Ministry of Infrastructure
and Water Management

The impact of digitalisation on the access to transport services: a literature review

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Met uitgebreide Nederlandse samenvatting op pagina 7

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Summary

Digitalisation in transport services provides various advantages to multiple parties, including travellers. At the same time, the increased use of digital technologies in transport services, such as public transport and shared mobility, creates new requirements on (potential) travellers. Having an up-to-date mobile phone with a data plan to check travel information, having an online account to manage a public transport subscription, checking in and out: not everyone can (or wants to) cope with these new requirements. There is often the assumption that in a country with a high smart-phone penetration rate such as the Netherlands, most people use digital media in a beneficial way for a wide variety of situations. However, having physical access to technology does not necessarily translate into all of the benefits that technology can provide. Furthermore, as digitalisation becomes increasingly embedded in transport services, keeping offline alternatives available becomes crucial for people who are not comfortable with (the pace of) digital transformations.

Introduction: digitalisation provides advantages and changes the rules

Digitalisation in transport is the result of decades of developments of Information and Communication Technologies (ICTs), progressively applied in the mobility sector. Whether it be to plan, book, pay for a trip in public transport, or to make use of shared mobility modes such as car sharing, digitalisation has taken a central role in how travellers access transport services. There are undeniably advantages to digitalisation in transport services. For travellers digital transformations mean instant access to travel information, more customisation and flexibility. For operators, they mean an efficiency improvement. For policymakers, they offer the potential to support society in the face of environmental, social and economic challenges, notably through a more optimised use of resources. Although digital media have not completely substituted for analogue ones, they are more than the mere conversion of information into bits and bytes. The gradual shift towards digital media in transport services has brought new, more or less formal rules, meaning new requirements on users. Manifestations of these rules include the *ov-chipkaart* (Dutch public transport smart card) with the check-in/check-out system and the central role the smartphone has taken within a decade. Arguably, not everyone can or wants to follow the pace of these digital transformations in transport services. Despite its advantages, the increase in digitalisation might thus also come with exclusionary effects.

Goal of the research

In response to questions from the Ministry of Infrastructure and Water Management, the Netherlands Institute for Transport Policy Analysis (KiM) investigates how digitalisation in transport services affects the mobility of people, with a particular attention to those with relatively lower levels of engagement with digital technology. Furthermore, this study specifically examines potentially exclusionary effects of digitalisation in transport services. This study is the first part of a research programme on the impact of digitalisation on the access to transport services conducted by KiM. By investigating the (social) impacts of an increased digitalisation in transport services, this study provides insight on topics such as quality of life and accessibility, which are two objectives of the Ministry of

Infrastructure and Water Management. This first study consists of desk research and is primarily concerned with understanding digital inequality in transport services, its mechanisms and potential consequences. As such, it forms a theoretical foundation for future work.

Literature review

Two complementary pathways were used to reach this goal. First, we conducted an explorative literature review on three aspects: digitalisation in transport services, digital inequality and transport-related social exclusion. Second, we conducted a systematic literature review on digital inequality in transport services. With its cross-disciplinary lens, this review provides structured knowledge on the mechanisms and possible consequences of digital inequality in transport services, people vulnerable to digitalisation and potential solutions.

Main results

The following paragraphs describe five main results of this study, on (1) digital by default in transport services, (2) digital inequality in transport services, (3) potentially exclusionary effects of digitalisation in transport services, (4) citizens who are likely to be vulnerable and (5) potential solutions put forward to mitigate digital inequality.

1. **A general picture: towards digital by default in transport services**
   A key finding of this study is that there is a shift towards digital by default in transport services. This means that digital channels (formally or informally) become the main communication channels. In public transport, even though digital and analogue media still often coexist, the latter may take a modified form – such as a premium on the offline product – potentially discouraging public transport use among those who need it. In shared mobility, this even goes further: not only is digital the default option, frequently it is the only option nowadays. Yet the growth of digital connectivity notwithstanding, the potential and the ability to use transport services play an important role in how socially included some individuals are.

2. **Digital inequality in transport services as a gradual and multi-layered phenomenon**
   A second key result of this study is that even when people do engage with digital technologies, being able to benefit from them is not obvious to all. Digital inequality is a complex and gradual process. This study shows that it is also the case in transport services; it is not simply about owning a smartphone or not. How people perceive and trust digital technologies in transport services, the types of devices and internet connection they have access to as well as the range of what they are able and willing to do with them also matter. In particular, because of the increased complexity and fragmentation of information sources, digital skills are likely to be important to be able to successfully navigate the world of transport services.

3. **Potentially exclusionary effects of digitalisation in transport services**
   A third finding is that the result of a low engagement with digital technology in transport services – due to technical design, limited resources, reticence in the face of a perceived digital push – might be a decreased use or a non-use of transport services where digital technologies play an increasingly important role. Another but more covert form of digital inequality that might unfold exclusionary effects concerns automation and algorithmic processing features of digitally-based transport services. If left unsupervised, these features may exclude – intentionally or not – groups of people that are already disadvantaged in some way, for instance by shunning poorer neighbourhoods because of a supposedly lower profitability. Overall, literature explicitly recognises that a low access to digital technologies in the context of transport services can result in a decrease in mobility and mobility options. Where some groups in the

population might see their mobility options expanding thanks to ICTs, people who are less comfortable with digitalisation and its pace might see their mobility options remaining the same or even shrinking. An example of this is shared mobility, increasingly present in cities. There is a risk for (further) polarisation. Ultimately, a (relative) decrease in mobility (options) could exacerbate transport disadvantage and the risk for transport-related social exclusion. Still, digital technologies are arguably one piece in a complex socio-technical system that poses challenges for meeting the needs of vulnerable populations in general.

4. Vulnerable groups

Vulnerability to digital inequality in transport services exists along dimensions of age (older adults and underage people), income level (people with lower levels), educational level (people with lower levels) and ethnicity (people from minorities). Still, there is a multiplicity of determinants that may cause and exacerbate the risk to have a low access to digital technologies in transport services, like learning and communication impairments.
In general, empirical evidence on who is concerned by this phenomenon remains scarce. Older adults tend to get relatively more attention in currently available studies. Although there is a generational effect at play in digital inequality, there are also structural effects, such as the fact that older adults tend to have fewer opportunities to engage with digital technologies than younger people anyway and the structural decline in cognitive abilities. While generational effects will probably disappear over a few generations, structural effects will likely remain. Nevertheless, older adults are not the only ones vulnerable to an increased digitalisation in transport services, and there are also a lot of nuances among this group.

According to the Netherlands Court of Audit, around 2.5 million people aged 16 or older have difficulties writing and/or counting, which likely translate into difficulties navigating the digital world.

5. Three solutions put forward

Finally, three ways in which negative impacts of digitalisation in transport services could be mitigated were uncovered from literature:

1. Designing technology in an inclusive and human-centred way. It is about organising technology around the way users process information and make decisions, keeping them in control and aware.
2. Teaching people how to use these technologies.
3. Retaining and refining analogue alternatives, safety nets and low-tech tools, as the internet, apps and smartphones do not work for everyone all the time.

Besides these approaches and against a background of promises that digitalisation in transport services will foster social inclusion, some scholars also call for a more people- and value-centered policy approach to digital technologies in transport services. An example of this would be to view public values such as accessibility as starting points in the innovation process, instead of final pieces.

Research agenda

Four main areas for future research are identified:

1. More empirical research about who is concerned by digital inequality in transport services and how it develops is needed. The present study provides transport researchers with a theoretical framework (the model of Van Dijk and the notion of indispensability) to approach this phenomenon of digital inequality.

2. More research on the contribution of digital inequality to transport-related social exclusion is desired. Digital inequality might be creating a new form of transport disadvantage, but people who are experiencing issues with digitalisation in transport services may already have had

issues when everything was still analogue. Digital inequality may be adding to existing disadvantages and thereby potentially exacerbating them, and/or possibly mitigating other forms of disadvantages. People may also have developed coping mechanisms, but it is still unclear what they consist of precisely.

3. Upon gaining a better understanding on these first two points, a third research avenue would be to formulate potential strategies to mitigate or prevent digital inequality in transport services, exploring advantages and disadvantages of each strategy.

4. Exploring the tangible benefits that people reap from having access to digital technologies to organise their daily mobility would allow for a better understanding of disparities in experiences among various groups and of the added value of investing in certain (policy) solutions.

The current research programme where this study is a first building block will touch upon these four points.

Samenvatting

De digitalisering van vervoersdiensten biedt diverse voordelen voor meerdere partijen, waaronder reizigers. Tegelijkertijd stelt de toename van digitale technologieën in vervoersdiensten, zoals openbaar vervoer en deelmobiliteit, nieuwe eisen aan (potentiële) reizigers. Een up-to-date mobiele telefoon met een data-abonnement om reisinformatie te kunnen checken, een online-account om een openbaarvervoerabonnement te beheren, het verplicht in- en uitchecken: niet iedereen kan (of wil) aan deze nieuwe eisen voldoen. Vaak wordt ervan uitgegaan dat inwoners van een land met een hoog aandeel smartphones, zoals Nederland, digitale media nuttig weten te gebruiken voor uiteenlopende situaties. Fysieke toegang tot technologie levert echter niet noodzakelijkerwijs alle voordelen op die technologie kan bieden. Nu de digitalisering steeds meer ingebed raakt in de vervoersdiensten, is het bovendien essentieel dat er offline alternatieven beschikbaar blijven voor mensen die minder op hun gemak zijn bij (het tempo van) digitale transformaties.

Inleiding: digitalisering biedt voordelen en verandert de regels

De digitalisering van vervoer is het resultaat van een decennialange ontwikkeling van informatie- en communicatietechnologieën (ICT), die geleidelijk een toepassing vinden in de mobiliteitssector. Digitalisering speelt een centrale rol in de manier waarop reizigers toegang hebben tot vervoersdiensten, zoals plannen, boeken of betalen voor een reis in het openbaar vervoer (ov) of het gebruik van een deelauto. Er zijn ontegenzeggelijk voordelen verbonden aan de digitalisering van vervoersdiensten. Voor reizigers betekent het directe toegang tot reisinformatie, meer mogelijkheden om deze informatie naar eigen hand te zetten en flexibiliteit. Voor de aanbieders betekent het vaak een efficiëntieslag. Voor beleidsmakers biedt het steun bij het aanpakken van maatschappelijke uitdagingen op milieu-, sociaal en economisch gebied, met name door een optimaler gebruik van middelen. Digitalisering is meer dan alleen de omzetting van analoge informatie in bits en bytes. De geleidelijke verschuiving naar digitale media in vervoersdiensten heeft nieuwe, min of meer formele regels met zich meegebracht, die nieuwe eisen stellen aan de gebruikers. Voorbeelden hiervan zijn de ov-chipkaart met het in- en uitchecksysteem en de centrale rol die de smartphone binnen één decennium is gaan innemen. Waarschijnlijk kan of wil niet iedereen het tempo van deze digitale transformaties in vervoersdiensten volgen. Ondanks de voordelen kan verdere digitalisering dus ook gepaard gaan met sociale uitsluitingseffecten.

Onderzoeksdoel

Naar aanleiding van vragen van het ministerie van Infrastructuur en Waterstaat heeft het Kennisinstituut voor Mobiliteitsbeleid (KiM) onderzocht hoe de digitalisering van vervoersdiensten mensen beïnvloedt in hun mobiliteit, met speciale aandacht voor mensen die relatief minder affiniteit hebben met digitale technologie. Daarnaast kijkt dit onderzoek specifiek naar mogelijke uitsluitingseffecten als gevolg van de digitalisering van vervoersdiensten. Dit onderzoek is het eerste deel van een onderzoeksprogramma naar de impact van de digitalisering op de toegang tot vervoersdiensten. Door de (maatschappelijke) effecten van een toenemende digitalisering van vervoersdiensten te onderzoeken, geeft dit onderzoek inzicht in leefbaarheid en bereikbaarheid, twee doelstellingen van het ministerie van Infrastructuur en Waterstaat.

De voorliggende literatuurstudie is vooral gericht op het begrijpen van de digitale ongelijkheid in vervoersdiensten, de mechanismen erachter en de mogelijke gevolgen. Als zodanig vormt dit onderzoek een theoretische basis voor toekomstig werk.

Literatuurstudie

Er zijn twee complementaire trajecten gevolgd. Ten eerste hebben we een verkennend literatuuronderzoek uitgevoerd naar drie aspecten: de digitalisering van vervoersdiensten, digitale ongelijkheid en vervoersgerelateerde sociale uitsluiting. Ten tweede hebben we een systematisch literatuuronderzoek uitgevoerd naar de digitale ongelijkheid in vervoersdiensten. Met zijn interdisciplinaire lens biedt dit onderzoek gestructureerde kennis over de mechanismen en mogelijke gevolgen van digitale ongelijkheid in vervoersdiensten, de mensen die erbij betrokken zijn en de mogelijke oplossingen.

Belangrijkste resultaten

In de volgende alinea's worden de vijf belangrijke onderzoeksresultaten beschreven, namelijk (1) digitaal als de standaard in vervoersdiensten, (2) digitale ongelijkheid in vervoersdiensten, (3) mogelijke uitsluitingseffecten van de digitalisering van vervoersdiensten, (4) mensen die naar verwachting kwetsbaar zijn en (5) mogelijke oplossingen om de digitale ongelijkheid te verminderen.

1. **Een algemeen beeld: naar een digitale standaard in vervoersdiensten**
   Een belangrijke bevinding van dit onderzoek is dat er een verschuiving plaatsvindt naar een digitale standaard in vervoersdiensten. Dit betekent dat digitale kanalen (formeel of informeel) de belangrijkste communicatiekanalen worden. Digitale en analoge media bestaan in het openbaar vervoer vaak nog naast elkaar. Wel kan het offline product anders zijn dan het digitale, er geldt bijvoorbeeld een toeslag op. Dit kan degenen die het offline product nodig hebben ontmoedigen om het ov te gebruiken. Bij deelmobiliteit gaat dit zelfs nog verder: niet alleen zijn digitale diensten hierbij de standaard, het is tegenwoordig vaak de enige optie.

2. **Digitale ongelijkheid in vervoersdiensten als een geleidelijk en gelaagd fenomeen**
   Een tweede belangrijke bevinding van deze studie is dat, zelfs wanneer mensen wel gebruikmaken van digitale technologieën, het voor hen niet noodzakelijk gunstig uitpakt. Digitale ongelijkheid is een complex en geleidelijk proces. Dit onderzoek toont aan dat dit ook van toepassing is op vervoersdiensten; het gaat niet alleen om het al dan niet bezitten van een smartphone. Ook van belang is hoe mensen digitale technologieën in vervoersdiensten ervaren en erop vertrouwen, het type apparaat en de internetverbinding waartoe ze toegang hebben en wat ze ermee kunnen en willen doen. Met name vanwege de toegenomen complexiteit en versnippering van informatiebronnen zijn digitale vaardigheden van belang om succesvol te kunnen navigeren door de wereld van vervoersdiensten.

3. **Mogelijke uitsluitingseffecten van de digitalisering van vervoersdiensten**
   Een derde bevinding is dat een laag engagement met digitale technologie in vervoersdiensten – vanwege het technisch ontwerp, beperkte middelen of terughoudendheid voor vermeende digitale 'push' – erin zou kunnen resulteren dat mensen minder of geen gebruik maken van die vervoersdiensten, waarbij digitale technologieën een steeds belangrijkere rol opeisen. Ook algoritmes kunnen digitale ongelijkheid in de kaart spelen ('exclusion by design'), door bijvoorbeeld mensen met een bepaald profiel beter te bedienen dan mensen met een ander profiel. Als hier geen

toezicht op wordt gehouden, kunnen 'de algoritmes' groepen uitsluiten die al op een bepaalde manier benadeeld zijn, bijvoorbeeld door armere buurten te mijden, omdat daar minder verdiencapaciteit is. Over het algemeen wordt in de literatuur expliciet erkend dat een beperkte toegang tot digitale technologieën in de context van vervoersdiensten kan leiden tot een afname van de mobiliteit en beperking van mobiliteitsopties. Waar dankzij ICT de mobiliteitsopties voor sommige bevolkingsgroepen zouden kunnen toenemen, zouden de opties voor mensen die zich minder op hun gemak voelen bij de digitalisering en het tempo daarvan, hetzelfde kunnen blijven of zelfs kunnen afnemen. Een voorbeeld is deelmobiliteit, die in veel steden aan een recente opmars is begonnen. Er bestaat een risico op (verdere) polarisatie. Uiteindelijk zou een (relatieve) afname van de mobiliteit(sopties) het risico van vervoersgerelateerde sociale uitsluiting kunnen vergroten. Overigens zijn digitale technologieën slechts één onderdeel van een complex sociaal-technisch systeem, waarin er diverse uitdagingen zijn om aan de behoeften van de kwetsbare bevolkingsgroepen in het algemeen te voldoen.

4. Kwetsbare groepen

Kenmerken van de kwetsbare groepen vinden we in de literatuur in relatie tot leeftijd (senioren en minderjarigen), inkomensniveau (mensen met een lager inkomen), opleidingsniveau (mensen met een lager opleidingsniveau) en etniciteit (mensen uit minderheidsgroepen). Er is een grote verscheidenheid aan determinanten die het risico op een beperkte toegang tot digitale technologieën in vervoersdiensten kunnen veroorzaken en vergroten, waaronder leer- en communicatieproblemen. Over het algemeen blijft empirisch bewijs over wie bij dit fenomeen betrokken is mager. Ouderen krijgen vaak relatief meer aandacht in de huidige studies. Hoewel er bij digitale ongelijkheid sprake is van een generatie-effect, zijn er ook structurele effecten. Bijvoorbeeld het feit dat ouderen toch al vaak minder gelegenheid hebben om gebruik te maken van digitale technologieën dan jongere mensen en verder de structurele achteruitgang van cognitieve capaciteiten bij ouderen.

Hoewel het generatie-effect waarschijnlijk over enkele generaties zal verdwijnen, zullen structurele effecten vermoedelijk blijven bestaan. Desondanks zijn niet alleen senioren kwetsbaar voor een toenemende digitalisering van vervoersdiensten en bovendien zijn er veel nuances binnen deze groep.

Volgens de Algemene Rekenkamer hebben ongeveer 2,5 miljoen mensen van 16 jaar of ouder moeite met schrijven en/of rekenen, wat zich naar verwachting ook vertaalt in problemen bij het navigeren door de digitale wereld.

5. Drie oplossingsrichtingen

Ten slotte zijn uit de literatuur drie manieren naar voren gekomen die de negatieve gevolgen van de digitalisering van vervoersdiensten kunnen verminderen:

1. Technologie op een inclusieve en mensgerichte manier ontwerpen. Het is van belang om de technologie te organiseren rekening houdend met de manier waarop gebruikers informatie verwerken en beslissingen nemen, zodat ze de controle houden en bewust blijven van de keuzes die ze maken.
2. Mensen leren hoe ze deze technologie moeten gebruiken.
3. Analoge alternatieven, vangnetten en lowtech tools behouden en verfijnen, omdat het internet, apps en smartphones niet altijd voor iedereen werken.

Naast deze oplossingsrichtingen, en gezien beloften dat de digitalisering van vervoersdiensten sociale inclusie juist kan bevorderen, roepen diverse onderzoekers ook op tot een meer mens- en waardegerichte beleidsaanpak van digitale technologieën in vervoersdiensten. Een voorbeeld daarvan is om publieke waarden zoals toegankelijkheid en mogelijkheden-voor-iedereen, niet als sluitstuk van innovatie te zien, maar als vertrekpunt daarvan.

Onderzoeksagenda

We hebben vier relevante onderwerpen voor toekomstig onderzoek geïdentificeerd:

1. Er is behoefte aan meer empirisch onderzoek naar de mogelijke betrokkenen bij de digitale ongelijkheid in vervoersdiensten en hoe deze zich ontwikkelt. De voorliggende studie biedt transport-onderzoekers een theoretisch kader (het model van Van Dijk en de notie van onmisbaarheid) om dit fenomeen van digitale ongelijkheid te benaderen.

2. Meer onderzoek naar de bijdrage van digitale ongelijkheid aan vervoersgerelateerde sociale uitsluiting is gewenst. Digitale ongelijkheid kan leiden tot een nieuwe vorm van vervoersachterstand, maar mensen die problemen ondervinden met de digitalisering van vervoersdiensten hadden wellicht al problemen toen alles nog analoog was. Digitale ongelijkheid kan de bestaande nadelen vergroten en daardoor mogelijk verergeren en/of andere soorten nadelen verminderen. Het is tevens mogelijk dat mensen coping mechanismen hebben ontwikkeld, maar het is nog onduidelijk waaruit deze precies bestaan.

3. Na beter inzicht in deze eerste twee punten te hebben verkregen, zou een derde onderzoeksrichting zijn om potentiële strategieën te formuleren om de digitale ongelijkheid in vervoersdiensten te verminderen of te voorkomen, waarbij de voor- en nadelen van elke strategie worden verkend.

4. Onderzoek naar de concrete voordelen die mensen halen uit de toegang tot digitale technologieën om hun dagelijkse mobiliteit te organiseren, zou kunnen leiden tot een beter begrip van hoe ervaringen tussen verschillende groepen variëren en de toegevoegde waarde van investeringen in bepaalde (beleids)oplossingen.

Er wordt via het lopend onderzoeksprogramma, waarvan dit onderzoek een eerste bouwsteen is, aandacht besteed aan deze vier punten.

1 Introduction

Over the past few decades, the adoption and increase in use of digital technologies in everyday lives has become a major trend, known as digitalisation. Manifestations for the general public include the smartphone revolution and the transitions from physical services and infrastructure to internet banking, e-government and e-health services. However, not everyone can or wants to follow the pace of such a digitalisation. The Netherlands Institute for Transport Policy Analysis (KiM) conducts research on digitalisation of transport services and possible consequences of this on travellers and potential travellers. In a first phase of the research, KiM presents a literature review on digital inequality in transport services.

