# Digital engagement for travel information among car and public transport users in the Netherlands

Durand, Anne; Hamersma, Marije; van Oort, Niels; Hoogendoorn, Serge

**DOI**
10.1016/j.trip.2024.101285

**Publication date**
2024

**Document Version**
Final published version

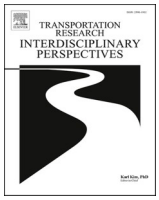
**Published in**
Transportation Research Interdisciplinary Perspectives

Transportation Research Interdisciplinary Perspectives 28 (2024) 101285

Contents lists available at ScienceDirect

Transportation Research Interdisciplinary Perspectives

journal homepage: www.sciencedirect.com/journal/transportation-research-interdisciplinary-perspectives



# Digital engagement for travel information among car and public transport users in the Netherlands

Anne Durand [a,b,*,1], Marije Hamersma [b], Niels van Oort [a,2], Serge Hoogendoorn [a,3]

[a] Delft University of Technology, Faculty of Civil Engineering and Geosciences, Department of Transport & Planning, P.O. Box 5048, 2600GA Delft, the Netherlands
[b] KiM Netherlands Institute for Transport Policy Analysis, Postbus 20901, 2500 EX, The Hague, the Netherlands

ARTICLE INFO

*Keywords:*
Digitalisation
Indispensability
Digital skills
Smartphone
Inclusive transportation
Transport disadvantage

ABSTRACT

As the offer of digital services in transport expands, understanding users' digital engagement and how it developed over time is important to make informed policy decisions. In particular, we lack an understanding of how both PT (public transport) *and* car users access and engage with digital technologies and perceive them to be necessary to travel. This article aims at bridging this gap, using a 2022 survey of representative samples from both populations in the Netherlands.

There is clear evidence of travellers getting more used to digital technologies over time. In 2022, at most 80% of car and PT users relied at least from time to time on their smartphone to look for travel information. As expected, higher digital skills correlate positively with the likelihood of using smartphone-based travel information. It is worth noting that PT users report higher digital skills than car users, while these samples do not differ significantly in terms of age and education levels. As such, low (perceived) digital skills might be a barrier to switching from the car to public transport.

Almost 75% of car and PT users think that travelling is more difficult nowadays without a smartphone, demonstrating a radical shift in societal expectations within a decade and a half. Alternatives like public information displays exist and are still used by the majority, but traditional communication channels are not deemed sufficient anymore to travel worry-free. These perceptions can contribute to shaping reality and may put those with a lower digital access at a disadvantage.

## 1. Introduction

From government welfare to banking services, many services that people use nowadays are mostly or only online, often through a 'digital-by-default' approach (Yates et al., 2015). This is also the case in transport, where (real-time) travel information has become a fundament in the digitalisation of transport (Ben-Elia & Avineri, 2015; Yigitcanlar et al., 2024).

Despite the advantages digitalisation brings to many people in term of travel efficiency, this development puts populations that are less comfortable with digital tools at risk. In recent years, transport scholars have increasingly drawn attention to the potentially exclusionary effects of transport relying a lot, or solely, on the use of Information and Communication Technologies (ICTs) (or digital engagement[4]) from its users (Durand et al., 2022; Keseru & Randhahn, 2023). Researchers have also collected data to understand digital access and engagement in transport, at the scale of countries (Goodman-Deane et al., 2024), regions or cities (Golub et al., 2022; Groth, 2019; Zhang et al., 2020).

While these studies offer valuable insights into the broader impacts of digital developments, they have limitations on at least three key

* Corresponding author at: Delft University of Technology, Faculty of Civil Engineering and Geosciences, Department of Transport & Planning, P.O. Box 5048, 2600GA Delft, the Netherlands.

*E-mail addresses:* a.l.m.durand@tudelft.nl (A. Durand), marije.hamersma@minienw.nl (M. Hamersma), n.vanoort@tudelft.nl (N. van Oort), s.p.hoogendoorn@tudelft.nl (S. Hoogendoorn).

[1] ORCID: 0000-0003-4928-4270.
[2] ORCID: 0000-0002-4519-2013.
[3] ORCID: 0000-0002-1579-1939.

