital inequality in transport services and subsequently to list topics where further research efforts are needed.

A main conclusion is that digital inequality, or the digital divide, is a multi-layered process. In both public transport and shared mobility, the smartphone has taken a central role within a decade, but having a smartphone does not mean that one can derive all of its benefits. The reviewed literature acknowledges this, notably by focusing on the nuances of material access as well as motivations and attitudes. The importance of digital skills and a diversity and frequency of usage are recognised but empirical research on these factors remains scarce. Overall, literature acknowledges that being unable or not willing to access, successfully and efficiently operate and use digital technologies in transport services may result in a disadvantage to use such services.

Deriving beneficial outcomes from digital technology involves more than personal resources. The socio-technical context in which individuals operate, such as characteristics and design of ICTs and the extent to which digital technologies are indispensable in mobility, also heavily influence digital exclusion from transport services, and therefore digital inequality. Yet as the reviewed papers reveals, people are increasingly expected to rely on ICTs to access and navigate public transport services. This can be concerning for a public service. Additionally, shared mobility modes often rely on ICTs as a sole mode of access. If these modes are to be further scaled up and promoted with the objective to encourage more multimodality and more environmentally sustainable travel patterns, the question of exclusion becomes more pressing.

There is evidence that digital inequality in transport services is patterned along the lines of socio-economic status. Older adults, women, people with lower education levels, with lower income levels, from minorities and from rural areas are seen as more likely to be vulnerable to digitalisation in transport services. Health and literacy also play a role in vulnerability to digitalisation in transport services. In general, literature acknowledges that digital inequality in transport services is likely to follow and possibly reinforce patterns of social inequality. As such, digital technologies are one piece in a complex socio-technical system that poses challenges for meeting the needs of vulnerable populations in general.

Notes

1. *Digital divide* and *digital inequality* are often used interchangeably (Scheerder, 2019). We favour the latter as it does more justice to the continuum of differences in digital media use and appropriation.
2. When using snowballing, we found a MIT master thesis (Rizos, 2010) that provides the first mention of a "transit digital divide" (p. 10). Even though it is not strictly speaking peer-reviewed material, we included it because of its pertinence and the fact that it can be used to look back on developments, since it is also one of the oldest selected study.
3. See Bijker and Law (1992) about biases from people – typically, dominant groups – shaping technologies.

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ORCID

Anne Durand http://orcid.org/0000-0003-4928-4270
Niels van Oort http://orcid.org/0000-0002-4519-2013
Serge Hoogendoorn http://orcid.org/0000-0002-1579-1939

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