1.1 Problem statement

The transport sector makes no exception with regards to digitalisation: Information and Communication Technologies (ICTs) are already applied and have transformed how people move around. In his seminal book on smart cities, Townsend (2013) contends that the application of digital technologies has proliferated in transportation systems, and notably in cities, more than in other planning disciplines. From real-time multimodal planners to GPS and applications providing access to mobility services like car sharing 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 (Aguiléra, 2019; Manders & Klaassen, 2019). From a policy perspective, digitalisation in transport services is also seen as promising, notably to support society in the face of environmental, social and economic challenges (Ministerie I&W, 2019b).

Still, in spite of these benefits and the diffusion of technologies, it is important not to overlook the fact that benefitting from the possibilities and the opportunities offered by digital technologies is conditioned by the readiness, willingness and ability to use them. According to the Netherlands Court of Audit, one in six people aged 16 or older have low numeracy and or literacy skills, most likely translating into difficulties navigating the digital world (Algemene Rekenkamer, 2016). Recent reports underscore the existence of a digital divide – digitale kloof – in the Netherlands (Baay et al., 2015; Bijl et al., 2017). This divide is likely to have consequences in terms of mobility, especially when travellers are increasingly invited to rely on digital tools and knowledge on how to navigate the digital world (Aguiléra, 2019; Pangbourne et al., 2018). Already before modern connected and mobile devices, Dutch transport experts and digital inequality researchers had warned that digital technologies may not be available to everyone, with possible consequences on mobility (Draijer, 1997; Ministerie V&W, 2001; Spittje & Witbreuk, 2005). Indeed, digitalisation is not simply about converting analogue information into bits and bytes. It brings with it new organisation structures that fundamentally transform our society (Benkler, 2006). These digital transformations can retain non-digital elements, completely, partially or not. In the two last cases, not wanting or not being able to engage with digital technologies might translate into a form of exclusion.

1.2 Goal, research question and policy perspective

Currently, one of the key aspects of the mobility policy in the Netherlands as defined in recent strategic reports is that transport services should be accessible to everyone (see Ministerie I&W (2019a), Ministerie I&W (2019c), Ministerie VWS (2019)). In that context, this research aims at getting a better and more nuanced understanding of how digitalisation in transport services

might affect people and the opportunities they have access to, with a special focus on the potentially exclusionary effects of digitalisation. The research question that this study seeks to answer is the following:

How does digitalisation in transport services affect mobility for the population in the Netherlands, with particular attention to people who might not be ready to follow the pace of such a digital transformation?

To answer this main research question, five sub-research questions are devised:

1) What is digitalisation in transport services, how is it developing and what are its drivers?
2) What are the mechanisms of digital inequality and how do they apply in the context of transport services?
3) Who might be negatively impacted by digitalisation in transport services?
4) What are potential outcomes of digital inequality in transport services?
5) What are suggested strategies to address digital inequality in transport services?

KiM conducts this study on behalf of the Ministry of Infrastructure and Water Management. The Ministry observes an increasing digitalisation in transport services. In general, this is perceived as an opportunity. At the same time, there is a realisation that such a trend does not necessarily provide benefits for everyone. More insights on the requirements that digitalisation in transport services places on various types of users can bring awareness among policymakers and in turn allow them to formulate adequate strategies to mitigate the potentially exclusionary impacts of digitalisation in transport services.

1.3 Definitions and scope of the research

1.3.1 Definitions

Digital technology: Nowadays, technology is quickly associated with digital or so-called 'modern' technology, i.e. smartphones or television[1], but analogue technologies also exist. In the latter, words, sounds and pictures are stored as representations on objects such as magnetic tape or plastic film. In digital technologies, digital code (numbers) is used to transmit signals and information between devices, and can then be converted back into media. For instance, cell phones are made up of – and by simplification, are – digital technologies transmitting voice and text via digital code.

Digitalisation: It represents "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. A synonym is digital transformation (Gray & Rumpe, 2017). Digital media do not necessarily completely substitute for analogue media, nor are they a simple conversion of information into bits and bytes. Digital information has unique properties as it is easier to transport, store and integrate than analogue information (Kool, Timmer, et al., 2018). Furthermore, it is widely recognised that digitalisation is changing society, from our economy to our culture and the way we interact with each other (Castells, 1996; Van Dijk, 1997). Table 1 provides examples of digital transformations.

1 See https://dictionary.cambridge.org/dictionary/english/technology (last accessed in March 2020)

Table 1: Examples of digital transformations

Name	Concept	Examples
Substitution	Analogue media → Digital media	VHS → DVD Book with public transport schedules (*spoorboekje*) → websites
Liquid digital	Digital media → Digital media (under a new form/structure)	DVD → Netflix, iTunes, Amazon Prime, etc. (on-demand platforms) 'Old' 9292 app → 'new' 9292 app
Coexistence	Analogue media → Digital media + Analogue media (possibly under a modified form)	Printed books only → printed books, e-books and audiobooks Static signage only (e.g. in public transport) → dynamic + static signage Paper tickets → paper tickets with a premium + smart cards/e-tickets
Digital only	Nothing → Digital media	Social media such as Instagram, Snapchat Ride-sourcing applications such as Uber

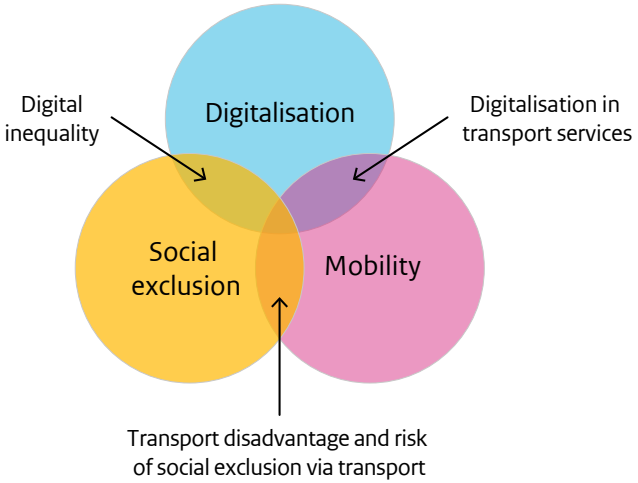
1.3.2 Scope of the research: actors, modes and travelling practices

First, this research focuses on digital inequality from the perspective of people, that is to say travellers or potential travellers, and not on digital inequality for businesses or operators. Second, we focus on transport services only, i.e. non-privately-owned forms of transport. Public transport and shared mobility services are our main points of attention. The latter mainly encompass bike sharing, car sharing, collective demand-responsive transport and ride sourcing, as described in an earlier KiM publication on MaaS (Durand et al., 2018). Even though technology inside of cars has significantly evolved in the past few years, private cars and bicycles are out of the scope of this study. The main reason is that people have arguably more freedom of choice and control regarding (the pace of) digital transformations in privately-owned modes of transportation than in transport services. For example, in 2020, someone with an aversion to digitalisation could still choose to purchase a vehicle without full smartphone integration or semi-autonomous driving and parking abilities, or choose not to use these features. By contrast, in transport services digitalisation is "speeding up" (Canzler & Knie, 2016) and leaves fewer options to travellers. We still acknowledge that digitalisation in cars, bikes has brought substantial changes (Schaap et al., 2017; Storm et al., 2015; Tillema et al., 2017). Third, tourism and air travel are out of scope, as we choose to focus on daily mobility, where exclusionary effects are more frequently being felt.

1.3.3 Scope of the research: general position of the study

The three main overarching themes of this study are digitalisation, social exclusion and mobility. The nexus between these themes form the position of this study, as depicted in Figure 1.

Figure 1: Central concepts of the research with the main themes (circles) and sub-themes



The intersections between each of these main themes are broad but we decided to focus on specific perspectives. We justify these choices below:

- The intersection between digitalisation and mobility refers to many concepts. The complementarity and substitution debate around ICTs and travel (see Mokhtarian (2002), Schwanen and Kwan (2008)), the experience of travel time and space (see Lyons and Urry (2005), Sheller (2004)) or changes in face-to-face interactions (see Line et al. (2011)) are all possible vantage points here. The reviews of Van Wee et al. (2013) and Lyons (2015) cover multiple aspects of the intersection between digitalisation and mobility. However, given the scope of this study and the previously mentioned objective, we choose the vantage point of digitalisation in transport services, as in, the manifestations visible to people of digital transformations in transport services.
- The perspective of digital inequality is chosen to investigate the intersection between digitalisation and social exclusion. Digital inequality research exists since 1995 (Van Dijk, 2019, p. 1) and investigates how various social groups access ICTs as well as how different types of engagement with technology lead to offline social (dis)advantages (W. Chen, 2013). In this study, we argue that this perspective can bring meaningful insights to transport researchers, policymakers and professionals.
- Finally, the most straightforward perspective is the one lying at the intersection between social exclusion and mobility, relating to transport disadvantage and a risk of transport-related social exclusion. Transport disadvantage is about "the need for households or individuals to make a rather great effort [...] [(in terms of time, money, overcoming distances, cognitive effort, skills, etc.)] to reach most locations where relevant activities for these individuals or households are taking place" (Jeekel, 2018, p. 4). Transport disadvantage is not exclusively experienced by socially disadvantaged groups though (Currie & Delbosc, 2010). For instance, people might experience problems looking for travel information online due to low skills, but they might have access to a network of people willing to help them to prepare their next trip. As such, they might have a transport disadvantage, but they would not necessarily be transport excluded. We frame transport disadvantage as part of the process of becoming at risk of transport-related social exclusion, i.e. of being socially excluded due to transport.

At the core of Figure 1 would be *digital inequality in transport services and its potentially exclusionary effects.*

1.4 Approach and structure of the report

This study is part of a research programme on the impact of digitalisation on the access to transport services conducted by KiM on behalf of the Ministry of Infrastructure and Water Management. This first study consists of desk research and is primarily concerned with understanding digital inequality in transport services, its mechanisms and potential consequences. As such, it forms a theoretical foundation for future work.

We use a two-step approach to reach our objectives, as shown in Figure 2. First, we provide relevant contextual information by investigating the intersection between each pair of themes. We use an explorative literature review to:

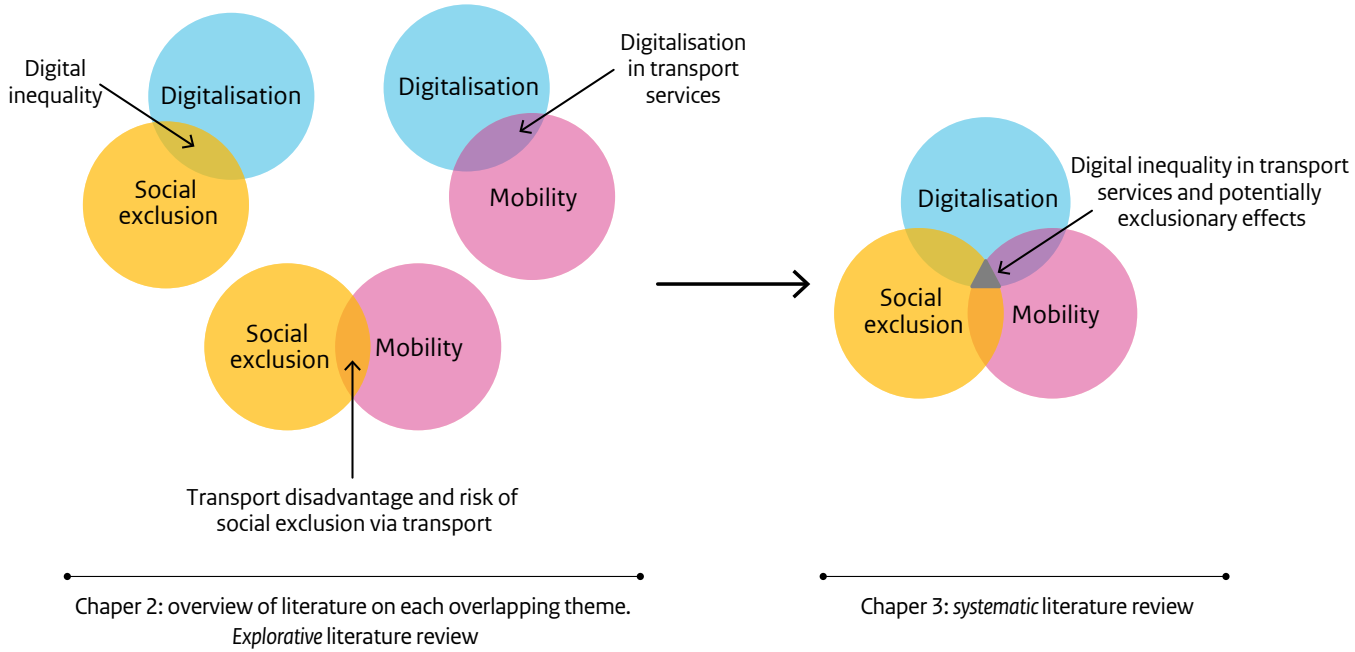
- Understand historical evolutions around digitalisation in transport services and digital inequality,
- Present and define relevant concepts around digital inequality, digitalisation in transport services and transport-related social exclusion,
- Give an overview of the state of digital inequality in the Netherlands.

Second, we conduct a systematic literature review to identify Dutch and international papers that investigated digital inequality in transport services, following the guidelines suggested by Van Wee and Banister (2016). To identify relevant studies, keywords are assigned to each of the themes of this study and their overlap depicted in Figure 1.

The studies that address the overlap between all themes, i.e. papers that would stand at the centre of Figure 1, are selected according to the method described in Appendix 1. In the end, we retain 28 studies, six of which have a Dutch perspective. The selected papers are detailed in Appendix 2. For the analysis of these papers, we adopt a cross-disciplinary approach by examining the selected studies through the lens of digital inequality research. More details on the analysis procedure are given in Appendix 1.

Our report is divided in four chapters. Following this introductory chapter, Chapters 2 and 3 follow the approach described in Figure 2, first with the disaggregate perspectives and second the systematic literature review that binds all themes. Chapter 4 is the conclusion, summarising the main findings, providing recommendations for future research and avenues for KiM follow-up studies on this theme.

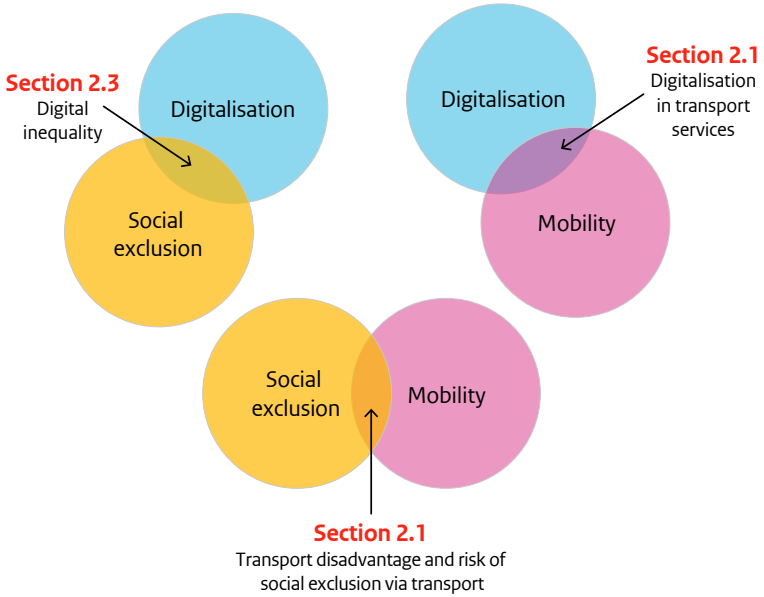
Figure 2: Schematic approach of the study.



2 Linking mobility, digitalisation and social inclusion

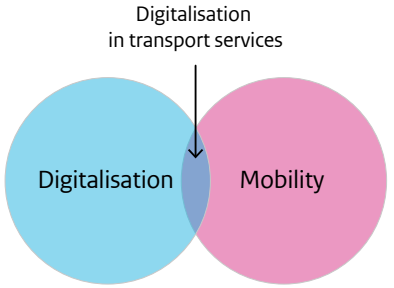
In this chapter, we present the results of the explorative literature review that focused on the intersections between respectively digitalisation and mobility, social exclusion and mobility and social exclusion and digitalisation, as shown in Figure 3. As such, this chapter provides the reader with a better understanding of important concepts in this study (digitalisation in transport services, transport-related social exclusion, digital inequality), of historical evolutions around digitalisation in transport services and of digital inequality in the Netherlands. Each section and this chapter close with a short conclusion summarising main takeaways.

Figure 3: Graphical description of the organisation of Chapter 2.



2.1 Digitalisation in transport services

This section first presents relevant historical developments around digitalisation in transport services, summarised in a timeline. Then, this section presents multiple perspectives on why the trend to rely on ICTs in transport services is likely to keep going on.



2.1.1 From analogue to digital: a timeline of digitalisation in transport services

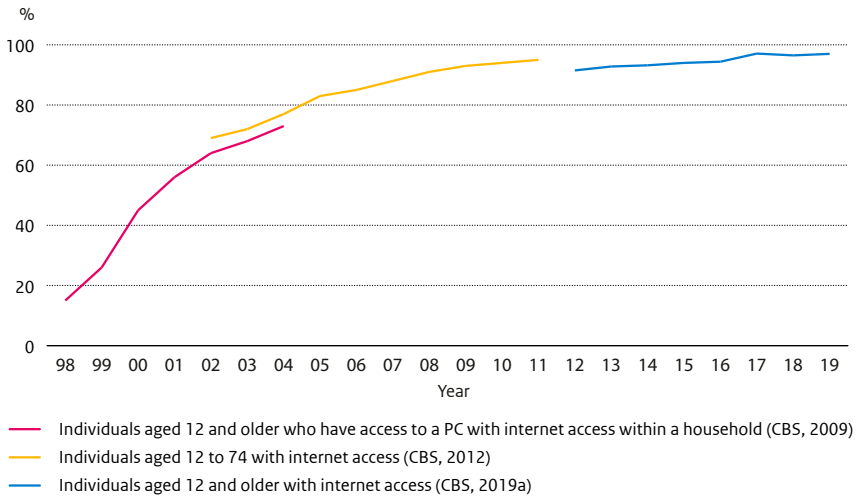
Digitalisation in transport as we know it nowadays is the result of decades of developments of modern technologies, progressively applied in transport services, as explained in this sub-section and summarised in the timeline in Figure 7, page 22.

Decades of development of modern technologies

Historically, telecommunications and information technology (IT) were two fields evolving distinctly (Huldtgren, 2014). The evolution of basic electronic components throughout the twentieth century paved the way for information digitisation and more widely speaking for digitalisation (Ampélas, 2001; Creeber & Martin, 2009a).

The 'digital convergence' was triggered in the early 1980s when telephone networks began to be digitalised (Huldtgren, 2014)[2]. With the commercialisation of the first personal computers in the early 1980s, digital tools became available at home. As capabilities increased, computers became available to non-specialists, notably through Windows (Creeber & Martin, 2009b). In parallel, the 'network of networks' was being built and in the early 1990s, the first 'World Wide Web' page became available (Creeber & Martin, 2009b). With the arrival of the 'Web 2.0' in 1999 emphasizing user-generated content and usability (O'Reilly, 2005), the online world took the form we know nowadays. The same year, the Wi-Fi protocol arrived in homes on new Mac products, marking a first step in wireless connectivity[3]. At this point in time, 26% of the Dutch population had access to the internet (Figure 4). Twenty years later, 97% of the Dutch population is estimated to have access to internet at home.
According to European research reported by CBS (Centraal Bureau voor de Statistiek – Statistics Netherlands), the Netherlands had the highest internet penetration rate per household in 2018, 98% (CBS, 2018).

Figure 4: Development of internet access in the Netherlands

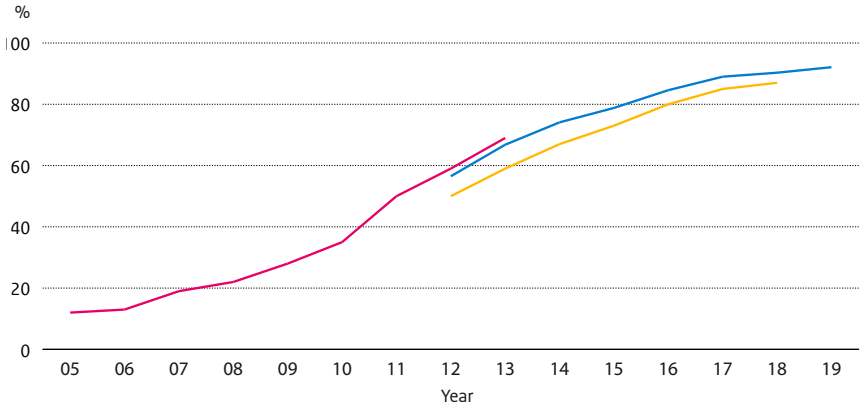


The development of personal and connected devices, largely deployed at relatively low costs, transformed the idea of the 'wired city' from a distant conception to a reality (Batty, 2012). Indeed, fifteen years after the first touchscreen phone and eight years after the first Blackberry, the evolution of processing and display capabilities were such that the first 'Pocket PC' touchscreen phone was introduced by Apple, the iPhone, directly sold to customers instead of via carriers (Sexton, 2009). Smartphone use then quickly spread: in 2007, 19% of the Dutch households with an access to the internet were using smartphones to navigate the internet, against 69% in 2013 (CBS, 2014). Modern smartphones gave a boost to the 3G mobile network, which then gave way to a faster network, the 4G. In 2019, the first commercial 5G network begun in Asia[4]. In the past decade, smartphones have become increasingly performant and innovations such as mobile payment and voice-activated assistants have developed[5].