[4] According to digital inequality scholar Ellen Helsper, 'digital engagement' is more appropriate than 'ICT use' because the latter suggests that technologies are embedded and invisible, while they always exist in the background.

https://doi.org/10.1016/j.trip.2024.101285
Received 24 September 2024; Received in revised form 10 November 2024; Accepted 20 November 2024
Available online 2 December 2024

areas. First, they do not track how digital engagement has evolved over the years, while such information would be insightful to better understand digital transformations. A second limitation is their lack of assessment of perceptions of the necessity of digital engagement and how these perceptions might influence actual digital participation. Insight into such societal expectations would contribute to a better understanding of the extent to which a system has indeed become digital by default. Groth (2019) attempted to measure these perceptions, but their statements were not specific to transport and did not end up into a single factor after data reduction, leaving a gap on that matter. Last but not least, most studies examining digital access and engagement tend to focus on public transport (PT) users (e.g. Un et al. (2022), Goodman-Deane et al. (2021)). This means that there is no data available to compare the digital engagement of users of different transport modes, while there are indications that a modal shift from the car to public transport is at least partly predicated on one's ability to retrieve travel information (Ravensbergen et al., 2022; Schmitt et al., 2019). To the best of our knowledge, the latest study comparing car and public transport users in terms of digital engagement dates from more than a decade (Farag & Lyons, 2012).

The goal of this study is to provide insights into the (process of) digital engagement of public transport *and* car users, and to shed more light on developments related to this digital engagement. Our study uses a survey distributed in 2022 among representative populations of PT and car users in the Netherlands. Our survey was distributed among participants of a longitudinal household panel, allowing us to track changes among some of our respondents between 2018 and 2022. We focus more on the smartphone than on other digital tools as smartphone-based services play such a central role in transportation systems nowadays (Yigitcanlar et al., 2024). We also place more emphasis on digital travel information services, since both car and PT users can use these services (unlike digital ticketing services, which are mostly in PT).

This study offers relevant insights for policymakers and transport professionals internationally. The Netherlands is one of the leaders on the European scene in terms of digitalisation (European Commission, 2022). It is particularly interesting to examine digital engagement and perceptions around the necessity of such an engagement in the context of a country at the forefront of digitalisation, as it allows other countries to better understand the ins and outs of widespread digitalisation. Besides, this snapshot in time of digital engagement as well as developments in digital engagement in transport can help transport decision-makers make informed policy decisions about future technological advances in the transport sector (Vrščaj et al., 2020).

After explaining the concepts of digital access, digital engagement and necessity of digital technologies in section 2, we explain our research methods and data in section 3. Section 4 presents our results. The article closes with a discussion and a conclusion in section 5.

## 2. Digital engagement and necessity of digital technologies

### 2.1. Digital engagement and its process

For a long time, digital engagement or ICT use boiled down to whether people had a computer and an internet connection or not, and were motivated to go online (Lupač, 2018). As the internet has become more widely accessible over the years, communication science researchers have developed and tested frameworks to describe and explain various degrees of digital engagement (Pick & Sarkar, 2016).

Besides the clear contribution of sociodemographic, socioeconomic and cultural aspects to explain digital engagement, four main components are frequently used to describe and explain *the process of digital engagement*, also called *digital access*: *motivation*, *material access*, *digital skills* and finally, *usage* or *engagement* itself (Helsper, 2021; Van Dijk, 2019). Motivation and material access are still used to explain digital engagement, with the latter no longer being limited to having an internet connection; nowadays, material access also covers the quality and the diversity of (peripheral) devices (smartphones, tablet, printers, etc.) one possesses (Van Deursen & Van Dijk, 2018). Digital skills cover various types of skills, from technical know-how to more strategic skills allowing users to evaluate content's quality and trustworthiness (Van Dijk & Van Deursen, 2014). Engagement is about the frequency of use of the internet and digital technologies, the type of activity performed and the duration of use (Van Dijk, 2005).

### 2.2. Necessity of digital technologies

In their literature review on digital inequality in transport, Durand et al. (2022) explained that several researchers in communication science are critical about *motivation* being the entry point to understand digital access. As digital technologies are becoming increasingly ubiquitous, *motivation* is no longer the main precondition to access technology it used to be. In a digital-by-default ecosystem, motivations matter less than they used to in the early internet days because alternatives to digital technologies are limited or invisibilised (Mariën et al., 2016). Lupač (2018) theorised this notion of necessity, which they call *indispensability*. How indispensable a digital engagement is, is highly contextual and depends on two aspects according to Lupač (2018):

- The level of embeddedness of a given digital technology in everyday routines and institutions,
- The availability of non-ICT alternatives, factoring in potential costs (time, money, energy, etc.) to access these alternatives.

In this study, we measure perceptions of indispensability, using the definition provided by Lupač (2018) as a starting point. We will also operationalise motivation, material access, skills and usage as explained in next section.

## 3. Methods and data

### 3.1. Choice of instrument: Netherlands Mobility Panel

We chose a household panel representative of the Dutch population to conduct our study, the Netherlands Mobility Panel (Mobiliteitspanel Nederland, MPN). The MPN is an annual online panel designed for the longitudinal study of travel behaviour in the Netherlands (see Hoogendoorn-Lanser et al. (2015)). In addition to the annual panel waves, MPN respondents occasionally take part in specific surveys, like the one designed for the current study. The choice for this instrument was motivated by two aspects:

- A few questions linked to digital access have already been used in the MPN in 2018 (see Zijlstra et al. (2020)), thereby allowing us to track evolutions within 4 years' time among the same respondents.
- The MPN has the advantage that we know a lot about respondents' travel behaviour. This gives us the unique opportunity to select and reach representative samples of PT and car users at a large-scale (national) level. Note that the representativeness is done on four variables: age, gender, education level and travel mode frequency.

The use of this online instrument means we cannot guarantee that we have representative samples in terms of digital engagement of all Dutch PT and car users. However, according to Statistics Netherlands (2023a, 2023b), 97 % of the Dutch population aged 12 and older had access to internet at home in 2022 and 74 % had at least basic digital skills in 2021. Besides, note that a recent national report on digital inclusion in the Netherlands, acknowledged as a trusted source, also made use of an online questionnaire only (Van Deursen, 2023). Nevertheless, we understand that the digital engagement we will measure through this instrument will likely be an overestimation of the real digital engagement of car and PT users.

### 3.2. Survey design

#### 3.2.1. Target population

We have two target populations: adult (18 years and older) public transport users, and adult car users with a driver's license. We consider people to be 'users' when they use a certain transport mode at least 6 times per year. This is because we want respondents to be able to recall how they usually search for travel information. Since these samples are representative, some PT users will also be car users, and vice-versa. Both car drivers and passengers are counted as car users. The rationale for including car passengers is that they can also assist a driver to look for travel information. We only selected passengers with a driver's license so that they would have a better understanding of the driver's information needs.

#### 3.2.2. Survey questions and statements

We kept our survey short since this MPN survey was also used for other research purposes. This meant that we had to be selective about the attitudinal statements (displayed in Table 1) and questions used to capture digital access (motivation, material access, skills and engagement) and perceptions of indispensability. A short explanation of the statements and questions we used is provided below.

For *perception of indispensability*, we got inspired by statements from Groth (2019) for #1, #2 and #3. We added statement #4 to have a second statement capturing the availability and usefulness of alternatives to personal ICTs. This statement was carefully chosen after deliberation between the authors, and after testing alternative statements with colleagues.

For the *motivation* component, we used four statements relating to the openness to digital technologies. Research shows that people who are more interested in digital tools – more "tech-savvy" – are more likely to use smartphone applications for transport-related purposes (Astroza et al., 2017; Jamal & Habib, 2020; Zijlstra et al., 2020). See statements #5 to #8. Note that statements #6 and #7 are repeated from Zijlstra et al. (2020) who used the same longitudinal panel as we did; therefore, we will be able to track evolutions among the same respondents between 2018 and 2022.

*Material access* does not necessarily require statements, as we can simply ask respondents whether they own devices. Still, given the state of research on digital inequality (see section 2.1), we decided to design three statements (#9 to #11) to capture the perception individuals have of the quality of their smartphone. In the field of transport, Golub et al. (2019) showed that the absence of a data bundle as well as battery and storage issues can hinder the use of a smartphone while on-the-go. Note that we will be able to track evolutions among the same respondents between 2018 and 2022 in terms of smartphone ownership.

We translated *digital skills* into a series of four statements (#12 to #15), as inspired by or copied from previous research. For *engagement*, a broad aspect, we specifically inquired about travel information devices and sources used by car and PT users (not shown in Table 1).

All statements were presented as a 5-point Likert scale. We also included a "No opinion" option to identify the extent to which respondents would feel addressed by statements. For the statements pertaining to skills, we replaced "No opinion" with "I don't know", in accordance with recommendations on measuring digital skills through statements (Van Deursen et al., 2014). Note that we kept all statements similar for both car and PT users to allow for comparisons and simultaneous analyses.