2 This is why the term Information and Communication Technologies (ICTs) is prevalent and closely associated with the term 'digital technologies' nowadays. These terms are used as synonyms in this report.
3 https://www.computerhistory.org/timeline/
4 https://mse238blog.stanford.edu/2017/07/ssound/1g-2g-5g-the-evolution-of-the-gs/
5 https://www.computerhistory.org/timeline/

In 2019 more than 92% of the Dutch population had access to a smartphone that can be used to navigate the internet (CBS, 2019b), as shown in Figure 5.

Figure 5: Adoption of the smartphone and mobile phones with internet capabilities among households and individuals in the Netherlands.



Digital technologies progressively applied in transport services

A consequence of the convergence of the internet and personal and connected devices is that mobility becomes truly connected (Aguiléra, 2019). Within two decades, the scenarios described by Rat and Iseger (Ministerie V&W, 1996), in which connected mobile devices would be used to look for personalised real-time information and as keys to access non-privately owned forms of transport (the focus of this study), became a reality. Digitalisation in transport is not limited to smartphones though. It is largely relying on the concept of Intelligent Transport Systems (ITS) which started to develop in the 1970s (Leviäkangas, 2016; Nowacki, 2008). ITS are defined as "the application of modern ICTs to transport systems" (Leviäkangas, 2016). Traditional actors in the transport service industry such as operators and planners have been seizing digitalisation as an opportunity to improve strategic planning, infrastructure management, operational tasks such as the management of resources and fleet, and the efficiency of administrative tasks (Ampélas, 2001; Davidsson et al., 2016; Rizos, 2010). Lowering costs while improving the efficiency and the quality of services has been a major reason to implement digitalisation in transport services (Herzogenrath-Amelung et al., 2015; UITP, 2017). In terms of impacts of ICTs visible to travellers, Ampélas (2001) and Aguiléra and Rallet (2016) propose three main categories:

1. Changes in terms of how travellers organise their mobility and new ways for them to be assisted. Digitalisation notably translated into the development of new ticketing methods, more and improved travel information and more integration (e.g. of information, of modes) (Ampélas, 2001; Blythe et al., 2000).
2. The emergence of 'new' shared mobility services.
3. The use of tools that allow travellers to conduct various activities while on-the-go and to conduct teleworking.

The first two categories directly concern digitalisation within transport services and will be successively detailed below. This is not an exhaustive list though, as other aspects in terms of travellers' management have moved online, such as "post-trip" actions like claiming money back or giving one's opinion to the transport service provider.

1. Organisation of mobility

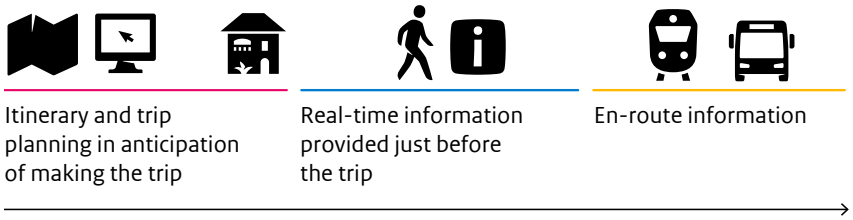
Ticketing and payment. In public transport, electronic ticketing was one of the first visible features of digitalisation. Replacing tokens, paper and magnetic ticketing, contactless ticketing (or 'smart cards') took off in the 1990s thanks to the exponential growth of internet, the increased sophistication of mobile communication technologies (Blythe, 2004) and successful applications of the chip card in other sectors (Boersma &

Bilderbeek, 1995). Early trials began in 1992 in London (Badstuber, 2018) and the first public transport smartcards were introduced in Seoul in 1996 (Reades et al., 2016). The *ov-chipkaart* – the Dutch public transport smart card – started to roll out in the Netherlands in 2005 (Boonla, 2011), but it had already been envisioned as a new ticketing solution that would integrate payment and access for at least a decade (Boersma & Bilderbeek, 1995). Nevertheless, installing a smartcard system involves significant changes and investments (Brakewood et al., 2014). An alternative strategy is mobile ticketing, made possible thanks to the spread of smartphones and connected objects such as smart watches. The three dominant technologies, near-field communications (NFC), passive ticketing and barcode, do require a form of internet connection at some point in the trip (Mesoraca & Brakewood, 2018). Furthermore, these technologies require online payment and therefore access to a banking application, to a credit card or a debit card. In some systems, these cards can also be directly used in a contactless way to simultaneously pay and get access to the transport system (Brakewood & Kocur, 2011). Fare collection systems can be adapted to support all of these payment and ticketing methods at the same time, like in London for instance[6].

In parallel to these developments, some public transport services have become cash-free, meaning that paying by cash has become impossible. Delays and costs due to cash processing are often named as the main reasons for this transition, such as in London (Pritchard et al., 2015; Transport for London, 2014). The Netherlands also offers examples of such cashless services in buses (9292, 2019). Sometimes, cash is still allowed but comes with a premium (Metlink, 2017; Transport for London, 2014).

Travel information. Travel information has been acknowledged as a "very significant factor in the success of public transport operations" since the 1980s (Nelson, 1995, p. 14). Having travel information allows one navigate the transport system as to efficiently and comfortably as possible, even in times of disruptions (Lamont et al., 2013). Even though the need for information depends on one's familiarity with the transport system, everyone needs travel information at some point (Kamga et al., 2013). Travel information comes in multiple sources as described in Table 2 and can be supplied at three key moments from a public transport user's perspective (Figure 6).

Figure 6: The stages of travel in public transport where travel information is needed, inspired from Grotenhuis et al. (2007).



6 See https://tfl.gov.uk/fares/

Table 2: Sources for travel information knowledge in transport services (inspired from Ampélas (2001), Bigby et al. (2019), Draijer (1997), Lamont et al. (2013), Nyblom (2014), Rizos (2010) and Vecchio and Tricarico (2018)).

Objective	Physical objects	Static or non-digital signage. Printed material. Scribbled paper notes.
	Communication with other people	Direct contact with people with a formal knowledge, like staff. Customer service call centres (direct communication).
	Automated communications	Automated Interactive Voice-Response telephone systems (automation of call centres' basic queries). E-alerts (e.g. alerts by Short Message Services (SMS)).
	Digital services and tools	Public sphere: information kiosks, dynamic signage in stations, at stops and in vehicles Personal sphere: websites/apps (through computers, tablets, phones), e-alerts.
Subjective or informal	Own knowledge. Contact with people with a more informal knowledge (social network, passers-by). Subjective information through rating mechanisms or social media.	

Traditionally, printed material, static signage and phone-based services were the main formal sources of travel information (Rizos, 2010). From the 1990s, ICTs were seen as having a significant role to play in the development of traveller information systems (Boldt, 1994). Deriving from digitalisation in the management of vehicles and infrastructure, real-time information in particular was perceived as having a key added value from a traveller's perspective (Ministerie V&W, 1996; Nelson, 1995). Technology progressively allowed this type of information to not only be available at stations and stops as it was traditional (Nelson, 1995), but also to everyone owning a mobile device. Thanks to advances in computing power, call centres were able to respond fast to callers' requests and provide real-time information. In the Netherlands, the 06-9292 phone number established in 1992 allowed people to get multimodal travel information at the country level in less than 30 seconds, with around 10 million phone calls a year three years after its launch (Ministerie V&W, 1996). In 1998, the NS (Dutch train provider) information number was the primary source of information when people were looking for train departure and arrival times, followed by printed timetables and in-station signage (L. Van Dijk et al., 2001). Despite this, commentators often note that public transport operators have been historically seen as slow to embrace technological innovations (Nelson & Mulley, 2013; TRCP, 1999).

Nevertheless, operators gradually started to implement multiple technologies that would slowly complement and eventually substitute paper- and phone-based systems. These systems were also deemed too costly, too labour-intensive, wasteful and simply outdated: kiosks, websites, applications and dynamic signage with both static and real-time information progressively rolled out (Rizos, 2010; TRCP, 1999). In the past two decades, the development of ICTs and in particular of the Web 2.0 and personal and connected devices have allowed for travel information to spread through

websites and applications (Rizos, 2010; Yeboah et al., 2019). Besides, the shift to online information has made subjective information about travel information available, such as ratings (of Uber drivers for instance) that can influence one's travel decision (Vecchio & Tricarico, 2018) or information posted by other users on social media. Nowadays, the latter is also used by operators as a channel to inform (potential) users.

Integration. Mobility integration has been a guiding principle in the development of multiple transport policies in several countries: integration public transport information, of fares, ticketing and payment, of services (coordination of schedules), integration of public and private transport, etc. (Durand et al., 2018). The pillars of such integration usually rely partly on ICTs (see integration ladder in Durand et al. (2018)). Originally designated under the header of ITS, smart mobility and Mobility-as-a-Service (MaaS) are nowadays used to names various integration initiatives (Pangbourne et al., 2019). Smart mobility refers in general to "emerging ICTs, autonomous, electric, connected and shared mobility technologies and services" (Golub et al., 2019) and tends to be strongly associated with smartphone use (Tomaszewska & Florea, 2018). Nowadays, the integration of planning, booking and paying into one digital platform is what we frequently call Mobility-as-a-Service (MaaS), which developed as multiple socio-technological trends, including digitalisation, intersected (Cohen & Jones, 2020; Lyons et al., 2019; Pangbourne et al., 2019). Often, MaaS also often encompasses access-based mobility services (Durand et al., 2018), as described below.

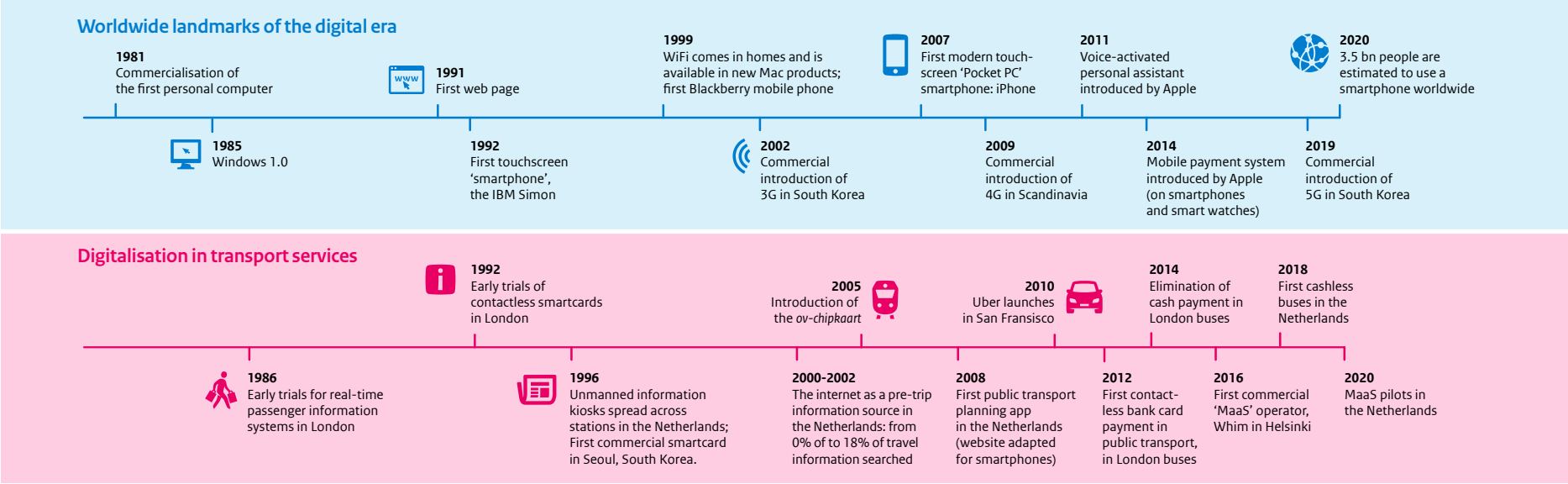
2. Shared mobility services

ICTs have enabled new players to emerge in the transport services' arena, operating shared mobility modes like ride sourcing, bike sharing and car sharing (Aguiléra & Rallet, 2016; Willing et al., 2017). Historically, access-based consumption was perceived as an inferior mode of consumption (Bardhi & Eckhardt, 2012). Still, most of these so-called 'new' mobility services are actually not new [7]. In general, advances in ICTs are considered to be one of the main contributing factors to the renewed popularity and the scale-up of these modes (Brake et al., 2007; Z. Chen et al., 2020; Ciari & Becker, 2017) along with economic and socio-cultural stimulants (Jorritsma & Jonkeren, 2017). The primary access gate of these services are often websites, smartphone applications or terminals activated via bank cards or smartcards (Fishman, 2016; Ricci, 2015; Shaheen et al., 2017; Shaheen & Cohen, 2018; Thomopoulos et al., 2015). These media may require a form of activation or registration before the trip itself. For instance, ride sourcing relies exclusively on people using an app on a smartphone (Clewlow, 2016; Frenken & Schor, 2017), which had become available to the wide public three years before Uber's introduction.

Figure 7 provides a timeline of digitalisation and digitalisation in transport services, summarising key landmarks. It also lets us see how interwoven digitalisation in transport services is with digitalisation in general.

7 See e.g. Ciari and Becker (2017) for car sharing, Ploeger and Oldenziel (2020) for bike sharing and Brake et al. (2007) for demand-responsive transport.

Figure 7: Timelines of digitalisation in transport services (with an emphasis on the Dutch situation) and worldwide landmarks of the digital era[8] (with a focus on the smartphone)



2.1.2 Why is the trend to rely on ICTs in transport services likely to keep going on?

In this section, we touch upon multiple perspectives explaining why the trend to rely on ICTs in transport services is likely to keep going on: a user and operator perspective as well as a policy perspective.

User and operator perspective

It is widely acknowledged that there is a growing dependence of modern life on digital technologies in general (Herzogenrath-Amelung et al., 2015). The previous section lets us see that transport services are also increasingly technology and if it allows for cost reductions and more efficiency, why not leveraging it? To better understand this growing reliance on digital technologies from a user perspective, we can use Dupuy's explanatory model on network dependency and resulting inequalities, inspired by telecommunications' research. He originally applied this model to explain car dependency[9] (Dupuy, 1999) and later digital dependency and divide (Dupuy, 2011). Applied to digital technologies in transport services, this model of network dependency translates as follows:

8 Sources are mentioned in the text above, except for the following: early trials for real-time information in London (Nelson, 1995), unmanned information kiosks in the Netherlands (Ministerie V&W, 1996), the internet as a pre-trip information source in the Netherlands (Van der Horst, 2006, p. 58), first trip planning app in the Netherlands (de Bruin, 2009), Uber launches in San Fransisco (Hartmans & Leskin, 2019), first commercial 'MaaS' operator Whim in Helsinki (https://whimapp.com/about-us/), 3.5bn people are estimated to use a smartphone worldwide (Statista, 2020), MaaS pilots in the Netherlands (Ministerie I&W, 2019b).

9 According to Dupuy (1999), "To belong to the [automobile] system has become essential, and to a large extent it is the fact that many others are in the system that motivates us to enter it (or to remain in it), to use a car, and thus to become dependent on it" (p. 12). What makes automobile dependence strong according to him is the cumulative interactions of club, fleet and network effects. A club effect is created by the amount of people who already possess a driver's license and who are therefore allowed a higher maximum speed. A fleet effect is related to the fact that the benefits of owning a car increase as more people own and use a car. A network effect is the fact that the more cars travel on the road network, the more this network gets attention and is being developed.

- There is a club effect in the sense that access to the digital world via smartphones, computers, smart cards and other connected or smart devices provide advantages to a "club" that are not available in the analogue world. Examples of advantages are access to shared mobility modes or access to cashless buses without the need to pay for a premium.
- There is a fleet effect in the sense that the more people have access to digital media in transport services, the more services and products are developed to serve these people. Examples of these services are smartphone applications that are developed and refined and quick customer support through social media channels.
- Together, these effects give rise to a network effect: the more people use digital media in transport services, the more beneficial it is to switch to digital media – both for operators and for users.

Altogether, these effects likely create a self-reinforcing dynamic whereby digital media provide travellers an advantage. This may also cause pressure to switch to digital media among those who are reluctant (for whatever reason it may be) to do so.

Policy perspective

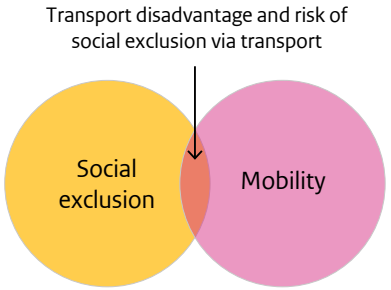
There is much attention for the potential environmental benefits of ICTs in transport services. Indeed, if the Netherlands is to comply with international climate agreements, the transportation sector needs to become considerably cleaner (Rijksoverheid, 2018). This is especially true for passenger mobility, as it is deemed to offer more options for emissions' reduction than freight and aviation (PBL, 2018). Between 2030 and 2050, 'clean mobility' is envisioned as a 'service', transport services are to be 'easily accessible' and car ownership 'less necessary and attractive', at least in urban areas (Rijksoverheid, 2018, p. 52). As ICTs keep on developing and internet use is on the rise for all population groups in the Netherlands (CBS, 2019c), digitalisation in transport services are often seen as having a central role to play in this shift towards more sustainable mobility patterns (see Nederlandse Digitaliseringsstrategie, Ministerie EZK (2018), Schets Mobiliteit naar 2040, Ministerie I&W (2019c). The shift towards a cleaner transportation sector is called the 'smart and green mobility transition' by the Ministry of Infrastructure and Water Management (Lodder et al. (2017)). 'Smart' and 'green' seemingly go hand in hand. Scholars acknowledge that with the opportunity to leverage on smart mobility services to transition towards less car-dependent patterns, the trend to rely on ICTs in transport is likely to keep going on (Banister, 2019; Groth, 2019). Nevertheless, Manders and Klaassen (2019) caution that environmental and social sustainability are often linked to technological solutions as "an incidental benefit rather than a prioritised aim" (p. 7) in the general smart mobility discourse in the Netherlands. In that sense, they warn of a technology push where economic and commercial stakes would be the main drivers, with social and environmental aspects being downgraded to possible side effects. Cohen and Jones (2020) remind us that tech actors have a lot to gain in selling the public stories about the immediacy and the inevitability of technologies, "which can give rise to a feeling of panic in the policy maker" (p. 81) who would not know how to address these transformations taking properly into account e.g. their social impacts.

Main takeaways of this section

Through the convergence of the internet and personal and connected devices, transport services have progressively embraced digitalisation too. This has led to many benefits. Yet with a growing dependency on digital technologies comes an increased pressure to go digital and an increased risk that technology be introduced as an end in itself rather than as a means to well-thought ends, with potentially adverse consequences on society.

2.2 Risk of social exclusion via transport

After examining the intersection between mobility and digitalisation, this section tackles the intersection between social exclusion and mobility. This section first shortly presents the ways in which mobility can support social inclusion (the opposite of social exclusion), before addressing the question of who is affected by transport-related social exclusion and the role of transport services in social inclusion.



2.2.1 Mobility as a support for social inclusion

The growth of digital connectivity notwithstanding, the potential and the ability to use physical means of transportation play an important role in social inclusion. The word potential has its importance here. The value of mobility is not limited to its role in helping people access destinations or people (Metz, 2000). Not only carrying out activities, but even having the possibility to do so and in various ways, is viewed as a key aspect of well-being (Sen, 1992), which is recognised as underpinning social inclusion (Pangbourne et al., 2010). For instance with older adults, Musselwhite and Haddad (2010) suggest that mobility does not only serve to fulfil practical needs – instrumental value of mobility – but also social or affective needs (e.g. the need for independence) and aesthetic needs (e.g. the need for the journey itself) – the intrinsic value of mobility. Both of these values of mobility can foster social inclusion (Shliselberg & Givoni, 2018).

2.2.2 Who is affected by social exclusion via transport and transport disadvantage?

Because of its role in supporting social inclusion, mobility is also acknowledged as one of the dimensions through which social exclusion can arise or be reinforced (Kenyon et al., 2002), hence the term *social exclusion via transport*[10] :

> *"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 social networks, due in whole or part to insufficient mobility in a society and environment built around the assumption of high mobility" (Kenyon et al., 2002, pp. 210-211).*

Social exclusion via transport first appeared on the policy agenda in the United Kingdom in 2002-2003 (Lucas, 2012). It is difficult to quantify it, notably because everyone is different and has therefore different needs for mobility. It is not only clustered within socially disadvantaged neighbourhoods, but rather seen as scattered amongst individuals within the population (Currie & Delbosc, 2010; Grieco et al., 2000), yet affecting more people experiencing other forms of exclusion (Lucas, 2012). A previous KiM report established that people with lower incomes, job seekers, older adults, ethnic minorities, people without a car or a driver's licence, people with a physical impairment and people living in rural areas are more at risk of experiencing social exclusion via transport (Jorritsma et al., 2018). In general, it is the combination of social disadvantage and transport disadvantage[11] that is seen as increasing the risk for social exclusion via transport (Jeekel, 2018; Lucas, 2012). People can experience transport disadvantage without being socially excluded (via transport) (Currie & Delbosc, 2010). An example would be someone who has no driver's license and lives in a remote location, but who still has a strong network to rely upon to reach the activities he/she needs and wants to.

10 This term tends to be used as a synonym to transport poverty (vervoersarmoede); see Jorritsma et al. (2018) and Lucas (2012) on this point.

11 As a reminder from Chapter 1, we define transport disadvantage as "the need for households or individuals to make a rather great effort [...] [(in terms of time, money, overcoming distances, cognitive effort, skills, etc.)] to reach most locations where relevant activities for these individuals or households are taking place" (Jeekel, 2018, p. 4).

2.2.3 Transport services, social exclusion and inclusion

In a society that heavily relies on cars, being unable to drive one is traditionally seen as a form of transport disadvantage (Lucas, 2004, 2012; Mattioli, 2013). Unless carless people have enough resources such as money or network or live close to the destinations they need to reach on a frequent basis, transport services play an important role in them being able to fulfil their mobility needs (Haustein & Siren, 2015; Jeekel, 2018), with possible consequences on how socially included they are. This is true for public transport but also for semi-public forms of transport services reaching groups with special needs due to health reasons, such as Special Transport Services. For some people, public transport is the main transport service they rely on to fulfil their mobility needs. They are called public transport captives (Beimborn et al., 2003) and include people without driver's license and those who cannot afford a car or drive one due to age, impairment or past driving behaviour (Chia et al., 2016). In the Netherlands, Zijlstra et al. (2018) report that approximately 68% of bus passengers do not see the car as a feasible alternative for the trip in question. This is in line with findings in the US reported by Lucas (2004, p. 260): two third of all public transport trips are made by captives. According to a recent KiM study focusing on Special Transport Services in the Netherlands, half of the users would not have travelled if such services were unavailable for their last completed trip (Zijlstra et al., 2019)[12]. The researchers concluded that these Special Transport Services are a necessary supplement to the range of travel options available to people with special needs.

Recently, shared mobility services have also been presented as having the potential to unfold social inclusivity effects (Daubitz, 2016). According to Clark and Curl (2016), shared mobility modes bring the promise of a level of mobility that might otherwise be unaffordable, and therefore decrease financial disadvantage for underprivileged society members. In line with this, many expect that integrated mobility services such as MaaS contribute to mitigate the risk of social exclusion via transport, as reported in Atkins (2015), Jittrapirom et al. (2018) and Mayas and Kamargianni (2017). Against this relatively optimistic "opinion camp" (Lucas, 2019, p. 3), some see this new landscape of transport services as "the concentration of transport wealth amongst the already privileged", paired with a partial or total impossibility to access this landscape for certain groups, notably those who cannot afford it or who do not live in the areas where they operate (Lucas, 2019, p. 3). While the blend of both scenarios may be the most plausible one (Lucas, 2019), many call for more research on this topic (Z. Chen et al., 2020; Macharis & Geurs, 2019; Pangbourne et al., 2019).

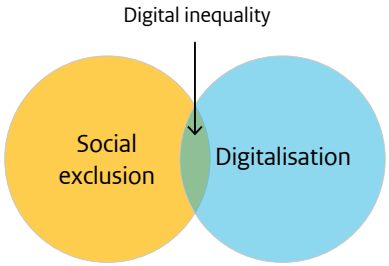
Main takeaways of this section

The potential and the ability to use physical means of transportation plays an important role in social inclusion. As such, mobility is also acknowledged as one of the dimensions through which social exclusion can arise or be reinforced. Some people may need to rely partly or mostly on non-privately-owned transport modes, such as public transport and semi-public forms of transport services to fulfil their mobility needs. This underpins the importance of these services for social inclusion. Furthermore, shared mobility services have also been presented as having the potential to unfold social inclusivity effects, although further evidence on that topic is needed.

12 This study investigated users of two socio-recreational Special Transport Services: regional transportation as implemented under the 2015 Wet Maatschappelijke Ondersteuning (WMO) (Social Support Act), and Valys, a pan-regional transportation service.

2.3 Digital inequality

The last intersection to examine is the one between social exclusion and digitalisation: digital inequality. This section present an overview of digital inequality research, followed by the presentation of a framework central in the rest of this report. The section ends with a short presentation of digital inequality in the Netherlands.



2.3.1 An overview of 25 years of digital inequalities research: evolution and important findings

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, pp. 45-51). Initially, the digital divide distinguished between people who had access to an internet connection and those who had not. Over the years, researchers have distinguished between three main levels of digital divide, as explained below.

1. First-level digital divide

A low motivation and a low material access are nowadays referred to as the first-level digital divide (Van Dijk, 2018). Initially, researchers started to explore barriers, motivations and reasons for (not) using the internet, the perceived uselessness of the medium being a top reason for non-use in early years (Katz & Aspden, 1997). Nowadays, this reason for non-use is still present, along with others such as a lack of interest and a rejection of the internet based on various grounds (issues around privacy, cybercrime, over-use) (Van Dijk, 2019). Another topic of attention in the early years of internet was whether people had a computer and an internet connection or not. As the internet has become more widely accessible over the years, this first-level digital divide also covers broader material and peripheral access (Van Deursen & Van Dijk, 2018), such as buying, replacing and maintaining a variety of devices (smartphones, tablet, printers, etc.). Having access to a diversity of devices – and in particular, not only to mobile devices – is recognised as particularly important as mobile devices do not provide the same possibilities than a computer, for instance for complex information search (Napoli & Obar, 2014).

Digital *divide* or digital *inequality*?

Originally, in the 1990s, the *digital divide* had a strong dichotomous connotation: those who had access to technologies versus those who do not ("haves" and "have-nots"). Although the term has been declined into levels that nuance its original binary meaning, the metaphor of the divide is still a source of confusion for many. In this study, we mainly use *digital inequality* as it "does more justice to the less delineated character of the differences in people's internet use and appropriation, differences that might exist on a continuum of disparities" (Scheerder, 2019, p. 14).

2. Second-level digital divide

In an attempt to crystallise the idea that access to technology does not provide all the benefits of the technology, Hargittai (2001) introduced the *second-level digital divide*: the skills divide. It is based on the idea that there are differences between groups in terms of skills necessary to effectively use the internet. Subsequently, scholars have classified types of skills and multiple frameworks of digital literacy have been developed (Helsper & Eynon, 2013; Van Deursen et al., 2016). Traditional digital skills frameworks distinguish between medium-related skills and content-related skills, such as the one defined by Van Dijk and Van Deursen (2014) and presented in

Table 3. According to Van Dijk and Van Deursen (2014), a certain level of mastery of the former is instrumental in order to develop and reap the benefits of the latter. This is all the more challenging as technology is always changing. These same skills are also important in traditional media such as print media (Van Dijk & Van Deursen, 2014). For instance regarding information skills, the internet has simplified many tasks thanks to search engines and shortcuts (like Ctrl + F). Yet one major difference is that information provided on the internet is virtually infinite. Therefore, high-order information skills are required to search, find, process, select and critically assess information and the legitimacy of sources (Van Deursen & Mossberger, 2018). With the advent of technologies such as speech recognition and personal assistants that simplify tasks such as searching for information, medium-related skills may become less relevant while information and navigation skills, and in particular being flexible and being able to critically assess and select advice, become crucial (Van Dijk, 2019, pp. 77-78; Van Laar et al., 2017). *The second-level digital divide* also includes differences in digital technology usage, i.e. the frequency of use of the internet and digital technologies, the type of activity performed and the duration of use (Van Dijk, 2005).

Table 3: Six types of digital skills (from Van Dijk and Van Deursen (2014))

Skill family	Type of skills	Description
Medium-related skills	Operational skills	Operating digital technology in basic ways, such as knowing which buttons to use and how to open a file
	Formal skills	Handling the formal structures of the medium, such as understanding how a browser works
Content-related skills	Information skills	Searching, finding, selecting and critically assessing information
	Communication skills	Transferring information to other people
	Content creation skills	Creating and generating new content and transforming it into a product or a service
	Strategic skills	Orienting, acting and deciding upon information to reach a particular goal and derive personal or professional benefits

3. Third-level digital divide

Next to the first- and the second-level digital divides, the concept of the *third-level digital divide* has been recently developed to designate the fact that access to the internet, its use and the possession of digital skills do not always lead to beneficial outcomes (Van Deursen et al., 2016). In general, studies show that the internet offers more positive and tangible outcomes to people with a higher social status (Van Deursen, 2018; Van Deursen & Helsper, 2015). This means, for instance, that they are more frequently able to be up-to-date with government information and they indicate feeling healthier thanks to online medical information. Van Deursen (2018) notes that the groups that could benefit the most from the ICTs are precisely those who have limited access to ICTs.

2.3.2 Modelling the link between social and digital inequalities: Van Dijk's model

While it was widely thought that the internet would reduce social inequalities in the early days of the Web, the past two decades have seen more critical voices being raised (Van Dijk, 2019, p. 110). Social and digital inequalities are two concepts intertwined in complex and dynamic ways, especially as the digital world increasingly affects the offline world. Which inequality was here first? Access to technology is one of the many factors potentially leading to social exclusion (Kenyon et al., 2002), but social exclusion also influences the possibility to access digital technologies. Digital inequality as a *reflection* of existing social inequality has been a long-established position (Selwyn, 2004). Still, this is not enough for several scholars: digital inequality also exacerbates social inequality (Van Dijk, 2019). Work on the third-level digital divide tends to confirm this position (Van Deursen & Helsper, 2015). This is a general picture though. Mariën et al. (2016) noted that qualitative studies in particular tend to show a more nuanced picture: socially advantaged groups can be digitally disadvantaged and socially disadvantaged groups can also use ICTs to their immediate advantage.

Multiple frameworks that try to identify and explain the links between social and digital inequalities exist[13]. In this study, we rely on the causal and sequential model of access to digital technology access model developed by Van Dijk (2005) and presented in Figure 8. Van Dijk's model focuses on the exclusion of individuals due to the integration of ICTs in all aspects of society and allows for a detailed level of analysis. It connects dimensions pertaining to people and to technology, and assumes that *access to technology*, in the sense of appropriation of technology, is achieved through successive layers[14].

The five core points of the model are as follows (Van Dijk, 2005, p. 15):

1. Inequalities in terms of personal and positional categories (named here determinants) in society produce an unequal distribution of resources.
   For instance, differences in occupations create differences in terms of income and therefore in money available to spend.
2. An unequal distribution of resources causes unequal access to digital technologies; it impacts factors of access to technology.
   For instance, having more money generally means being able to replace devices more frequently.
3. Unequal access to digital technologies also depends on the characteristics of these technologies.
   For instance, tiny keypads can make mobile devices difficult to access for people with low vision.
4. Unequal access to digital technologies brings about unequal outcomes of participation in society.
   For instance, being able to navigate online stores may give access to cheaper products than those of the local store, allowing to save money for other purposes.
5. Unequal participation in society reinforces inequalities regarding positional categories and unequal distribution of resources.
   For instance, having fewer opportunities to access online information may influence access to higher education.

Through its multi-dimensional and multi-layered nature, this model is generally regarded as broad enough to explain a complex phenomenon such as digital inequality in a variety of situations, yet still relatively simple (Mariën et al., 2016). The model can also be read in a circular manner, as there are feedback loops: the fact that gaining skills can influence attitudes on technology for instance is included.

13 See Mariën et al. (2016) for an overview.
14 See also Dedding et al. (2017) for a recent application of this model in Amsterdam.

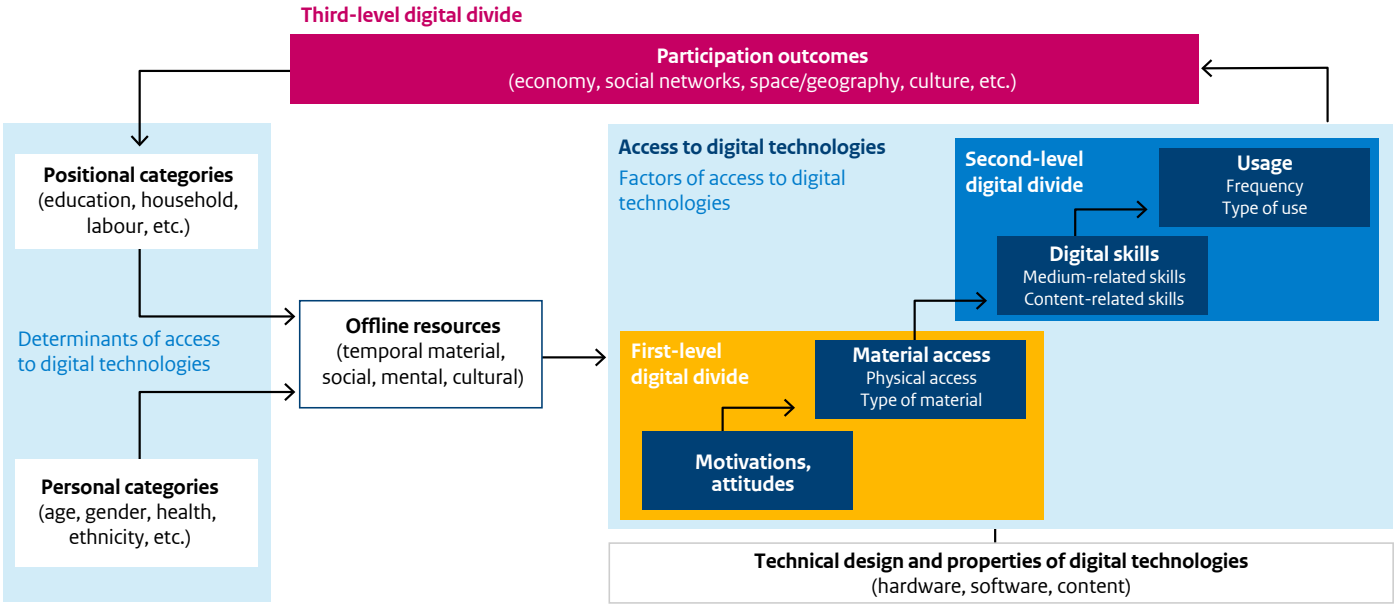


Figure 8: Van Dijk's model of causal and sequential model of access to digital technology (Van Dijk (2005), updated based on Van Dijk (2019). The use of the term 'determinant' is inspired by Scheerder et al. (2017)).

Digital inequality research is still relatively young and dynamically evolving along with technologies. Some criticisms of (studies using) Van Dijk's model include a narrow focus on socio-economic status, little attention towards social support and proxy use, the lack of some feedback loops between elements and 'motivation' as the entry point (Mariën et al., 2016; Mariën & Vleugels, 2011). Recently, Van Dijk (2019) has responded to these points, notably by giving more details in his model (as presented in Figure 8), by explicitly emphasizing the existence of feedback loops and by calling for a wider focus than solely socio-economic status. Regarding motivation as an entry point, Mariën et al. (2016) question it because as ICTs are becoming more and more ubiquitous and profoundly entangled in institutions and daily practices, there is a "digital push" (p. 62), and therefore motivation is no longer the precondition to access technology it used to be. Digital has become the default option: *digital by default*[15], and the individual ability to deal with this push may be what increasingly defines digital inequality according to them, instead of being motivated to use digital technologies. Digital inequalities exist through a(n) (increasing) digital dependency (Dupuy, 2011). In this context, Lupač (2018, p. 161) argues that in order to better investigate digital inequalities, it is necessary to assess how indispensable ICTs are in a given field by examining:

15 This principle is listed by the European Union as a key principle to "accelerate the digital transformation of government" (European Commission, 2016). According to Council of the European Union (2017), the transport field should also comply to this principle. Inclusiveness and accessibility are also listed as key principles.

1. How embedded these technologies are in everyday routines and in institutions of this field,
2. How available non-ICT alternatives are, taking into account that an alternative costing a lot of extra resources (time, money, etc.) is not necessarily a 'real' alternative.

If people have sufficiently good non-digital alternatives, then *digital by default* is not necessarily detrimental in terms of social inclusion. This notion of indispensability is therefore added to the framework for this research used in Chapter 3. It does not invalidate Van Dijk's model as research has shown that even though each factor influences the next ones (Van Deursen, 2018), it is not necessary to have fully 'completed' one factor to be able to access the next one (see e.g. the privacy paradox: this refers to individuals who state that they are concerned about their privacy but who are willing to do little to protect their data (Herzogenrath-Amelung et al., 2015)).

2.3.3 Digital inequality in the Netherlands

What about digital inequality in the Netherlands? Although the Netherlands has the highest internet amount of people with a home internet connection in Europe (98%) (CBS, 2018), some studies have prompted interest and raised awareness on the topic of digital inequality in the Netherlands in the past decade. The work of CBS (2019c) on computer/internet illiterates – *digibeten* – lets us see that having a home internet connection does not necessarily imply making use of it, as 3% of the population aged 12 or more had not used the internet in 2018 yet did have an internet connection at home. This figure did decrease since 2010 though, when 10% of the population aged 12 or more was estimated to be "internet illiterate". Aside from *digibeten*, another term that frequently comes forward in recent Dutch studies is *digitale kloof* – digital divide. Baay et al. (2015) and more recently Bijl et al. (2017) identified a digital divide in the Netherlands. Baay et al. (2015) brought attention to people with low literacy levels in particular. Having sufficient literacy is deemed as an important precondition to be able to develop digital literacy (Algemene Rekenkamer, 2016). According to Baay et al. (2015), 300,000 people have a double disadvantage in the sense that they are illiterate and they have no to few digital skills. Furthermore, they estimate that 13% of the people with low literacy levels never use a computer.

How many people have low literacy levels in the Netherlands?
In 2013, the Ministry of Education, Culture and Science estimated that 1.3 million people had low literacy levels (Algemene Rekenkamer, 2016). However, this figure only shows a part of the bigger picture as it does not account for counting problems and for people older than 65. Taking into account these limitations, the Netherlands Court of Audit estimated that 2.5 million people aged 16 or older have difficulties writing and/or counting, which likely translate into difficulties navigating the digital world (Algemene Rekenkamer, 2016). This is 1 out of 6 people (aged 16 and older) in the Netherlands.

How does the Dutch population perform in terms of the four factors of access to technology presented in the model of Van Dijk in Figure 8, namely motivation and attitudes, material access, skills and usage? Although many people in the Netherlands are nowadays connected to the internet, digital inequality still exists and its social, economic and cultural consequences are acknowledged (Bijl et al., 2017; Wennekers et al., 2018).

MOTIVATIONS, ATTITUDES

A recent study conducted among a representative sample of the Dutch population sheds light on differences between various socio-demographic and –economic groups within the Dutch population (Van Deursen, 2018). According to this study, attitudes regarding the use of the internet do not differ much among gender and age groups. Older adults remain nevertheless more likely to have fewer motivations to use the internet, and 22% of the adults aged 66 and older had never used it in 2018 (CBS, 2019c; Van Deursen, 2018).

MATERIAL ACCESS

Van Deursen (2018) finds that older adults and to a lesser extent people with a lower educational level are less likely to have access to the internet. *Generational effects* are at play here: in general, people born after 1980 have been educated and have grown up with digital media (Van Dijk, 2019). *Structural effects* are also taking place though: younger people tend to be naturally more open to new innovations, have more cognitive abilities and the educational system invites them to use new digital technologies early on (Van Dijk, 2019, p. 45). While generational effects will probably disappear over a few generations, structural effects will likely remain. Regarding educational level, the gap in material access has mostly been closing in developed countries (Van Dijk, 2019). In general though, since education, work and subsequently income are the main factors driving the distribution of material, social and cultural resources, disparities still exist. In the Netherlands, men, working people and people with higher education levels are more likely to have access to diverse and quality material – and to be able to maintain them – which in turn influences skills, usage and outcomes (Van Deursen & Van Dijk, 2018).

DIGITAL SKILLS

According to CBS (2016), 22% of the Dutch population aged 12 or more had no to few basic digital skills in 2015. This is about 3 million people. According to Van Deursen (2018), although operational skills are generally high, strategic and information skills are lacking among multiple groups within the population. He estimates that only 42% of the Dutch population has enough information skills[16]. According to Van Deursen et al. (2015), the gap between people with higher educational levels and people with middle to lower educational levels widened in terms of digital skills between 2010 and 2013, linked to an increase and fragmentation of information sources as previously explained. This is also why some older people have higher digital skills than younger adults: they are better able to critically assess and select information (Van Dijk, 2019). Kennisnet (2017) highlights that youngsters usually tend to overestimate their digital skills, in particular their information and strategic skills. Finally, social support from relatives does not seem to fully compensate for the lack of digital skills (Van Deursen, 2018).

USAGE

Regarding usage, people with a higher socio-economic status (in terms of income and educational level) use more frequently the internet and for a diversity of activities, including activities that further improve their social status. This suggests the existence of a usage gap among the Dutch population (Van Deursen, 2018; Van Deursen & Van Dijk, 2013).

16 According to CBS (2016), 89% of the Dutch population has more than basic information skills. The discrepancy between this percentage and that of Van Deursen (2018) comes from the fact that the items used in the CBS study to measure information skills are broader than the scale used by Van Deursen and actually contains operational skills such as copy or move files.

Main takeaways of this section

Top statistics in terms of smartphone and internet penetration rates hide the more complex reality that benefitting from what the digital world has to offer is not only about possessing a device or an internet connection. The type of material, digital skills and personal factors are just a few aspects that play a crucial role in how people appropriate themselves ever-evolving digital technologies. In particular, as information provided on the internet is virtually infinite and as technologies become increasingly used for decision-making, high-order information skills are required to search, find, process, select and critically assess information and the legitimacy of sources. In general, digital inequality tends to reflect and reinforce social inequality. In the Netherlands, digital inequality still exists and its social, economic and cultural consequences are acknowledged.

2.4 Conclusion

Digitalisation in transport services is the result of decades of developments of modern technologies, progressively applied in the field of transport. Through the convergence of the internet and personal and connected devices, transport services have progressively embraced digitalisation too. Yet with a growing dependency on digital technologies comes an increased pressure to go digital. At the same time, the potential and the ability to use physical means of transportation is acknowledged as playing an important role in social inclusion, with a central role for transport services within certain groups of the population. Top statistics in terms of smartphone and internet penetration rates hide the more complex reality that benefitting from what the digital world has to offer is not only about possessing a device or an internet connection. The type of material, digital skills and personal factors are just a few aspects that play a crucial role in how people appropriate themselves ever-evolving digital technologies. In general, digital inequality tends to reflect and reinforce social inequality.
The elements discussed in this chapter come together in the next chapter, which presents the results of a systematic literature review on digital inequality in transport services and its potentially exclusionary effects.

3 Results of the systematic literature review on digital inequality in transport services

Building on the contextual elements from the previous chapter, this chapter highlights the results of the systematic literature review on digital inequality in transport services, where all three central concepts previously discussed come together as shown in Figure 9.

Figure 9 (right):
Focus of this chapter: the intersection of the central themes.