### 3.3. Data collection

The survey was distributed in May and June 2022. We targeted 2,200 respondents in total. As we did not want to overburden respondents using both PT and the car, we split the group in two equal groups, car and PT users. The target profile of each population group was defined based on the Dutch national travel survey, ODiN (Statistics Netherlands,

**Table 1**
Statements on the perception of indispensability of digital technologies, on motivation, material access and digital skills.

| Theorised factors | | # | Statement | Copied from or inspired by (when applicable) |
|---|---|---|---|---|
| Perception of indispensability of digital technologies | Level of embeddedness | 1 | Travelling is more difficult without a smartphone. | Groth (2019) |
| | | 2 | Navigation systems, travel apps and websites are needed in order to travel nowadays. | Alonso-González et al. (2020) Groth (2019) |
| | Availability of non– (personal) ICT alternatives | 3 | I can always travel where I want to, even if I don't have any digital travel information. | Groth (2019) |
| | | 4 | Public information displays like signs along the road or in public transport provide enough information to be able to travel worry-free. | – |
| Motivation: openness to digital technologies | | 5 | I like trying out new apps and digital services. | Caiati (2018) |
| | | 6 | It's not a problem for me to use my smartphone, tablet or computer to book products or services (like tickets). | Zijlstra et al. (2020) |
| | | 7 | It's not a problem for me to use my smartphone, tablet or computer to pay for products or services (like tickets). | Zijlstra et al. (2020) |
| | | 8 | I avoid the use of digital tools when possible. | Caiati (2018) |
| Material access: perceived smartphone quality *(only for smartphone owners)* | | 9 | I always have enough mobile data (such as 4G, 5G) to use my smartphone on-the-go. | – |
| | | 10 | I always have enough battery to use my smartphone on-the-go. | – |
| | | 11 | I always have enough storage on my phone for apps I need. | – |
| Digital skills | | 12 | It is easy for me to learn to use new apps. | Sell et al. (2014) |

(*continued on next page*)

**Table 1** (*continued*)

| Theorised factors | # | Statement | Copied from or inspired by (when applicable) |
|---|---|---|---|
| | 13 | I can always find the piece of travel information I need online. | Goodman-Deane et al. (2024) |
| | 14 | I find the use of travel apps and websites difficult. | Geržinič et al. (2023) |
| | 15 | Planning a trip with an app or a website takes me a lot of effort. | Van Acker et al. (2021) |

2024), where age, gender, education level and travel mode frequency were used to define representativeness.

Based on earlier data collected through the MPN, we knew which MPN respondents to target to reach these two representative samples. At the start of the survey, each respondent got a control question to determine whether they fitted in the pre-determined category (car or PT), needed to be directed to the other questionnaire or were no longer part of the target population. A total of 1,740 respondents completed the survey (79 % of the target population).

### 3.4. Data preparation

Prior to conducting analyses, we cleaned the data. Any respondent who answered the questionnaire under 3 min, or who answered straight lines down in matrix questions four times or more, was deleted. A total of 83 respondents were deleted. Thus, we have a net sample of 1,657 respondents, of which 972 are car users and 685 are PT users. 370 of these individuals also completed the 2018 MPN study (22 % of the net sample). Since our sample was no longer fully representative for the targeted populations, we computed weights based on the two target profiles established with the Dutch national travel survey. Our final samples are representative for the populations of car and PT users in the Netherlands (see Appendix A).

### 3.5. Data analysis methods

Our analyses were carried out in SPSS Statistics 29 and consist of three techniques: descriptive analyses, a data reduction technique (see 3.5.1) and regression analyses (3.5.2). These analyses allow us to describe the process of digital engagement and perceptions of indispensability, and examine links between these aspects and sociodemographic, socioeconomic, and mobility-related variables.

#### 3.5.1. Data reduction

We used a data reduction technique to look for relationships among the factors that may be different from the theorised factors. The technique we use for the statements from Table 1 is an Exploratory Factor Analysis (EFA). An EFA examines the possibility of a few latent variables accounting for many individual variables (Schreiber, 2021). We will use these latent variables as (in)dependent variables in subsequent regression analyses. Since we cannot run an EFA with missing values, statements on material access were excluded from the analyses and will be analysed descriptively.