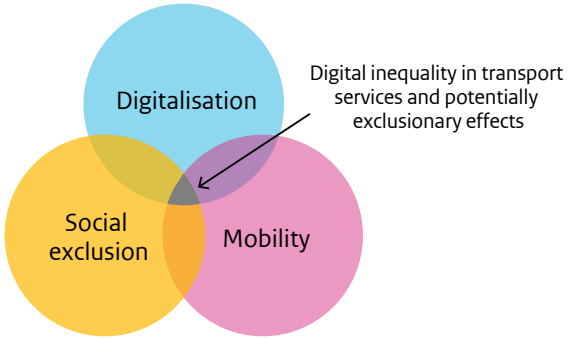
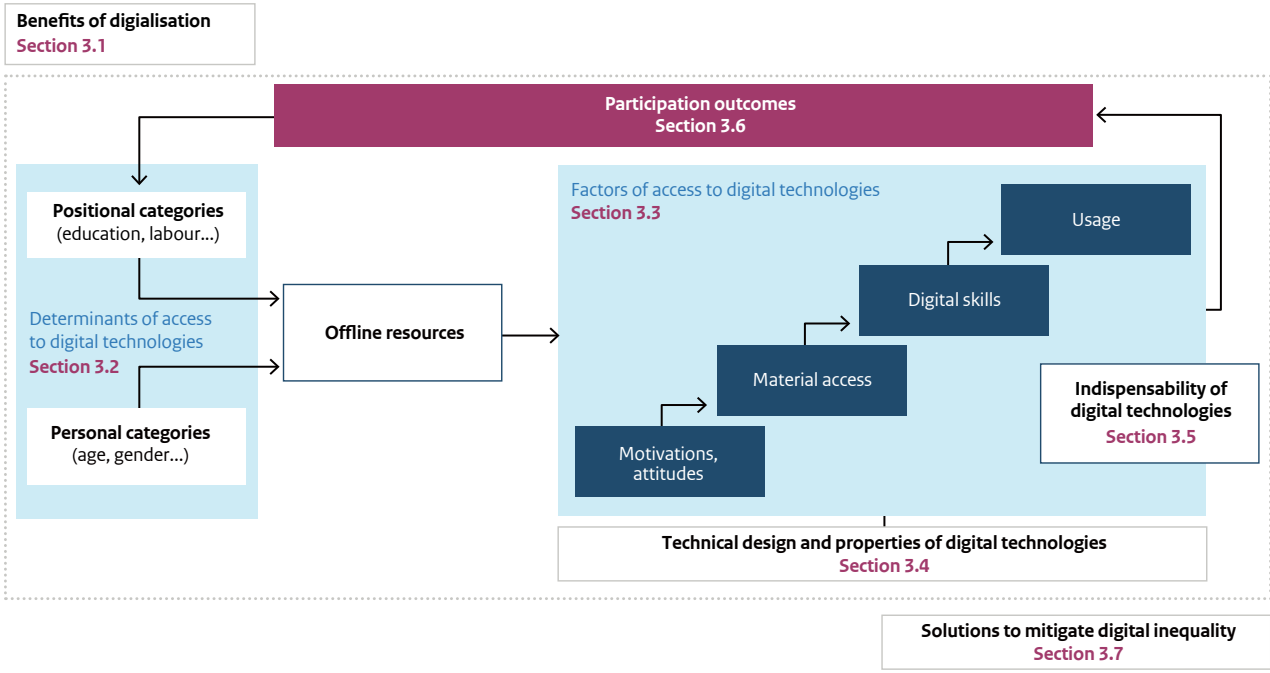


Figure 10 (below):
Graphical description of the organisation of Chapter 3.



The model of Van Dijk, complemented with the criteria of indispensability as presented in Chapter 2, is used as a lens to read and organise the literature review's results. Next to this, the literature review also highlights benefits of digitalisation in transport services as well as solutions put forward to mitigate digital inequality. For more details on how the content of the selected papers was analysed, see Appendix 1. A graphical description of the organisation of this chapter is provided in Figure 10. A table detailing which themes are tackled in which study can be found in Appendix 3, to avoid long strings of references in the text.

3.1 The benefits of digitalisation in transport services

To begin with, the potential of digital technologies in transport services to improve travellers' experience has been acknowledged for decades. Online travel information makes information that was previously unavailable for some easy to access and potentially more understandable. As such, it can contribute to a decrease in the resistance to use transport services (Snellen & de Hollander, 2017; Vecchio & Tricarico, 2018), especially for inexperienced users (Canzler & Knie, 2016). Furthermore, having a mobile internet access makes it possible for travellers to get real-time information during the trip, thereby significantly increasing convenience (Rizos, 2010; Sochor & Nikitas, 2016). Digital technologies can also affect subtle factors in mobility such as perceptions of access, security, communication and access to help (Shirgaokar, 2018; Sochor & Nikitas, 2016). Studies focusing on older adults confirm this: more information creates more security, people feel reassured. Kamga et al. (2013) found that access to real-time information through kiosks can also promote a greater confidence among travellers. Besides travel information, there is a recognition that the use of smartphones and the possibilities they offer (e.g. coupling with banking accounts) provides a lot of convenience (Chee, 2018; Musselwhite, 2019).

The wide palette of customisation digital technologies allow for can provide personalised assistance to people who may otherwise not or sparsely travel, thereby directly addressing the risk for transport-related social exclusion (Harvey et al., 2019; Pangbourne et al., 2010). For instance, transport applications and websites can provide features that address language barriers, impairments and low-income issues (Bekiaris et al., 2009; Gebresselassie & Sanchez, 2018). People with complex communication needs enjoy having access to information through the internet as it spares them direct interactions, which can be complicated for them (Bigby et al., 2019). Furthermore, shared mobility services, enabled in part through ICTs, can be used to meet the needs of groups who previously had a low range of transport options available (Malik & Wahaj, 2019; Snellen & de Hollander, 2017). According to Canzler and Knie (2016), 'new' forms of mobility could safeguard mobility without the need for private vehicles (see section 2.2), car ownership and license being "two significant barriers to transportation equity" (Golub et al., 2019, p. 4). Nevertheless, this discourse around the benefits for specific groups may contribute to the framing of technology as a compensatory tool rather than a positive development (Pangbourne, 2018). This in unhelpful, especially as it makes non-inclusive designs seem more acceptable, because it is assumed that an 'a posteriori' compensatory solution will be developed for these specific groups (Bekiaris et al., 2009). Next section specifically zooms in on groups who might be vulnerable to digitalisation in transport services.

Main takeaways of this section

The potential of digital technologies in transport services to improve travellers' experience has been acknowledged for decades. Furthermore, digital technologies can enlarge the palette of available modes and provide personalised assistance to people who may otherwise not or sparsely travel, thereby directly addressing the risk for transport-related social exclusion.

3.2 Determinants of digital inequality in transport services

Most of the selected papers in this systematic literature review focus on specific groups. This conveys the perception that some groups are more vulnerable than other groups to an increase in digitalisation in transport services.

3.2.1 Main personal and positional categories of vulnerable groups

As acknowledged in Chapter 2, groups that are found to be disadvantaged in a traditional socio-economic sense are also usually found to be the most

at risk, respectively of digital exclusion and of transport disadvantage. According to literature, vulnerabilities in terms of access to digitally-based transport services exist along dimensions of *age* (older adults and underage people), *income level* (people with lower ones), *educational level* (people with lower ones) and *ethnicity* (people from minorities).

Multiple studies agree on the fact that older adults in particular are vulnerable, 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 et al., 2010). Older women who used to be driven by their husband are particularly at risk of having their mobility needs unmet (Pangbourne, 2018; Shirgaokar, 2018). Second, older adults are recognised as more likely to be reluctant to engage with technology (Harvey et al., 2019; Pangbourne, 2018). This may come from the fact that they have managed their mobility during their whole life without these technologies. 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 in general, coping with new technologies can be difficult (Harvey et al., 2019; Pangbourne et al., 2010). Younger users are traditionally seen as less likely to be affected (Shirgaokar, 2018), although children are also at risk, since they do not have credit cards and they cannot use modes such as ride sourcing on their own (Chee, 2018).

Additionally, people with lower incomes and lower educational attainments are also seen as more vulnerable. For instance in the Netherlands, the OV Ombudsman (2019) (Dutch public transport ombudsman) reports how the transition from the offline to the online purchase of a yearly public transport subscription causes issues for people with lower income levels. While the option to split payments in monthly instalments used to be available offline, it is nowadays only available online. Offline subscriptions are therefore only yearly subscriptions, to be paid in one go. Finally, ethnicity is deemed an important factor in a few North-American studies. Van Dijk (2019) notes though that differences in motivation among specific ethnic groups are in fact "related more to economic deprivation, discrimination and cultural preferences than to race" (p. 42).

There are two caveats here though. First, it is unlikely that there is homogeneity within and among all these groups. For instance for older adults, people aged 65 and people aged 85 will be different. In the Netherlands, the job seekers in low-income neighbourhoods interviewed by Bastiaanssen (2012) reported getting on well with journey planning apps, planning websites and the *ov-chipkaart*. One could argue that the coverage of this topic was relatively limited in this study though. Second, when comparing this list of vulnerable people with the groups mentioned in section 2.3.3, we see that this list is unlikely to be exhaustive. There is a multiplicity of determinants playing a role in access to digital technologies. These groups may also overlap; for instance, older people and people with low income levels (OV Ombudsman, 2019).

3.2.2 A multiplicity of determinants involved in the process of exclusion from digital technologies in transport services

Multiple aspects may cause and exacerbate the risk to have a low access to digital technologies in transport services. Indeed, not having access to a trip planning app for instance may be due to a low income, but this could also stem from being undocumented and not mastering sufficiently a certain language. People with learning disabilities such as dyslexia or with low literacy and/or low numeracy levels are at risk of being excluded from transport services relying on digital tools (Lamont et al., 2013; Malik & Wahaj, 2019). Having a communication impairment (of cognitive, visual or auditory nature) can also be a barrier (Bigby et al., 2019). Again, having an impairment does not automatically translate into exclusion from transport services relying on digital technologies (Van der Meulen et al., 2018). Furthermore, people who are experiencing issues with digitalisation in transport services may already have had issues when everything was

printed out: for them, a low access to ICTs is a layer on top of other layers of transport disadvantage (Bigby et al., 2019; Lamont et al., 2013).

Main takeaways of this section

Vulnerabilities to digital inequality in transport services exist along dimensions of age, income and educational levels as well as ethnicity. Nevertheless, this is a small list that hides many other personal conditions such as impairments and low literacy levels. Besides, vulnerable groups are by no means homogenous in their access to digital technologies.

3.3 Factors of access to digital technologies in transport services

In the model of Van Dijk, determinants influence offline resources, which in turn affect the factors of access to technology. This section successively addresses the four factors of access to digital technologies as shown in Van Dijk's model.

MOTIVATIONS, ATTITUDES

The first stage of access to digital technology is influenced by resources and determinants but remains by nature fundamentally psychological (Van Dijk, 2019). Groth (2019) defines the "mental preconditions to use modern ICTs" with five affective and cognitive categories: autonomy, excitement, flexibility, privacy and status. In general, 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 by literature is a *rejection of the technology due to a perceived lack of 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. Online travel information is sometimes perceived as unreliable. In general, there is a need for being in control and protect one's vulnerability. This need is perceived to go against the heavy reliance on technology on which some systems are based (Harvey et al., 2019; Pangbourne et al., 2010). In particular, with its sole reliance on technology to access it, shared mobility is sometimes seen as unsure, unreliable and unsafe (Shirgaokar, 2018). Privacy seems to be a growing concern because of the ability of digital technologies in transport to track people's journeys and because of the collection of personal data by transport companies (Groth, 2019). Vecchio and Tricarico (2018) note that even when anonymising data, 'big data' is so ubiquitous and highly detailed that profiling people would still be possible. Data leakages at companies such as Uber in 2016 may further accentuate this mistrust (Jin et al., 2018). The rejection of digital technologies in transport services due to privacy concerns is not necessarily always enacted upon (e.g. privacy paradox), but it is a cause for concern.

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 applications and their potential added value in transport services remain invisible (Groth, 2019; Sochor & Nikitas, 2016). This is the case notably for older adults. It could also be that the information people are looking for is unavailable, e.g. information on amenities such as seats, sheltered spaces or toilets (Harvey et al., 2019; Lamont et al., 2013). This might (further) decrease the interest in technology.

These two main reasons are closely linked with other reasons, such as a lack of money, a perceived lack of skills and time, lack of ability to acquire such skills and the fear to appear foolish (Sochor & Nikitas, 2016). A 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. While applications are often free or come at a nominal cost, the device to access them is not free – whether it be a computer, a tablet or a smartphone – and nor is the data plan or the stable internet connection, as acknowledged in literature. The cost of technology to access the ride becomes a barrier before even the cost of the ride itself (Chee, 2018; Jin et al., 2018). 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 the devices and the need to replace them regularly annoys people, who feel pushed to adopt newer forms of digital technology. This is a recurrent remark in literature. 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. Naturally, the impacts here are not limited to mobility. In addition to smartphone-related considerations, money is also needed to afford peripheral devices such as printers, essential to be able to print e-tickets when one does not have access to a smartphone (OV Ombudsman, 2019).

In addition to money-related concerns, literature highlights that owning a smartphone is not enough. One needs to ensure that there is enough battery, that it is being repaired (or replaced) when broken (or stolen) and that the operating system is continuously up-to-date and operating to support the applications running on it. For instance, Golub et al. (2019) found a higher than (US) average smartphone penetration rate among their respondents, inhabitants of low-income neighbourhoods in Portland (89% versus 81% (Pew Research, 2019)). However, the picture would be incomplete if the researchers had not questioned their respondents about their data plans: 25% of them had already cancelled their data plan at least once because of costs, similarly to the US average of 23%. Owning the device in itself is not enough, as digital inequality researchers started to argue two decades ago.

DIGITAL SKILLS

Concerns pertaining to digital skills, and notably the skills required to use a smartphone, are also raised in literature. In his interviews with public transport operators, Rizos (2010) noted two conflicting views regarding the future of traveller information systems. The first one saw traditional ways of disseminating information as fundamental (e.g. static information such as prints, call centres) and here to stay, while the second, or so-called 'progressive vision', predicted that smartphone penetration and further developments in transport technologies would make this type of dissemination of information obsolete. Although 'progressive' operators did recognise the existence of a digital divide, there was the belief that the digitally disadvantaged would "catch up" and that smartphone penetration would be so ubiquitous that physical displays would no longer need to be relied upon for information needs. A decade later, smartphone penetration has indeed increased, but this reasoning reveals a fundamental misunderstanding of digital inequality: having or even giving access to the physical technology does not mean that people benefit from what the technology has to offer them. As Chee (2018) acknowledges, "devices are merely gateways or 'dummy terminals' that provide access to the truly valuable network, society and broader webs of significance" (p. 266). Material access is not enough.

Travel information has been progressively digitalised over the years, replacing more traditional alternatives like paper, call centres and asking staff at station. While such information systems only required common

and usual literacy, newer technologies require new skills. The importance of skills in looking for travel information frequently comes back in literature. The exact types of digital skills are rarely made explicit though, even if information and medium-related skills are often hinted at. As such, this remains a relatively abstract concept. An exception is Vecchio and Tricarico (2018), who argue that "interpretative skills" are needed to "to individuate and process a significant amount of information" (p. 4). Indeed, with the proliferation of online information, there is a widespread idea that people have enough choices and chances to be informed (Snellen & de Hollander, 2017). Yet people can still report being unaware of public transport options and experiencing travel planning as difficult. On the other side of the spectrum, the amount of information and the complexity of its structure can also be overwhelming (Sochor & Nikitas, 2016). Lamont et al. (2013) highlight that web-based journey information is almost unusable for people with dyslexia because it is too rich, too complex and too hard to process.

In general, literature points to the fact that digital technologies may be contributing to an increase in complexity in transport services via a fragmentation of information and service provision. Past tendencies in transport were a "simplification via standardisation" as contended by Canzler and Knie (2016). The researchers argue that this is partly why car use has become so prevalent: the system as a whole, from the car itself to the infrastructure around it (e.g. traffic lights) was standardised and made relatively easy to understand. With digitalisation in transport services, much more complicated and heterogeneous systems have emerged, where users require more competences. It is not excluded though that after a period of transitions, more standardisation occur in transport services, making the system simpler to understand and use. Still, as devices and their 'smart' software increasingly do all the work (e.g. a suggestion to take mode A instead of B), information and strategic skills are needed more than ever to understand how these systems produce advice and whether or not to follow it (Van Deursen & Mossberger, 2018). As complexity (visibly or invisibly) increases, knowing where to turn to and how to take action on digital information become important skills, as summarised by Vecchio and Tricarico (2018, p. 3):

> *"The simple availability of information is not sufficient to influence individual mobility preferences, since people may be differently able to access and process information [...] the very ability to process information, understanding its contents and putting it into use, may change according to different cognitive and literacy skills. The ability to make use of information is a dynamic skill, which could be acquired, adapted or lost over one's life."*

Skills related to privacy management also become important. Groth (2019) calls "critical thinkers" the group of people who enjoys making use of digital technologies in transport services but remain careful about what they share. Herzogenrath-Amelung et al. (2015) emphasize the risks incurred by gathering an increasing amount of personal data in transport services, which people may not always be aware of. Users may downplay these risks because of smartphone applications "seemingly emanat[ing] from self-contained gadgets [that] encourage the user to focus only on their immediate benefits, disregarding any risk that ensues from these applications" (p. 209).

USAGE

Although it is acknowledged that not only knowledge but also practice (usage) is important in the take-up of ICTs in the transport context (see for instance Pangbourne et al. (2010)), this factor has not been discussed much in literature. Given that the three previous factors already lack empirical research, it comes to little surprise that this aspect is relatively absent in literature. Based on digital inequality research, it can be expected that a low-frequency and a low-diversity use of transport-related digital technologies hamper the range of positive outcomes from technology use.

Main takeaways of this section

Being able and willing to appropriate oneself digital technologies in transport services is conditioned by multiple factors, and not simply by whether one possesses a smartphone or a computer. First, motivations and attitudes matter. Main reasons for non-use of ICTs applied in transport services are the rejection of the technology due to a perceived lack of security, privacy and reliability and a lack of interest or perceived added value. Second, having up-to-date, connected and functioning material is crucial. Third, digital technologies in transport services require skills to find, assess, select and appropriate oneself information in a crowded landscape of available information. Fourth, a low-frequency and a low-diversity use of transport-related ICTs likely make the appropriation of these technologies harder.

3.4 The technical characteristics of digital technologies in transport services

The factors described above are also under the influence of the technical characteristics of digital technologies, a core component of the model of Van Dijk: "Unequal access to digital technologies also depends on the characteristics of these technologies" (Van Dijk, 2005, p. 15). Literature highlights two ways in which the technical characteristics of digital technologies can impact transport services people have access to.

First, *the technical design of hardware and software* is an important component to be able to access digital technology and a fortiori to derive benefits from such technology, such as using transport services. Small keypads and pictograms as well as a navigation logic and gestures designed with experienced ICT users in mind can hamper access to digital technology, with negative consequences in terms of mobility (Harvey et al., 2019; Pangbourne et al., 2010). Van Dijk (2019) argues that *usability* is an important technical characteristic of contemporary digital media, affecting the possibility of developing digital skills. Drawing from Shneiderman (1980) and Nielsen (1994), he defines usability as the combination of: "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), to which he adds intuitiveness.

Second, with a growing automation of digital technologies comes an increased risk of selectivity (Van Dijk, 2019). As such, digital technologies can directly impact the physical offer of transport services available to a specific person. Being excluded from a service based on location is seen as one of the manifestations of social inequality but also of digital inequality and impacting mobility. Indeed, there is a risk that commercial initiatives that developed their transport services primarily based on digital infrastructure (such as ride sourcing platforms) shun certain neighbourhoods because they are not profitable enough (Snellen & de Hollander, 2017). In addition, algorithms that are used to dispatch transport services might learn from available data which neighbourhoods have more potential than others (Chee, 2018; Snellen & de Hollander, 2017). Indeed, people who are not present in data are invisible to 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[17]. Wang and Mu (2018) investigated whether the prevalence of digital technologies in transport would strengthen social exclusion and (digital) inequality or would mitigate some long-lasting socio-spatial inequality. They concluded that there was no evidence yet

17 The discussion around discrimination with transport data generated by sensors, smartcards, applications, surveys and websites goes beyond the digital inequality issue; see for instance Martens (2006). See also Bijker and Law (1992) about built-in biases of the people – typically, dominant groups – shaping technologies.

that the Uber products were related to an aggravation or an alleviation of the existing socio-spatial disparities at neighbourhood levels in Atlanta. Still, they caution that the "virtual transportation infrastructure" provided by ride sourcing initiatives such as Uber raise questions about digital inequality.

Main takeaways of this section

The technical design and characteristics of ICTs influence access to digital technologies. Known examples of this are issues related to low accessibility (small keypads, small fonts on websites, etc.) and low usability. A more covert example concerns automation and/or algorithmic processing features of digitally-based transport services. If left unsupervised, they may exclude – intentionally or not – groups of people that are already disadvantaged in some way, for instance by shunning poorer neighbourhoods.

3.5 The indispensability of digital technologies in transport services

The indispensability of digital technologies as presented in Chapter 2 is defined by the *embeddedness of these technologies* and the *availability of non-ICT alternatives* in a given field. Such indispensability can be found at different levels in public transport and shared mobility.