We need to assume equidistance between the different levels of the Likert scales, meaning that the 'No opinion' and 'I don't know' levels need to be removed to allow for an EFA (Gaskin & Happell, 2014). All statements had less than 2.2 % of responses in the 'No opinion' or 'I don't know' categories, therefore, we decided to keep all statements. Then, we recoded 'No opinion' and 'I don't know' to match the 'Neutral' response. We are aware that this is not ideal but removing the 169 respondents who had answered at least once a 'No opinion' or 'I don't know' would result in too much loss of information; besides, this recoding is common practice (Geržinič et al., 2023).

We performed the EFA employing the Principal Axis Factoring extraction method with oblimin oblique rotation on twelve statements. This type of rotation enables correlation between factors and therefore replicates better human behaviour (Williams et al., 2010). The Kaiser-Meyer-Olkin (KMO) measure verified the sampling adequacy for the analysis, KMO = 0.837 ('meritorious' according to Kaiser and Rice (1974)), and all KMO values for individual items were greater than 0.67, which is above the acceptable limit of 0.5 (Kaiser & Rice, 1974). We used the scree plot criterion to determine the number of factors, given that the average communality is lower than 0.6 (Field, 2018) (see Appendix B). This leads us to retain 2 factors. The factors are saved using the regression method.

Table 2 shows the pattern matrix together with Cronbach's alpha (α), to measure how consistent our post-EFA factors are (Field, 2018). The scales of reverse-phrased statements were reversed to compute Cronbach's alpha. The factors show a good reliability. The post-EFA factors are not exactly in line with those from the survey design phase (Table 1), but plausible in terms of interpretation. What we had initially conceptualised as two factors, namely 'Motivation: openness to digital

**Table 2**
Pattern matrix of the Exploratory Factor Analysis (N = 1657).

| Item | 1: Perception of indispensability of digital technologies in transport | 2: Digital skills and experience |
|---|---|---|
| [2] Navigation systems, travel apps and websites are needed in order to travel nowadays. | 0.656 | |
| [3] I can always travel where I want to, even if I don't have any digital travel information. | −0.652 | |
| [4] Public information displays like signs along the road or in public transport provide enough information to be able to travel worry-free. | −0.646 | |
| [1] Travelling is more difficult without a smartphone. | 0.543 | |
| [12] It is easy for me to learn to use new apps. | | 0.786 |
| [14] I find the use of travel apps and websites difficult. | | −0.772 |
| [15] Planning a trip with an app or a website takes me a lot of effort. | | −0.758 |
| [7] It's not a problem for me to use my smartphone, tablet or computer to pay for products or services (like tickets). | | 0.723 |
| [6] It's not a problem for me to use my smartphone, tablet or computer to book products or services (like tickets). | | 0.722 |
| [13] I can always find the piece of travel information I need online. | | 0.684 |
| [8] I avoid the use of digital tools when possible. | | −0.592 |
| [5] I like trying out new apps and digital services. | | 0.441 |
| % of variance | 12 % | 35 % |
| α | 0.725 | 0.877 |

technologies' and 'Digital skills', represents in fact one factor. It seems that digital skills correlate with one's openness to using digital technologies. This makes sense as the internet merges into everyday life (Van Dijk & Van Deursen, 2014). Besides, our statements for 'Motivations: openness to digital technologies' may have been too focused on technical aspects. We name this factor 'Digital skills and experience'. The first factor corresponds to what we had expected.

#### 3.5.2. Regression analyses

After descriptively analysing the statements constituting these factors, we conduct Ordinary Least Square (OLS) regression analyses on both factors to uncover variables that explain each of these factors. We use the same set of independent variables for each regression. The variables which were ultimately included in the models were selected through a careful process of hierarchical regression (see Field (2018)) based on their potential importance (based on previous research), their contribution to a better fit of the model, and their low correlation with other variables included in the model:

- *Sociodemographic and socioeconomic variables:* Gender, age, education, and household income,
- *Mobility-related variables:* Car and public transport use frequencies, personal PT smartcard possession (car users can possess a PT smartcard too),
- *Technology-related variables:* Number of types of digital devices owned (between one and three possible: smartphone, tablet and computer or laptop).

Additionally, we conducted binary logistic regression analyses to explain engagement (usage) in relation to the previous concepts (perception of indispensability, digital skills) and other sociodemographic, socioeconomic and mobility-related variables. We conduct two regressions because we distinguish between car and PT travellers, as the question on the types of travel information sources used was slightly different for both populations. We added a few independent variables compared with the two previous regressions, as justified below:

- *Sociodemographic and socioeconomic variables:* Besides the variables cited above, we control for address density as a low address density is often associated with a more infrequent PT service, and therefore a higher need for travel information.
- *Mobility-related variables:* Not only did we control for car/PT use frequency, but also for the frequency of *unfamiliar* trips with the car or PT. Unfamiliar trips have been shown to lead to a higher need for travel information (Berggren et al., 2019; Chorus et al., 2007; Farag & Lyons, 2012).
- *Technology-related variables:* We used the two post-EFA access factors here, and controlled for the access to a digital navigation system for car users, as it could be used as a substitute to smartphone-based navigation.

## 4. Results

We present our results starting with the perception of indispensability, followed by the components of digital access (material access, digital skills and experience, and engagement). We first descriptively analyse our statements and questions, then move on to explanatory analyses (where possible) to uncover the role of sociodemographic, socioeconomic, mobility- and technology-related variables in these various aspects of digital access. We also draw comparisons between car and PT users where relevant.

### 4.1. Perceived indispensability of digital technologies in transport

Our results show a clear embeddedness of digital technologies – and the smartphone in particular – in travelling practices. A majority of car and PT users (59 %) (strongly) agree with the fact that navigation systems, travel apps and websites are needed to travel nowadays. Almost three quarters of car and PT users (73 %) think that travelling is more difficult nowadays without a smartphone (69 % of car users, 81 % of PT users).

Nevertheless, a majority (57 %) of car and PT users state that they can always travel where they want to, even without having personal digital travel information. Therefore, viable alternatives do exist. Still, only 36 % agree or strongly agree with the fact that public information displays like signs along the road or in public transport provide enough information to be able to travel worry-free. Therefore, the more traditional communication channels are not deemed sufficient anymore. This could also indicate that people's need for travel information has changed compared to when there was less or no digital travel information available.

Public transport users (fully) agree more often that travelling without a smartphone is more difficult and that digital tools are needed to travel nowadays than car users (Fig. 2). Nevertheless, on average, the factor 'perception of indispensability of digital technologies' is not statistically different between car and PT users (Mann-Whitney $U$ test, $U = 386916$, $z = 1.843$, $p = 0.065$), nor is it between individuals who use PT more or just as much as the car and those who do not ($U = 282221$, $z = -1.526$, $p = 0.127$).

A linear regression analysis conducted on the factor shows that age significantly predicts the perceived indispensability of digital tools in transport (Table 3). Older generations are less likely to perceive digital technologies in transport as indispensable than younger car and PT users. A possible explanation is that older car and PT users have had more experience throughout their life without digital technologies and may therefore be more familiar with alternatives or feel less dependent on personal digital tools. Women are significantly more likely to perceive digital technologies in the context of transport as indispensable. Respondents possessing a personal PT smartcard are more likely to perceive digital technologies in transport as indispensable.

### 4.2. Material access to a (connected) device

A large majority (98 %) of our sample has access to a smartphone. This is more than in the general population: 91 % of the Dutch population aged 16 and older had a smartphone in 2022 (Statistics Netherlands (2023b)). While it can be expected with our data collection, our scope also matters: we can expect that people using PT or the car at least six times a year are more used to digital technologies than the average population. Our sample excludes by default people who may not travel much or who have lost their driver's license due to old age for instance.

Looking into the sample of respondents who also participated in the 2018 survey, we see an increase in smartphone ownership. 87.5 % had a smartphone back in 2018, against 97 % in 2022. We can only speculate on the reasons behind such a change, like a progressive diffusion of smartphones among the so-called laggards and the COVID-19 pandemic that increased the usefulness of smartphone adoption (Sin et al., 2021). Research shows that 90 % of Dutch adults used smartphones to access the internet in 2023, against 85 % in 2020 (Van Deursen, 2023).

Fig. 3 shows responses to the three statements on the (perceived) quality of respondents' smartphones, among smartphone owners. 3 % of smartphone owners disagreed or strongly disagreed with all three statements. Therefore, in total, at least 5 % of Dutch car and PT users either cannot use a smartphone because they do not have one, or run into issues pertaining to mobile data, battery and storage when using it. 19 % of smartphone owners (strongly) disagreed with at least one of the three statements. Therefore, at least one in five PT and car users may not be able to always access online travel information.