3.5.1 A shift towards digital by default and concerns around the availability of non-digital alternatives in public transport

In the case of public transport, literature highlights how travellers are increasingly expected to conduct tasks via digital channels by default. Snellen and de Hollander (2017) note growing expectations that people make use of ticketing machines to purchase tickets or that they use their smartphone to find travel information. This is the digital 'push' previously mentioned, particularly negatively experienced in the case of a public service (Pangbourne et al., 2010). This echoes to the study of Rizos (2010), who noted that soon after the first modern smartphone was released, the iPhone, US and Canadian public transport operators were already expecting that people would "bring-their own access" to travel information. The pervasiveness of the smartphone nowadays reinforces this expectation, as a "smart mobility tool of choice [...] ubiquitous in various aspects of urban living, with a high presence in transport-related functions" (Gebresselassie & Sanchez, 2018, p. 5). This creates an increased *dependency on and embeddedness of* digital technologies in transport services.

Although digital and analogue media may still often coexist in public transport, the latter often may take a modified form, potentially discouraging its use (see Table 1). The OV Ombudsman (2019) mentions several examples, such as the yearly public transport subscription that can no longer be paid offline on a monthly basis or when the lack of smartphone and printer means that discounted train e-ticket become time- and energy-consuming to get. 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 of people that already feel vulnerable to fulfil their mobility needs, like people with an impairment or older adults (Pangbourne, 2018; Snellen & de Hollander, 2017). In particular, responding to irregularities or last-minute changes in the service can become particularly problematic without connected mobile device and less staff around (Bigby et al., 2019). A station kiosk can be an alternative to staff; however, as Kamga et al. (2013) highlight, certain technical features of such "an oversized smartphone" (p. 221) may present challenges for people who do not have experience with such devices. For instance, studies show an age-related decrease and difficulty in using public information kiosks and ticket machines (Pangbourne et al., 2010).

3.5.2 Shared mobility: more than digital by default, digital only

In shared mobility, not only is digital the default option, it is also nowadays frequently the only option (Canzler & Knie, 2016; 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). Here, digital technologies are indispensable. 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 mostly a problem in developing countries (Pangbourne et al., 2019), although the ban on cash in buses in developed countries such as the UK and the Netherlands also raises questions (OV Ombudsman, 2019). Although commercial shared mobility providers may target the population they want, namely people with smartphones and bank accounts, they still use public space and this '*digital only*' way of communicating with users can still raise questions in terms of exclusion, as detailed in next section.

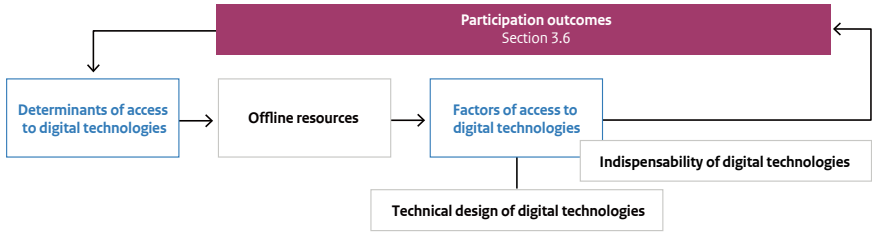
Main takeaways of this section

There is an increased dependency on and embeddedness of digital technologies in transport services. Although digital and analogue media may still often coexist in public transport, the latter often may take a modified form, potentially discouraging its use. This shift towards digital by default is even more pronounced in shared mobility, where digital is also nowadays frequently the only option.

3.6 The consequences of digitalisation in transport services in terms of mobility and social exclusion

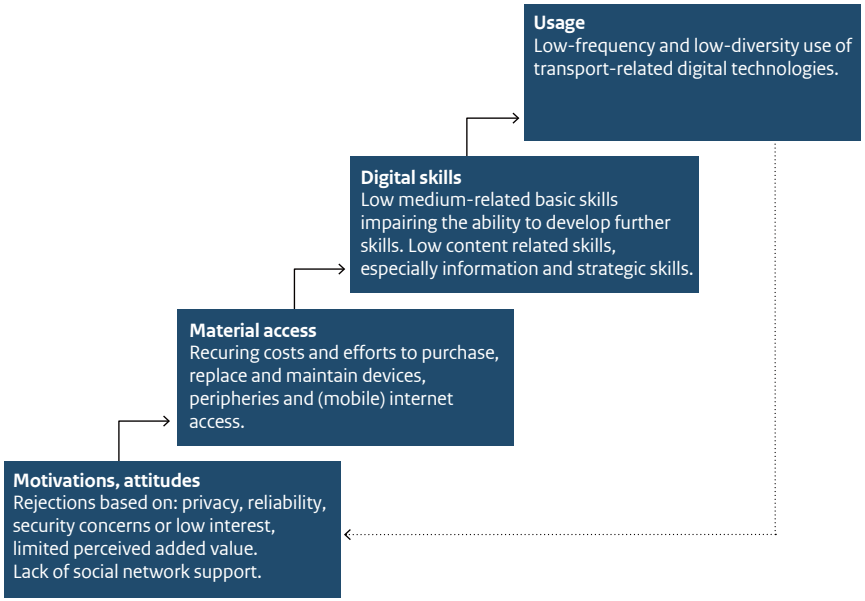
The consequences of digitalisation in transport services in terms of mobility and social exclusion are the participation outcomes mentioned in Figure 11, which is a simplified version of Figure 10. In this study, we focus on detrimental participation outcomes, in particular exclusionary effects. These are the result of a combination of the factors of access to technology, the indispensability of digital technology and the technical design of digital technologies. This section brings together the presented results by detailing these mechanisms of digital inequality and their potentially exclusionary outcomes.

Figure 11: A simplified version of Van Dijk's model of access to technology, with the addition of the indispensability criteria.



Each factor of access to technology (Section 3.2) is influenced by determinants, offline resources and the other factors of access to technology (Van Deursen, 2018). As a result, individuals may engage more or less in digital technologies. Barriers for each factor are summarised in Figure 12. Altogether, they can result in exclusionary effects. Given the relatively nascent state of research on digital inequality in transport services, this summary is by no means exhaustive, but rather provides a first indication of existing mechanisms of digital inequality.

Figure 12: Identified barriers to access to digital technologies in transport services, with feedback loop to account for Van Dijk's model circularity.



It is worth noting that these barriers are not only related to one's choices, perceptions and life conditions, but they are also heavily influenced by technical designs and the general *digital by default* context in transport services ('indispensability' in Figure 11):

- Regarding technical designs, the usability of a given technology affects the possibility of developing digital skills. In particular, the design of hardware and software (e,g, of apps) can exclude certain groups within the population: it is a form of *exclusion by design*. While low accessibility issues (due to e.g. low vision, discomfort with small keypads, etc.) are getting increased recognition and are progressively being addressed (Gebresselassie & Sanchez, 2018) (see e.g. the NS Perronwijzer app in the Netherlands), a more hidden form of exclusion by design concerns automation and/or algorithmic processing features of digitally-based transport services. If left unsupervised, they may exclude – intentionally or not – groups of people that are already disadvantaged in some way[18].
- A shift towards *digital by default* and concerns on the availability of non-digital alternatives in public transport raise concerns around transport-related social exclusion (Snellen & de Hollander, 2017). In the *digital only* case of shared mobility, the potential for exclusion becomes even clearer[19]. It can be argued that shared mobility is in an early innovation phase, where a selective participation makes sense. However, if these modes are to be further scaled up with the objective to encourage more environmentally sustainable travel patterns (see section 2.1.1), the question of exclusion becomes more pregnant (Canzler & Knie, 2016; Pangbourne et al., 2019). This is especially true as the production of multimodal travel behaviour – a central element of this 'modal shift' suggestion – is conditioned by access to digital technologies (Groth, 2019).

Overall, literature explicitly recognises that low engagements with digital technologies could limit the use of transport services, with consequences on mobility in general (see e.g. Groth (2019); Lamont et al. (2013)). This exacerbates the risk for transport disadvantage and transport-related social exclusion. Not only is the risk for exclusion pointed out in literature, but also the risk for polarisation (Jin et al., 2018) and a "technological gentrification" of transport services (Pangbourne et al., 2019, p. 43). This is the idea that a tech-savvy elite would never be constrained in their access to technology and therefore be able to use transport services as they want while more vulnerable groups would struggle. As Van Dijk (2019, p. 130) argues, "relative [digital] inequality matters in a network society where some are able to take greater advantage of resources [...] than others". In general

18 See the recent call for action in the Netherlands from the Rathenau Institute on that topic (Kool, Dujso, et al., 2018), and Park and Humphry (2019) for concrete examples of such exclusion in social welfare services in Australia.

19 The term of *exclusion by design* would also fit here; see Z. Chen et al. (2020); Nixon and Schwanen (2019).

though, there is still very little empirical evidence available in literature on how digital inequality contributes to transport-related social exclusion. Furthermore, digital technologies are arguably one piece in a complex socio-technical system that poses challenges for meeting the needs of vulnerable populations in general, as underlined by Pangbourne (2018).

Main takeaways of this section

When embedded in digital by default contexts, low levels of engagement with digital technologies can foster digital inequality with potentially detrimental consequences on the access to transport services. Ultimately, digital inequality in transport services could reproduce and exacerbate transport disadvantage and the risk for transport-related social exclusion. There is still little empirical evidence on how digital inequality contributes to transport-related social exclusion though. Furthermore, digital technologies are arguably one piece in a complex socio-technical system that poses challenges for meeting the needs of vulnerable populations in general.

3.7 Solutions put forward

In light of these potentially detrimental consequences, two main types of solutions are put forward in literature: practical solutions to mitigate the concrete consequences of digital inequality in transport services and solutions at a more strategic level.

3.7.1 Practical solutions

Literature suggests three broad types of approaches when it comes to mitigating (the impacts of) digital inequality in transport services. All of these solutions have advantages and disadvantages; ultimately, what matters is a blend of approaches.

Adapting technology to people is the solution that is most frequently cited. The importance of a design that is simple and user-centred from the start and as a whole is highlighted (Bekiaris et al., 2009; Harvey et al., 2019). For instance, not only applications need to have an inclusive design, but also the device to access them (Pangbourne, 2018). In general, features that meet the needs of vulnerable groups and take into account the increased sense of vulnerability that some people have in relation to ICTs would be helpful (Golub et al., 2019; Lamont et al., 2013). These features could be hidden when not needed (Harvey et al., 2019). Inspired by Endsley and Jones (2016), Harvey et al. (2019) conclude that user-centred and inclusive design is not only about asking what people want or not, but about "organising technology around the way users process information and make decisions, keeping them in control and aware" (p. 176). Content-wise, some studies report that more integration of services would be desirable since the fragmentation of the transport system is seen as problematic (Bigby et al., 2019; Harvey et al., 2019).

Teaching people how to use technology is also a cited solution. Training is put forward with the idea that technology can empower people (Bigby et al., 2019; Sabie & Ahmed, 2019). For instance, Harvey et al. (2019) mention 'older champions' who could teach peers how to use technology in a language that they understand and Golub et al. (2019) highlight the demand from their respondents for in-person trainings at trusted facilities. Nevertheless, the selected literature never discusses the different ways to teach people and their pros and cons. For instance, teaching could be done in a reactive way by staff: help and support is provided when people ask for it. Here, training staff could also be needed (Bigby et al., 2019). Alternatively, a more proactive way could also be considered, although the right target group may be less easy to reach. Furthermore, knowing the specificities of who is being taught is crucial. For instance, Harvey et al. (2019) underline that there is a strong need among older adults to practice as soon as they have learnt, otherwise the knowledge may be lost.

Still, relying on teaching as a solution can give the idea that people need to adapt to a technology that was not designed with them in mind. Lamont et al. (2013) argue that the societal or medicalised discourse of deficit (e.g. a learning impairment, a communication impairment, teach people because they do not know something) hides another reality: the condition itself is not disabling, but the environment is.

Retaining and refining offline alternatives, safety nets and low-tech tools are deemed important as the internet, apps and smartphones do not work for everyone all the time. In terms of low-tech tools, Harvey et al. (2019) and Pangbourne et al. (2019) contend that smart cards can introduce people to other services through technology, since they are relatively easier to use compared with smartphones for instance. Yet evidence from the Netherlands shows that this is highly context-based, as smart cards can still be difficult to use: money needs to be loaded on it through machines and checking in and out is not easy for everyone, especially when switching from one operator to the other (Ettema & Cornea, 2018; Snellen & de Hollander, 2017). It is not only about the (digital) tool itself, but the whole system around it. Free and public internet and charging stations are also mentioned as important safety nets for people who do own a smartphone (Golub et al., 2019). Literature highlights the need to provide real alternatives to digital technology that would not necessarily cost more (money, time, energy). In general, literature emphasizes the importance of being able to interact with people rather than machines and calls for the development of a culture where help seeking and giving are more valued (Bigby et al., 2019; Sabie & Ahmed, 2019).

3.7.2 A more people- and value-centred policy approach to digital technologies in transport services

There are compelling arguments for positive social developments from technological innovations in transport services. Still, scholars warn of the technological determinism surrounding these innovations ("technology X will fix (social) problem Y") and call for an in-depth consideration among operators and policymakers about digitalisation in transport services, the values it serves and where it is heading towards. For instance, through a critical analysis of the MaaS rhetoric, Pangbourne et al. (2019) caution that MaaS's "promise of freedom cannot be delivered with respect to well-being and inclusion" (p. 44). This is due to the fact that MaaS and shared mobility in general seem to promise everything to everyone, with social sustainability usually viewed as a mere positive 'side effect' (Gebresselassie & Sanchez, 2018; Pangbourne et al., 2019). Rather than a new revolutionary paradigm of ownership-free mobility, some scholars see here a striking parallel with the automobile paradigm, which has not delivered the socially inclusive system it promised (Canzler & Knie, 2016). Yet estimating the impacts of technology before it is fully formed and embedded in society is nearly impossible. For instance, the interviews from Rizos (2010) a decade ago reveal that some public transport authorities in Canada/US had greatly underestimated digitalisation in transport services and, by extent, its impacts:

> *"Other [public transport operators] suggest that old-fashioned printed schedules and other media will always remain, and that the new Web and smartphone applications are merely optional gadgetry that only builds upon the existing baseline of available information for the sake of convenience" (p. 58).*

Yet the difficulty in understanding technological developments is not a reason for policymakers, operators and authorities to be passive (Pangbourne et al., 2019; Sochor & Nikitas, 2016). While uncertainty around technological developments means that a predict-and-provide (measures, resources) policy approach has become difficult, literature calls for more envisioning, for creating a vision around what society wants from technology and society and then decide (and provide) based on that (Snellen & de Hollander, 2017). In this debate on the role of policy in digital transformations, some of the selected literature calls for public values and people to be placed at the core of transport policy decisions involving innovations, echoing to the call of

the Rathenau Institute in the Netherlands (Kool, Dujso, et al., 2018; Kool, Timmer, et al., 2018). Thinking about the broader impacts of digitalisation is not and does not involve a technophobic approach, as Herzogenrath-Amelung et al. (2015) explain, but rather an approach to develop ex-ante frameworks that would help shaping the development of ICTs in transport services, instead of having to use less impactful ex-post legislative measures that mitigate risks and potential misuse.

Main takeaways of this section

There are three main categories of practical solutions put forward in literature: adapting technology to people, teaching people how to use ICTs and retaining and refining offline alternatives, safety nets and low-tech tools. Nevertheless, literature also calls for a more people- and value-centred policy approach to digital technologies in transport services, to participate in the shaping of ICTs in transport services instead of having to use less impactful ex-post legislative measures that mitigate risks and potential misuse.

3.8 Conclusion

While digitalisation offers benefits such as increased convenience and customisation, there are mechanisms through which digital inequality in transport services may arise. Vulnerabilities exist along dimensions of age, income and educational levels as well as ethnicity. Nevertheless, this is a small list that hides many other personal conditions such as impairments and low literacy levels. Furthermore, literature warns of the impacts of *digital by default* in public transport, *digital only* in shared mobility and forms of exclusion based on technical design. When embedded in such contexts, low levels of engagement with digital technologies can foster digital inequality with potentially detrimental consequences on the access to transport services. While there are practical solutions put forward, literature calls for a more people- and value-centred policy approach to digital technologies in transport services.

4 Conclusion and research agenda

Transport services increasingly rely on digital technologies. Benefitting from their possibilities and opportunities is not obvious to everyone. This study aimed at exploring how and why digital transformations in transport services may have potentially exclusionary effects. As such, this study shed light on digital inequality in transport services, i.e. how various social groups access ICTs and how different types of engagement with technology, when embedded in a certain context, can lead to disadvantages in terms of mobility and subsequently in terms of social exclusion.

This study sought to answer the following main research question, guided by five sub-research questions:
How does digitalisation in transport services affect mobility for the population in the Netherlands, with particular attention to people who might not be ready to follow the pace of such a digital transformation?

1) What is digitalisation in transport services, how is it developing and what are its drivers?
2) What are the mechanisms of digital inequality and how do they apply in the context of transport services?
3) Who might be negatively impacted by digitalisation in transport services?
4) What are potential outcomes of digital inequality in transport services?
5) What are suggested strategies to address digital inequality in transport services?

To answer these questions, explorative literature reviews on respectively digitalisation in transport services, transport-related social exclusion and digital inequality were conducted, followed by a systematic literature review on digital inequality in transport services. This chapter provides the main conclusions of this study and avenues for further research.

4.1 Conclusion per research question

4.1.1 What is digitalisation in transport services, how is it developing and what are its drivers?

Digitalisation in transport services is the gradual integration of and reliance on multiple digital technologies in the field of mobility. It is the result of decades of developments of modern technologies, progressively applied in this field. Manifestations include changes in the way people organise their mobility (planning, ticketing, paying), an increasing integration of mobility, as well as the emergence of shared mobility services, to which digital technologies gave a boost. Although digital media have not completely substituted for analogue ones in transport, they are also not only the mere conversion of information into bits and bytes. The gradual shift towards digital media in transport services has brought new, more or less formal rules, meaning new requirements on users, such as the central role the smartphone has taken within a decade. For travellers, these digital transformations mean more customisation and flexibility, for operators more efficiency while maintaining costs low and for policymakers, the potential to support society in the face of environmental, social and economic challenges through a better use of resources.

Transport services are becoming increasingly reliant on ICTs as part of a growing dependence of modern life on digital technologies more generally. As more and more people use digital media in transport services, a self-reinforcing dynamic is created whereby ICTs give travellers an advantage – provided that they are able and willing to use these technologies. At the same time, it is important to realise that these digital transformations are

not just 'happening to us'. They are embedded in society, they are shaped by and shaping groups of individuals bearing responsibility. While digitalisation in transport services may have the potential to contribute to a more environmentally (and socially) sustainable mobility system, there are also a lot of economic and commercial stakes in the introduction of these digital technologies. When left unchecked, these stakes may fuel a technological push that downplays consequences on society in general.

4.1.2 What are the mechanisms of digital inequality and how do they apply in the context of transport services?

There are complex mechanisms at play behind digital inequality. The appropriation (or 'access') to digital technologies can be divided into four successive layers (or 'factors'): motivations and attitudes towards ICTs, material access, digital skills, and usage of ICTs. These factors of access to digital technology are conditioned by an individual's resources (time, money, social network, etc.), which depend on one's personal characteristics and position within society, such as age, health, occupation and education. At the same time, the context in which individuals operate influences their access to digital technology. Technical characteristics of digital technologies, the embeddedness of these technologies in everyday practices and the extent to which non-digital alternatives are available impacts how individuals engage with digital technology.

Digital is becoming the default option to communicate with (potential) transport services' users. As such, a relatively low engagement with digital technologies can foster digital inequality in transport services. In terms of motivations and attitudes, digital technologies in transport services tend to be rejected based on privacy, security or reliability concerns, a lack of social network support and/or a perception that the technology is not useful or interesting. In terms of material access, periodic costs and efforts to purchase, replace and maintain devices, peripheries and (mobile) internet access can be dissuasive. In terms of digital skills, low operational and content-related skills can be barriers to engage with digital technology. Yet in transport services' increasingly complex and fragmented digital landscape, content-related skills such as information and strategic skills – knowing how and where to look for information, and how to act upon it – become crucial. In terms of usage, it can be expected that a low-frequency and a low-diversity use of transport-related digital technologies hamper the range of positive outcomes from technology use.

As such, digital inequality in transport services is not a binary state, as the oft-used expression 'digital divide' – *digitale kloof* – could let it presuppose. There is a gradual scale of digital inequality. Furthermore, top statistics in terms of smartphone and internet penetration rates hide the more complex reality that benefitting from what the digital world has to offer is not only about possessing a device or an internet connection. Not all of the 92% of the Dutch population with a smartphone can effectively (or is willing to) look for travel information on their mobile device, let alone use it to book or pay for a trip. The bigger picture is more complex and nuanced.

4.1.3 Who might be negatively impacted by digitalisation in transport services?

Vulnerability to digital inequality in transport services exists along dimensions of age (older adults and underage people), income level (people with lower levels), educational level (people with lower levels) and ethnicity (people from minorities). Still, literature highlights that there is a multiplicity of determinants that may cause and exacerbate the risk to have a low access to digital technologies in transport services, like learning and communication impairments. So far, studies that investigated digital inequality in transport services have mostly focused on reaching specific groups, which are expected to be vulnerable because of the difficulties they encounter with ICTs in general and/or because they are likely to be transport disadvantaged.

Older adults in particular get relatively more attention. Although there is a generational effect at play in digital inequality – people born during the eighties and after have often been educated and have grown up with digital media – there are also structural effects at play: younger people tend to be

naturally more open to new innovations, have more cognitive abilities and the educational system invites them to use new digital technologies early on. While generational effects will probably disappear over a few generations, structural effects will likely remain. Furthermore, the general picture is more nuanced than older people versus younger ones, particularly in terms of digital skills. Indeed, studies show that younger adults may be lagging behind in terms of being able to look for, critically select, assess and act upon digital information. Yet because of the increased complexity and fragmentation of information sources, digital skills are likely to be important to be able to navigate transport services. However, recent digital inequality studies in the Netherlands indicate that there might be a widening gap in terms of digital skills, with people with higher educational achievements being at an advantage. Furthermore, according to the Netherlands Court of Audit, around 2.5 million people aged 16 or older have difficulties writing and/or counting, which likely translate into difficulties navigating the digital world.