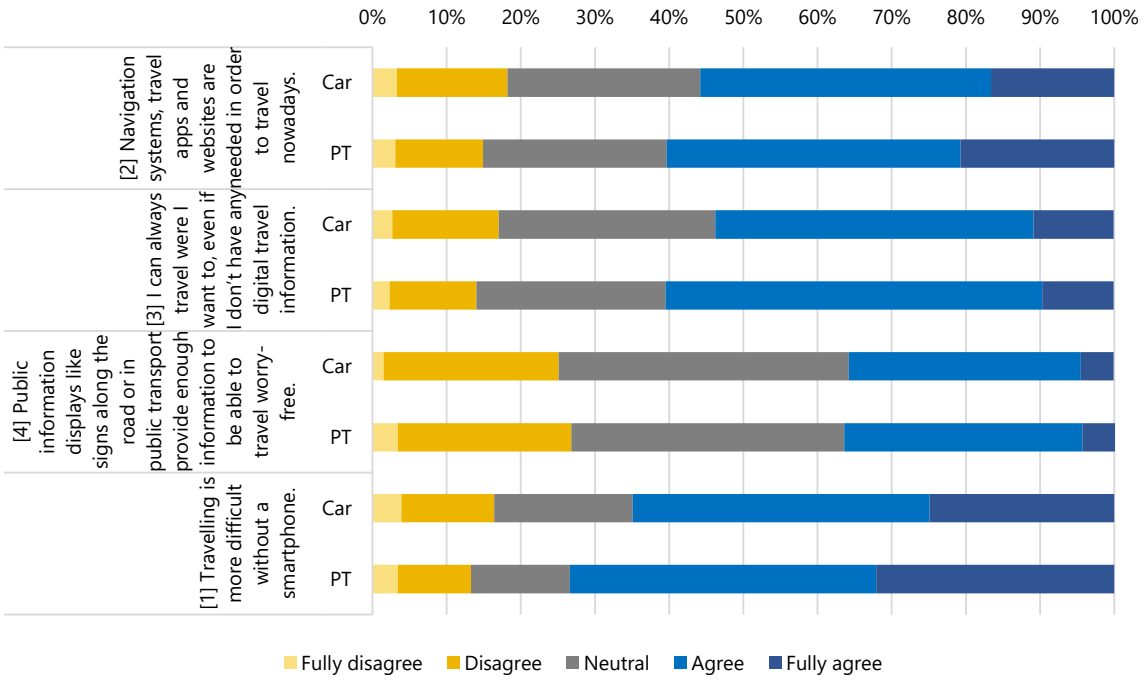



**Fig. 2.** Responses to the statements on the perception of indispensability of digital technologies in transport, sorted according to the EFA results and differentiated between car users (N = 972) and PT users (N = 685).

### *4.3. Digital skills and experience*

Overall, Dutch car and PT users consider themselves to be relatively skilled with digital technologies; see Fig. 4 for the responses to the statements. Four in five car and PT users do not find the use of travel apps and websites difficult, and planning a trip with these tools does not take a lot of effort for a similar share of car and PT users. Again, four in five car and PT users do not mind booking or paying for products and

**Table 3**
OLS regression analysis for factor 'Perception of indispensability of digital technologies'. Coefficients statistically significant at 95 % level ($p < 0.05$) in bold font.

| Variable | Levels | **Perception of indispensability of digital technologies** Unst. B | Sig. |
|---|---|---|---|
| Intercept | | **−0.328** | **0.010** |
| *Sociodemographic and socioeconomic variables* | | | |
| Gender | Men | – | – |
| | Women | **0.153** | **0.000** |
| Age | 18–34 | – | – |
| | 35–49 | **−0.202** | **0.001** |
| | 50–64 | **−0.330** | **0.000** |
| | 65 and older | **−0.443** | **0.000** |
| Education | Basic, secondary, and basic vocational | – | – |
| | (Advanced) vocational and college | −0.014 | 0.825 |
| | University (academic education) | −0.007 | 0.915 |
| Household income | Below modal | – | – |
| | Modal | 0.031 | 0.646 |
| | Between modal and twice modal | 0.027 | 0.645 |
| | Twice modal and more | 0.068 | 0.304 |
| | Does not know or want to say | −0.009 | 0.902 |
| *Mobility-related variables* | | | |
| Car use frequency | 4 times a week or more | – | – |
| | Once to 3 times a week | 0.004 | 0.088 |
| | Between once and 3 times a month | 0.046 | 0.611 |
| | Between once and 11 times a year | 0.080 | 0.782 |
| | Never | 0.121 | 1.118 |
| PT use frequency | Once a week or more | – | – |
| | Between once and 3 times a month | −0.068 | 0.399 |
| | Between once and 11 times a year | 0.042 | 0.516 |
| | Never | 0.011 | 0.884 |
| Owning a personal PT smartcard | No | – | – |
| | Yes | **0.132** | **0.008** |
| *Technology-related variable* | | | |
| Number of possessed types of technological devices | | **0.132** | **0.000** |
| *Model statistics* | | | |
| N | | 1657 | |
| $R^2$ | | 0.06 | |
| Adjusted $R^2$ | | 0.051 | |