4.1.4 What are potential outcomes of digital inequality in transport services?

As ICTs are becoming increasingly ubiquitous and entangled in transport services, retaining non-digital alternatives that do not necessarily cost extra resources (time, money, etc.) is important to ensure individuals keep getting access to transport services. Indeed, the growth of digital connectivity notwithstanding, the potential and the ability to use transport services play an important role in how socially included some individuals are. In particular, unless carless people have enough resources such as money or social network or live close to the destinations they need to reach on a frequent basis, transport services play an important role in them being able to fulfil their mobility needs. In public transport, even though digital and analogue media still often coexist, the latter may take a modified form, potentially discouraging its use. This can be, for instance, a premium applied on a paper ticket or a yearly public transport subscription that can no longer be paid offline on a monthly basis. In shared mobility, this even goes further: not only is digital the default option, it is also nowadays frequently the only option. Naturally, commercial shared mobility providers may target the population they want, namely people with smartphones, bank accounts and credit cards. However, 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 pregnant. Additionally, the technical design and characteristics of ICTs can also have exclusionary effects. Known examples of this are issues related to low accessibility (small keypads, small fonts on websites, etc.) and low usability. A more covert example concerns automation and/or algorithmic processing features of digitally-based transport services. If left unsupervised, they may exclude – intentionally or not – groups of people that are already disadvantaged in some way, for instance by shunning poorer neighbourhoods. In general, digital inequality research has already established that digital inequality tends to reflect and exacerbate existing social inequality.

In short, a potential outcome of digital inequality in transport services is a limited or non-use of transport services, with possible consequences on mobility and the amount of available mobility options in general. Where some groups in the population might see their mobility options expanding due (in part) to ICTs through shared mobility modes notably, people who are less comfortable with digitalisation and its pace might see their mobility options remaining the same or even shrinking. This risk for polarisation is acknowledged in literature. Ultimately, digital inequality in transport services could reproduce and exacerbate transport disadvantage and the risk for transport-related social exclusion. There is still little empirical evidence on how digital inequality contributes to transport-related social exclusion though. Furthermore, digital technologies are arguably one piece in a complex socio-technical system that poses challenges for meeting the needs of vulnerable populations in general.

4.1.5 What are suggested strategies to address digital inequality in transport services?

Literature suggests three main practical approaches when it comes to mitigating (the impacts of) digital inequality in transport services:

1. Adapting technology to people is the most frequently cited solution, where organising technology around the way people process information and make decisions is seen as key.
2. Teaching people how to use technology is frequently mentioned, but it is often unclear how this should take place (e.g. reactive or proactive). Furthermore, relying on teaching as a solution can give the idea that people need to adapt to a technology that was not designed with them in mind.
3. Retaining and refining offline alternatives, safety nets and low-tech tools are mentioned as the internet, apps and smartphones do not work for everyone all the time. In general, literature emphasizes the importance of being able to interact with people rather than machines and calls for the development of a culture where help seeking and giving are more valued.

Besides these approaches and against a background of promises that digitalisation in transport services will foster social inclusion, literature also calls for a more people- and value-centered policy approach to digital technologies in transport services.

4.1.6 Main research question: How does digitalisation in transport services affect mobility for the population in the Netherlands, with particular attention to people who might not be ready to follow the pace of such a digital transformation?

Digitalisation in transport services offers many benefits for a variety of parties, from travellers to potential travellers, public transport operators and policymakers. Although digital media have not completely substituted for analogue ones in transport, digitalisation in transport services has progressively brought new, more or less formal rules, meaning new requirements on users. For instance, the smartphone has taken a central role in transport services, only within a decade. However, the physical access to a digital technology, e.g. a smartphone, does not necessarily provide all the benefits of this technology. A common misunderstanding is that digital inequality is set to disappear as smartphone penetration rates grow. Digital inequality in general is a complex and gradual process. This study shows that it is also the case in transport services. How people perceive digital technologies and the range of what they are able and willing to do with them also matter. As digital is progressively becoming the default way of communicating with (potential) travellers in transport services, low levels of engagement with digital technologies coupled with limited non- or low-digital alternatives can foster digital inequality in transport services. This has potentially detrimental consequences on mobility and subsequently on social inclusion, possibly exacerbating existing social inequalities. There is a share of the population who does not reap the benefits of digitalisation in transport services for a variety of reasons, but the size of this group remains unknown to this day. This study is a first step towards a better understanding of digital inequality in transport services. Empirical research is needed to develop and refine this understanding.

4.2 A research agenda for digital inequality in transport services

There seems to be a nascent but growing awareness of digital inequality in transport services, attested by the fact that the majority of the selected papers in the literature review are from 2018 or 2019. Throughout this report, multiple gaps in knowledge have been highlighted. With this study, we hope to have provided transport researchers with a first framework (the model of Van Dijk and the notion of indispensability) to approach digital inequality in transport services, notably to continue investigating the mechanisms involved in digital inequality in transport services. KiM will address some of these research gaps, as mentioned below.

Next studies from KiM on a related topic

As part of a direct follow-up of this study, KiM will be empirically investigating two research avenues: *mechanisms of digital inequality in transport services* and the *contribution of digital inequality to transport-related social exclusion*. Regarding *mechanisms of digital inequality in transport services*, i.e. how it develops and unfold among various groups, both the list of barriers for each factor of access to technology and the list of vulnerable groups mentioned in this literature review provide a first idea but they are unlikely to be exhaustive. Overall, literature gives first indications on who is likely to be more vulnerable to an increasing reliance on ICTs in transport services and in which way. Yet empirical evidence is scarce and often stems from small samples. Results sometimes even seem contradictory and the question of access to ICTs in relation to mobility is often summarised in a couple of questions; it is rarely the main focus. This is why more research is desired on this topic. Regarding the *contribution of digital inequality to transport-related social exclusion*, there is still very little empirical evidence available in literature on how digital inequality contributes to transport-related social exclusion. Digital inequality might be creating a new form of transport disadvantage. However, people who are experiencing issues with digitalisation in transport services may already have had issues when everything was still analogue. As such, digital inequality may be adding to existing disadvantages and thereby potentially exacerbating them, and/or possibly mitigating other forms of disadvantages. People may also have developed coping mechanisms, such that they might be at a disadvantage (i.e. low skills), but they can rely on their social network for help. For both of these research avenues, starting with a structured qualitative approach would be desirable. Indeed, a qualitative approach allows for flexibility (Flick, 2009), which is particularly suitable for the nascent state of research on this topic and its complexity.

Still as part of this research programme, KiM will be investigating *strategies to mitigate or prevent digital inequality in transport services*, as these are currently underexplored. For instance, although training is frequently mentioned, literature examined for this study never discusses the different ways to teach people and their pros and cons. Best practices in terms of how to adapt technology to people and how to retain offline alternatives are also seldom explicitly discussed. Here, drawing experience from other fields with a more mature understanding of digital inequality could be useful.

Besides this research programme, KiM has a research project planned in its yearly Work Programme on the links between ICT use and mobility in general. KiM will possibly use this project to explore another research avenue highlighted in this report: *the tangible benefits* that people reap from having access to digital technologies to organise their daily mobility. Are people with a low technology engagement really "missing out on something" that they cannot otherwise compensate? Who is able to reap such benefits and thanks to which determinants/factors? Inspired by third-level digital divide research (Van Deursen & Helsper, 2015), this would require an exploration that goes further than simply "ICTs in transport services provide convenience". This could allow for a better understanding of disparities in experiences among various groups and of the added value of investing in certain (policy) solutions.

Other valuable research avenues and approaches

Besides the qualitative approach suggested above on the *mechanisms of digital inequality in transport services* and the *contribution of digital inequality to transport-related social exclusion*, there would also be value in quantitatively investigating these research topics. This could be done for instance at the level of carefully selected population groups, in order to uncover nuances within specific groups. Indeed, as some population groups – such as older adults – are often considered as homogenous entities (Alsnih & Hensher, 2003), nuances among these groups are missed, possibly leading to stigmatisation and inadequate policies. Furthermore, a quantitative research on mechanisms of digital inequality in transport services at the level of the

population could be interesting, as it might bring to light latent issues with digitalisation in transport services within supposedly less vulnerable groups. In addition, there are multiple gaps in knowledge in terms of the *uncertainty around technologies and privacy concerns*. Technology can be misused (e.g. hacking) and can fail (e.g. power cuts, low battery). It would be relevant to investigate how app-based mobility service users experience these forms of uncertainty. Privacy issues and their impact on travel also require further research, as already underlined by Groth (2019). While this can be part of a study on the mechanisms of digital inequality in general, this would also fit well within an investigation on the values embedded in the design of these technologies, which might ultimately cause a form of exclusion by design. Besides, investigating how exclusion by design takes shape in various transport modes and the role that ICTs play in that – similarly to what Nixon and Schwanen (2019) did on bike sharing – would offer relevant insights for general research on digital inequality in transport.

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Appendices

Appendix 1: Method for the systematic literature review

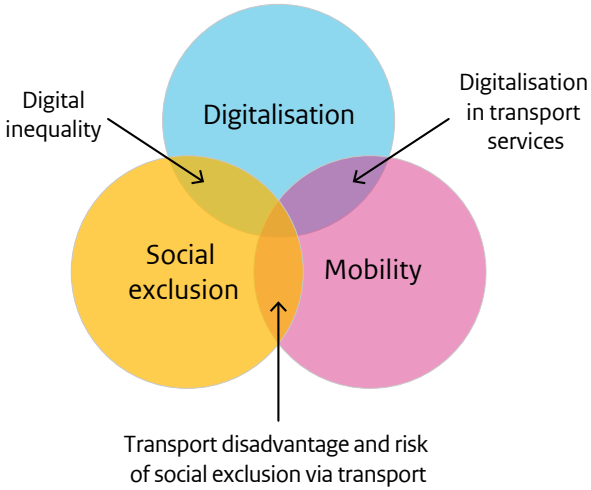
This appendix details successively:

1. How relevant studies were identified for the systematic literature review presented in Chapter 3,
2. How these studies were analysed to produce Chapter 3.

Identification of relevant studies

The identification of relevant studies starts with the identification of relevant keywords in English and in Dutch. Then, studies were searched through five queries in both languages. After this, a structured process was used to screen and select relevant studies.

Figure 13: Central concepts of the research with the main themes (circles) and sub-themes



Keywords

To identify relevant studies, keywords are assigned to each of the themes of this study and their overlap depicted in Figure 13. The goal here is to find papers that address the overlap between all three themes, i.e. papers that would stand at the centre of Figure 13. Therefore, we are not specifically interested in the papers found for each theme or for the intersection between each pair of themes. The strategy to find keywords, given in Table 4, was as followed:

- The keywords are chosen to be broad enough to cover a variety of fields, where scholars may be using different terminologies.
- The departure point for each theme is the keyword shown in Figure 13.
- Known relevant sources were used to add keywords to each theme.
- Synonyms, historic terms, antonyms and homonyms for these main keywords were brainstormed, discussed and identified by all of the authors. This is done to ensure that the bias to more modern technologies in particular is reduced. However, because older sources are not always as easily retrievable as newer ones, we cannot completely prevent this bias.

We justify here some choices in keywords:

- For the theme *Social exclusion*, 'social inclusion' and 'social exclusion' alone were not deemed to be sufficient, as some scholars use different concepts that (at least partly) encompass these notions, such as 'social participation' (Cass et al., 2005), 'social engagement' (Bennett, 2019), 'social sustainability' (Jeekel, 2017), a component of which is 'equity' (Gebresselassie & Sanchez, 2018). Social inclusion is usually a key point in equity analyses (Jin et al., 2019; Lucas, van Wee, et al., 2016).

- For *Digitalisation in transport services*, only keywords referring to broad trends and developments around this theme were used. We expect that relevant studies for this literature review focusing on one specific feature of digitalisation in transport, for instance smartcards, have also used a more generic term such as "intelligent transport systems" when addressing digital inequality and social exclusion concerns.
- For *Social exclusion via transport*, we used terms that are often used interchangeably with this concept as Lucas, Mattioli, et al. (2016) note, such as 'transport/mobility poverty', 'transport disadvantage' and 'accessibility poverty'. Other terms that are also often closely used include 'transport accessibility' (Pyrialakou et al., 2016), 'unmet travel needs' (Ryan & Wretstrand, 2019) and 'transport inequality' (Lucas, 2012).
- We used a similar process for *Digital inequality*. Terms that are often closely used with 'digital inequality' and 'digital divide' were added, such as 'digital skills' and 'internet skills' (Van Deursen, 2010), 'digital literacy' (Scheerder et al., 2017), 'access to ICT' (Selwyn, 2004) and 'e-inclusion' (Van Dijk, 2012).
- For *Mobility*, we do not focus on specific modes, therefore 'car sharing' or 'ride sourcing' are not included as keywords. The reasoning behind this choice is threefold:

1. Relevant papers looking at e.g. digital inequality in car sharing would likely use words such as 'mobility' or 'travel' in their abstract or keywords, and therefore they would be covered,
2. If not, other selected papers would likely mention them, and the relevant results would then be covered as we are not only interested in empirical results but also literature reviews/overviews of empirical studies,
3. The scope is already large enough, looking in details at each specific mode could make the literature review too broad.

Table 4: Keywords in English and Dutch languages

Theme	Keywords in English	Keywords in Dutch
Digitalisation	digital* OR technolog* OR analog OR telematics OR ICT	digital* OR technolog* OR informatica OR telematica OR analoog OR ICT
Mobility	mobilit* OR transport* OR travel* OR trip*	transport OR mobiliteit* OR vervoer* OR reis* OR reizen OR verplaats* OR ritten
Social exclusion	"social* inclu*" OR "social* exclu*" OR “social participation” OR “social* sustainab*" OR *equit* OR “social engagement”	“sociale achterstand” OR “sociale uitsluiting” OR “socia* inclusi*” OR “sociale participatie” OR “maatschappelijke participtie” OR “socia* duurzaam*” OR rechtvaardig*
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 MaaS OR “mobility innovation” OR “transport innovation” OR “mobility app*” OR “transport technolog*”	“mobility-as-a-service” OR MaaS OR “digitalisering van vervoersdiensten” OR reisinformatie OR “integrale mobiliteit” OR mobiliteitsapp OR mobiliteitsinnovatie OR reis*app OR “slimme mobiliteit”
Social exclusion via transport	“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”	vervoersarm* OR mobiliteitsarm* OR “toegang tot het mobiliteitssysteem” OR ((billijk* OR gelijkwaardig* OR inclusie) AND (mobiliteit OR vervoer OR verplaatsingsmogelijk* OR transport)) OR transportarm* OR “inclusie* transport” OR “inclusie* mobiliteit” OR “toegankelijkheid van het mobiliteitssysteem” OR “toegankelijkheid van het vervoersysteem” OR mobiliteitsgeluk
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”	“digitale kloof” OR “digitale ongelijkhe*” OR “digitale vaardighe*” OR “e-inclusie*” OR einclusie* OR “toegang tot technologie” OR “toegang tot ICT” OR “digitbeet” OR “digita* *clusie*” OR “digitale uitsluiting”

Queries

Each query is the intersection (boolean AND) between one or multiple sets of keywords, as can be visualised in Figure 14. For instance, Q3 is: (keywords *Social exclusion via transport*) AND (keywords *Digitalisation*).

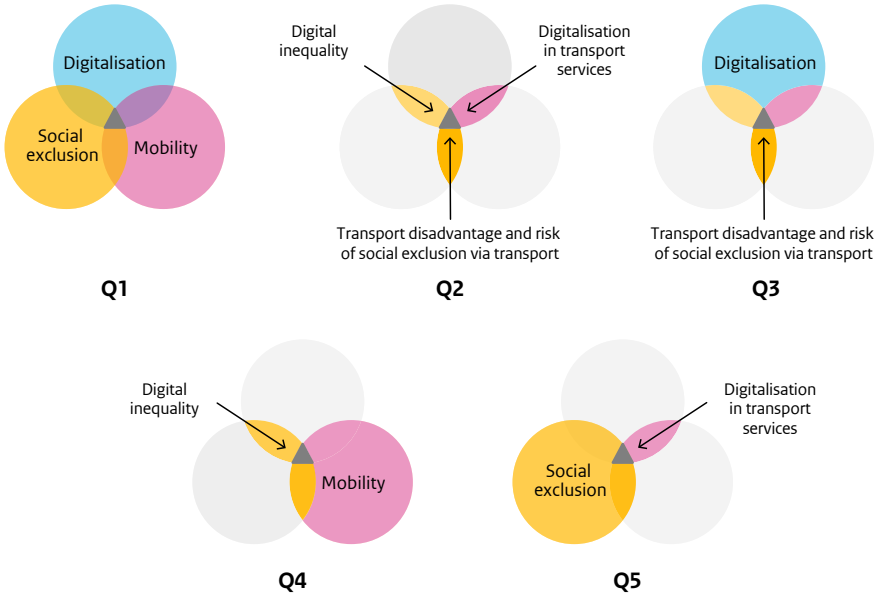


Figure 14: Queries used for the systematic literature review

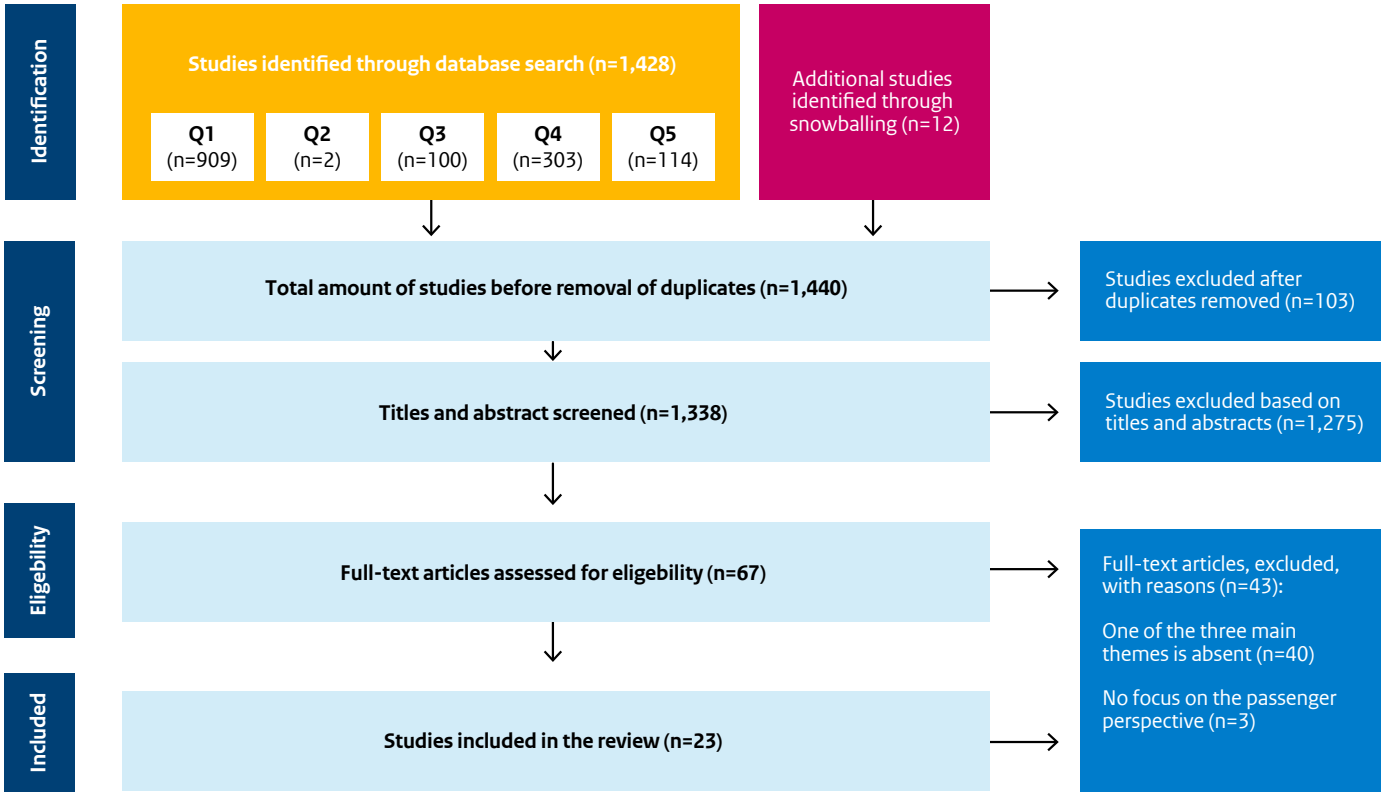
In English, we used the scientific database Scopus. Titles, keywords and abstracts of journal articles, conference proceedings and book chapters were scanned through the queries shown in Figure 14. In Dutch, we used the browser Google for the search process, still using the queries. Here, we also considered grey literature such as unpublished scientific work and studies from governmental institutes. This process was conducted in October 2019.

Screening and selection process, use of snowballing

For the screening and selection process, we distinguish between the search with the Dutch keywords and with the English keywords.

Using the English keywords: We borrow from medical standards to conduct the systematic literature review. The PRISMA guidelines to select papers (Moher et al., 2009) is followed. This takes place in four steps, shown in Figure 15. Given the high amount of studies to screen, the web application Rayyan was used (Ouzzani et al., 2016). It allows for a smoother and quicker screening process (Step 2 of PRISMA) by providing semi-automation features. We identified fifteen papers through the database search previously presented. In order to be as complete as possible in the search process, a forward and backward snowball review were conducted on the papers found at the Eligibility step, as described by Van Wee and Banister (2016). Kitchenham and Charters (2007) consider these techniques as useful additions to systematic database searches. However, because of reaching saturation in qualitative research is, in theory, impossible (O'Reilly & Parker, 2012) and because of the rapid development of fields such as digitalisation and smart mobility, an exhaustive review may per se be impossible. When using snowballing, we found a master thesis from the MIT for which no peer-reviewed paper could be found but which was deemed particularly pertinent to include as it provides the first mention of a 'transit digital divide', and can be used to 'look back' on developments, since it is one of the oldest selected studies (see Rizos (2010)). After reconciliation, a total of twenty-three articles were included to be analysed.

Figure 15: PRISMA flowchart for the systematic literature review, English keywords (October 2019).



We excluded papers at the screening phase for the following reasons:

- They were focusing solely on the development and the evaluation of assistive technologies in transport (such as specific devices to help vision-impaired people navigating public transport) or on the (design of a better) user experience. Assistive technologies are digital devices used in the context of transport, but we do not categorise them as 'endogenous' manifestations of digitalisation in transport and they are, as such, out of scope. The needs of specific groups of users are indeed usually taken into account only "a posteriori" (Bekiaris et al., 2009).
- They were focusing on issues around substitution and complementarity of ICTs in transport (or multitasking, etc.), delineated as out of scope in Chapter 1.
- They did not cover the themes at all.

We excluded papers at the eligibility phase (n=43) for the two main following reasons:

- Some papers did not elaborate in the full text on digital inequality aspects (n=16), social exclusion aspects (n=3), digitalisation in transport (n=11) while the abstract/keywords/title could let us think so, such as studies on mobility of specific groups, assistive technologies in transport and user experience studies.
- Three papers covered the suppliers' perspective such as Velaga et al. (2012), which nevertheless has the appropriate title "Transport poverty meets the digital divide".

Using the Dutch keywords: Each Google search yielded a limited number of results. We selected relevant studies by screening texts online, using the same criteria as the ones mentioned above for the search in English (n=5). Forward and backward snowballing yielded no additional paper.

Analysis of relevant studies

Not only is the selection process of papers important for a literature review, but the way results are analysed and presented is also crucial (Van Wee & Banister, 2016). Driven by our research questions, we adopted two concurrent approaches based on content analysis to examine the papers. The main limitation of our analysis is that it was performed by one researcher only, meaning that there is a potential bias. However, results were regularly presented and brainstormed with three other researchers.

Approach 1: Directed content analysis relying on Van Dijk's model, complemented by the criteria of indispensability

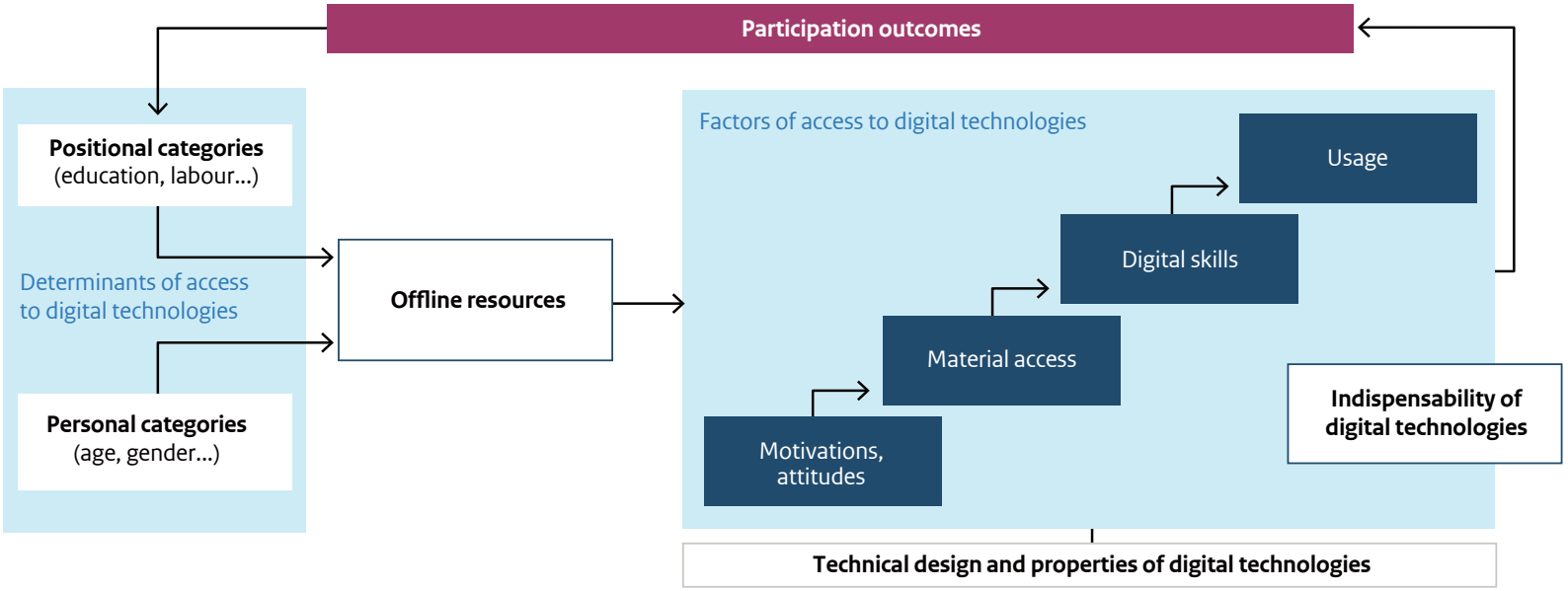
The research questions we sought to answer through this approach are the following:

2) What are the mechanisms of digital inequality and how do they apply in the context of transport services?
3) Who might be negatively impacted by digitalisation in transport services?
4) What are potential outcomes of digital inequality in transport services?

We examined independently each selected paper through a directed content analysis. A directed contend analysis implies starting the analysis with a theory as guidance (Hsieh & Shannon, 2005), to read and cluster insights from literature. This approach is therefore essentially deductive. Note that since literature remains limited, not only were we interested in the empirical results of the selected papers, but also in their overview of literature.

In our case, Van Dijk's model and the criteria of indispensability that we attached to it (as presented in section 2.3.2) were used as the lens through which the selected papers were examined. A simplified version is shown in Figure 16.

Figure 16: Van Dijk's model of causal and sequential model of access to digital technology (Van Dijk (2005), updated based on Van Dijk (2019), complemented with the criteria of indispensability (Lupač, 2018).



It resulted in five main topics emerging:

- Determinants of digital inequality in transport services (discussed in section 3.2),
- Factors of digital inequality in transport services (section 3.3),
- The technical design of technologies (section 3.4),
- The indispensability of digital technologies in transport services (section 3.5),
- Consequences of digitalisation in transport services (section 3.6).

We chose to discuss resources in relation to the factors of access to technology, as it is common to do so in digital inequality research (see the book of Van Dijk (2019), The Digital Divide).

Approach 2: Conventional content analysis for the benefits of digitalisation and solutions to digital inequality in transport services

Through this approach, we sought to provide answers related to the two following research questions:

1) What is digitalisation in transport services, how is it developing and what are its drivers?
5) What are suggested strategies to address digital inequality in transport services?

The approach we adopted here was a conventional content analysis, which is deemed most appropriate when existing theory on a given topic is limited (Hsieh & Shannon, 2005). Here, there is no preconceived category, "allowing the categories and names for categories to flow from the data"; it is essentially an "inductive category development" (Hsieh & Shannon, 2005, p. 1279). Chapter 2 already offered answers to research question 1. Therefore, for the systematic literature review, we mainly sought whether there would be new relevant insights. One recurring theme that emerged from the papers pertains to the benefits of digitalisation in transport services. These are frequently characterised as a main reason why digital technologies are increasingly being relied upon in transport services. Two main sub-categories that emerged here are the improvement in travellers' experience and digital technologies' ability to target specific groups to address social exclusion. Regarding research question 5, two main categories emerged: practical solutions one the one hand, and a more critical reflection on the development of technologies in transport services on the other hand. Within practical solutions, three sub-categories emerged: teaching people how to use technology, adapting technology to people and retaining and refining offline alternatives, safety nets and low-tech tools.

Appendix 2: Selected papers for the systematic literature review

The method applied to select papers has resulted in a diversity of paper, with a variety of primary angles[20], as shown in Table 5. Table 6 presents the selected papers, by detailing their main objectives, their data collection (if applicable) and the framework they employed for analysis, if specified. When relevant, the geographical scope is specified. The diversity in primary angles and frameworks hints at the fact that there is a lot of diversity in how digital inequality in transport services is approached.

Table 5: Primary angles in the 28 selected papers.

Primary angle	Amount of papers
Transport policy, public transport	11
Urban science, geography	5
Human factors and ergonomics	4
Ethics in ICTs	3
Medicine	2
Sociology	2

20 Of the journals, conferences or books for English literature; of the authors' field for Dutch literature.

Table 6: Presentation of the 28 selected papers.

Author(s) and year	Main objective of the study	Data collection (n=sample size)	Framework for analysis, if specified
Bastiaanssen (2012)	Get insights on how transport possibilities influence job seekers' work re-integration in low-income neighbourhoods	Interviews (n=18) in Rotterdam, The Netherlands	Motility and time-space geography
Bekiaris et al. (2009)	Analyse the contribution of ICTs to accessible transportation and define mobility-impaired users' needs in the era of intelligent mobility	Literature, interviews with transportation institutions and operators, organisations and societies of people with disability	-
Bigby et al. (2019)	Investigate the barriers of experiences of train passengers with communication disabilities	Individual interview or focus groups (n=21) in Sydney, Australia	-
Canzler and Knie (2016)	Engage with the reasons why the private car is losing its significance and with the role and challenges of digitalisation in the new mobility era	n.a.	-
Chee (2018)	Assess the social issues that come from an increasing reliance upon digitally-based transport services; focus on US context	n.a.	Social justice perspective
Ettema and Cornea (2018)	Examine transport experiences of people living in rural areas in the Netherlands	Two focus groups (n=13) in Zeeland, The Netherlands	-
Gebresselassie and Sanchez (2018)	Bring forward issues of social sustainability in the 'smart mobility' discourse	Literature review on the intersection of "smart" and "sustainability". Analysis of 60 transport apps	-
Golub et al. (2019)	Assess equity issues of smart mobility in low-income neighbourhoods	Two focus groups (n=12+not specified) and survey, online (n=155) and in-person (n=153) in Portland, US	-
Groth (2019)	Integrate the approach from transport poverty into multimodal behaviour research to offer a critical perspective on smart mobility	Survey handed over to respondents or dropped in mailbox (n=620) in Offenbach/Main, Germany	Transport poverty approach on mode options' distribution
Harvey et al. (2019)	Analyse how more older adults could access transport technologies and the key barriers to engage with such technologies	One-to-one interviews (n=32), experts' interviews (n=4) in the UK	-

Author(s) and year	Main objective of the study	Data collection (n=sample size)	Framework for analysis, if specified
Jin et al. (2018)	Analyse the impact of ride sourcing on society; focus on the US context	Systematic literature review of the impacts of ride sourcing on efficiency, equity and urban development	-
Jorritsma et al. (2018)	Define a framework for the concept of transport poverty to investigate which groups are impacted; focus on the Dutch context	Literature review on transport poverty	Transport poverty from the perspectives of social exclusion, social capital and capability, transport justice
Kamga et al. (2013)	Examine the implementation of interactive passenger kiosks in New York, US	Passenger intercept surveys (n=563), usage logs and field observations (40h)	-
Lamont et al. (2013)	Analyse the role of travel information provision in mobility-related social exclusion of people with dyslexia	Six focus groups (n=52) in the UK	Interactions between person-type factors and factors related to the transport system (acceptability, availability, affordability, accessibility)
Malik and Wahaj (2019)	Explore the social and economic implications of ride sourcing	Semi-structured interviews (n=14) in Pakistan	Social exclusion and inclusion
Musselwhite (2019)	Examine older people's attitudes towards transport-related technology	Four focus groups (n=36) in the UK	-
OV Ombudsman (2019)	Analyse the complaints submitted by Dutch PT users on the topic of digitalisation	Complaints of Dutch travellers	-
Pangbourne et al. (2010)	Improve the understanding of the relationship between older people, ICT, ITS and healthcare	Four focus groups in the UK and supplemental questionnaires (n=48)	-
Pangbourne (2018)	Demonstrate that mobility and technology are intertwined in complex ways	n.a.	-
Pangbourne et al. (2019)	Investigate the extent to which MaaS promises can be delivered, and the unanticipated societal implications of a widespread MaaS adoption	Literature review (peer-reviewed studies and grey literature)	Multi-Level Perspective of socio-technological transitions
Rizos (2010)	Highlight and discuss implementations practices and challenges of PT travel information systems	Literature review and interviews with Canadian and American PT authorities (n=13)	-
Sabie and Ahmed (2019)	Document the struggles of accessing digital services for refugees	One-on-one interviews (n=19) in Canada	Human-Computer Interaction (HCI) perspective

Author(s) and year	Main objective of the study	Data collection (n=sample size)	Framework for analysis, if specified
Shirgaokar (2018)	Investigate how private and public sectors can work to increase ride sourcing as a mobility option for older adults	One-one-one interviews (n=76), four focus groups (n=24) in Canada	Theory of Acceptance Model (TAM) (usefulness/ease of use)
Snellen and de Hollander (2017)	Discuss how ICTs are changing mobility and how they challenge public values in policymaking; examples from the Dutch context	Interviews with experts in the field of digitalisation in transport	Public values (accessibility, availability, affordability, acceptability)
Sochor and Nikitas (2016)	Develop an understanding of how older people and visually impaired people perceive transport technologies	Bristol, UK: survey sent by post (n=491) and three focus groups (n=30). Stockholm, Sweden: semi-structured interviews (n=23) and survey (n=252)	Urban access (transport-oriented social inclusion)
Van der Meulen et al. (2018)	Investigate how people with a mild impairment decide to make use of digital tools to support them and what they need from them	Three focus groups (n=17) and one-on-one interviews (n=5) in The Netherlands	-
Vecchio and Tricarico (2018)	Discuss the impacts of mobility innovations in shaping individuals' mobility preferences	Literature review on mobility information and new technologies	Human geography, urban policy and behavioural economics
Wang and Mu (2018)	Explore spatial disparities of accessibility using Uber in Atlanta, US	UberX and UberBLACK data	Accessibility (expectation and variability of waiting time)

Appendix 3: Main topics in the literature review and corresponding relevant studies

Theme	**Studies** *(studies selected during the systematic literature review process only)*
Section 3.1: The benefits of digitalisation in transport services	
An improvement of travellers' experience through digitalisation	Canzler and Knie (2016); Chee (2018); Kamga et al. (2013); Musselwhite (2019); OV Ombudsman (2019); Rizos (2010); Shirgaokar (2018); Snellen and de Hollander (2017); Sochor and Nikitas (2016); Vecchio and Tricarico (2018)
Technologies targeting specific groups	Bekiaris et al. (2009); Bigby et al. (2019); Canzler and Knie (2016); Gebresselassie and Sanchez (2018); Golub et al. (2019); Groth (2019); Harvey et al. (2019); Malik and Wahaj (2019); Pangbourne (2018); Pangbourne et al. (2010); Sabie and Ahmed (2019); Snellen and de Hollander (2017); Sochor and Nikitas (2016)
Section 3.2: Determinants of digital inequality in transport services	
Section 3.2.1: Main personal and positional categories of vulnerable groups	
Older adults as a vulnerable group	Chee (2018); Ettema and Cornea (2018); Gebresselassie and Sanchez (2018); Golub et al. (2019); Harvey et al. (2019); Jin et al. (2018); Kamga et al. (2013); Malik and Wahaj (2019); Musselwhite (2019); Pangbourne (2018); Pangbourne et al. (2010); Shirgaokar (2018); Sochor and Nikitas (2016)
Underage people as a vulnerable group	Chee (2018)
People with lower income levels as a vulnerable group	Chee (2018); Gebresselassie and Sanchez (2018); Golub et al. (2019); OV Ombudsman (2019); Pangbourne (2018)
People with lower educational levels as a vulnerable group	Groth (2019); Jin et al. (2018)
Minorities as a vulnerable group	Golub et al. (2019); Sabie and Ahmed (2019)
Section 3.2.2: A multiplicity of determinants involved in the process of exclusion from digital technologies in transport services	
Impairments and low literacy/numeracy levels as barriers to access digital technologies	Bekiaris et al. (2009); Bigby et al. (2019); Gebresselassie and Sanchez (2018); Lamont et al. (2013); Malik and Wahaj (2019); OV Ombudsman (2019); Sabie and Ahmed (2019); Van der Meulen et al. (2018)
Vulnerable groups having issues with analogue tools as well	Bigby et al. (2019); Lamont et al. (2013)
Section 3.3: Factors of access to digital technology in transport services	
Motivation and attitudes	
The importance of attitudes and motivation	Groth (2019); Musselwhite (2019); Sochor and Nikitas (2016)

Theme	**Studies** *(studies selected during the systematic literature review process only)*
Rejection due to a perceived lack of security, privacy and reliability	Ettema and Cornea (2018); Harvey et al. (2019); Pangbourne (2018); Pangbourne et al. (2010); Shirgaokar (2018); Snellen and de Hollander (2017). For privacy in particular, see Golub et al. (2019); Groth (2019); Jin et al. (2018); Vecchio and Tricarico (2018)
Rejection due to unfamiliarity/lack of interest or usefulness	Ettema and Cornea (2018); Groth (2019); Harvey et al. (2019); Lamont et al. (2013); Shirgaokar (2018); Sochor and Nikitas (2016)
Importance of the social network	Harvey et al. (2019); Sabie and Ahmed (2019)
Material access	
Cost of material access	Chee (2018); Groth (2019); Harvey et al. (2019); Jin et al. (2018); Kamga et al. (2013); Rizos (2010)
Push towards owning more/newer digital technology	Bekiaris et al. (2009); Bigby et al. (2019); Harvey et al. (2019); Pangbourne (2018); Pangbourne et al. (2010)
Owning a smartphone is not enough	Golub et al. (2019); Groth (2019); Harvey et al. (2019); Vecchio and Tricarico (2018)
Digital skills	
Material access is not enough: need for digital skills	Chee (2018); Golub et al. (2019); Groth (2019); Pangbourne et al. (2010); Rizos (2010); Sabie and Ahmed (2019)
Importance of digital skills to look for travel information	Groth (2019); Jin et al. (2018); Jorritsma et al. (2018); Rizos (2010); Sabie and Ahmed (2019); Snellen and de Hollander (2017); Vecchio and Tricarico (2018)
Digitalisation leading to an increase in complexity in transport services	Bekiaris et al. (2009); Canzler and Knie (2016); Lamont et al. (2013); Shirgaokar (2018); Snellen and de Hollander (2017); Sochor and Nikitas (2016); Vecchio and Tricarico (2018)
Privacy management as a digital skill in transport services	Groth (2019)
Section 3.4: The technical characteristics of digital technologies in transport services	
Importance of the technical design of hardware and software; usability	Harvey et al. (2019); Pangbourne (2018); Pangbourne et al. (2010)
The risk of a (spatial) selectivity of algorithms	Chee (2018); Snellen and de Hollander (2017); Vecchio and Tricarico (2018); Wang and Mu (2018)
Section 3.5: The indispensability of digital technologies in transport services	
Section 3.5.1: A shift towards digital by default and concerns around the availability of non-digital alternatives in public transport	

Theme	**Studies** *(studies selected during the systematic literature review process only)*
Growing dependency of public transport on ICTs	Bekiaris et al. (2009); Bigby et al. (2019); Gebresselassie and Sanchez (2018); Harvey et al. (2019); Pangbourne (2018); Pangbourne et al. (2010); Rizos (2010); Snellen and de Hollander (2017)
Concerns around the availability of non-digital alternatives in public transport	Bigby et al. (2019); Kamga et al. (2013); Musselwhite (2019); OV Ombudsman (2019); Pangbourne (2018); Pangbourne et al. (2010); Snellen and de Hollander (2017)
Section 3.5.2: Shared mobility: more than digital by default, digital only	
Digital only in shared mobility	Canzler and Knie (2016); Golub et al. (2019); Groth (2019); Malik and Wahaj (2019); Pangbourne et al. (2019); Snellen and de Hollander (2017); Vecchio and Tricarico (2018)
Banking divide	Golub et al. (2019); Pangbourne et al. (2019)
Section 3.6: The consequences of digitalisation in transport services in terms of mobility and social exclusion	
A decrease in mobility and a risk of transport-related social exclusion as outcomes of low access to digital technology	Bekiaris et al. (2009); Bigby et al. (2019); Chee (2018); Groth (2019); Jin et al. (2018); Jorritsma et al. (2018); Lamont et al. (2013); Vecchio and Tricarico (2018)
Exclusion from environmentally sustainable transport services	Canzler and Knie (2016); Groth (2019); Pangbourne et al. (2019); Snellen and de Hollander (2017)
Section 3.7: Solutions put forward	
Section 3.7.1: Practical solutions	
Teaching people how to use technology	Bigby et al. (2019); Golub et al. (2019); Harvey et al. (2019); Lamont et al. (2013); Sabie and Ahmed (2019); Shirgaokar (2018)
Adapting technology to people	Bekiaris et al. (2009); Bigby et al. (2019); Golub et al. (2019); Harvey et al. (2019); Lamont et al. (2013); Pangbourne (2018); Pangbourne et al. (2010); Shirgaokar (2018); Sochor and Nikitas (2016)
Retaining and refining offline alternatives, safety nets and low-tech tools	Bigby et al. (2019); Ettema and Cornea (2018); Golub et al. (2019); Harvey et al. (2019); Lamont et al. (2013); OV Ombudsman (2019); Pangbourne et al. (2019); Sabie and Ahmed (2019); Snellen and de Hollander (2017)
Section 3.7.2: A more people- and value-centred policy approach to digital technologies in transport services	
Technological solutionism in transport services' innovations	Canzler and Knie (2016); Gebresselassie and Sanchez (2018); Jin et al. (2018); Pangbourne et al. (2019)
The need for a more people- and value-centred approach	Pangbourne et al. (2019); Rizos (2010); Snellen and de Hollander (2017); Sochor and Nikitas (2016)

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