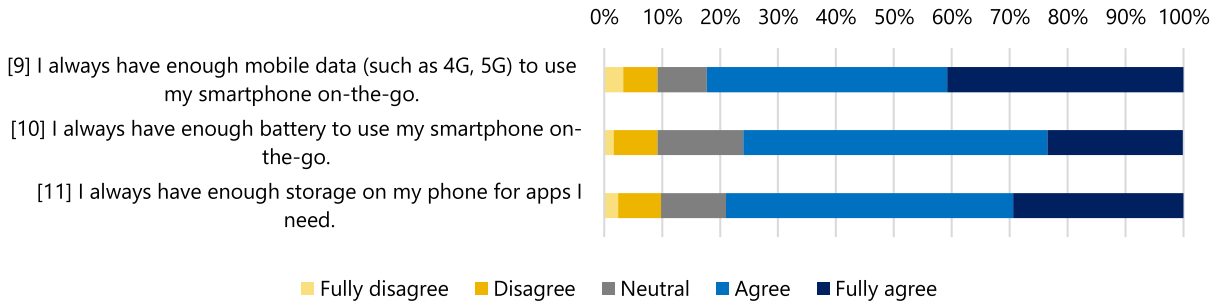



**Fig. 3.** Responses to the statements on the perceived quality of the smartphone, by smartphone owners (N = 1,629).

services like tickets online. Answers are more split when it comes to liking trying out new apps and digital services: more car and PT users like it than dislike it, but 22 % disagree about liking this.

Booking and paying for products and services online were also part of the 2018 MPN survey, albeit as questions, not statements. Back then, 31 % of our 370 respondents had stated that they found it a problem to book products and services online. This share has dropped to 11 % in 2022. Similarly, 26 % of our 370 respondents had stated that they found it a problem to pay for products and services online. This share has dropped to 10 % in 2022. Nevertheless, for almost each statement, between 6 % and 10 % of car and PT users seem to struggle with various aspects of digital skills applied in transport.

The older the car and PT user, the less likely they are to report high digital skills for travel-related purposes (Table 4). Education is also clearly linked with digital skills and experience: car and PT users with an academic, (advanced) vocational or college education are significantly more likely to be digitally skilled than car and PT users with a basic, secondary or basic vocational education. These findings align with research on digital inclusion in general (Van Deursen, 2023), and in transport research too (Durand et al., 2022; Goodman-Deane et al., 2021). Individuals with more than a modal household income are also more likely to report higher digital skills than individuals with a household income below modal. Men are significantly more likely to report higher digital skills for travel-related purposes. As Goswami and Dutta (2015) showed, women tend to be more anxious about digital technologies than men, reducing their self-effectiveness and increasing perceptions of digital technologies requiring greater effort.

As can be expected, infrequent and non-PT users as well as infrequent and non-car users usually consider themselves less digitally skilled and experienced to look for travel information than frequent users. People who travel more, likely had to acquire digital skills to look for travel information, if they did not possess them already. Having sufficient digital skills to look for travel information might also foster the possibility to travel. However, we are not able to draw conclusions on the direction of causality.

'Digital skills and experience' scores for our sample of PT users are significantly higher than for our sample of car users (Mann-Whitney *U* test, U = 409710, z = 4.040, p < 0.001). We also find that individuals who use PT more or just as much as the car score significantly higher in terms of digital skills (U = 297444, z = 3.292, p < 0.001). Note that there is no significant difference in age, educational and income levels between our samples of car and PT users.[5]

### 4.4. Engagement with digital technologies to look for travel information

96 % of the respondents commonly use some form of personal digital tool to access travel information before or during their trip: a smartphone, a tablet, a laptop/PC/desktop or a navigation system. Looking into the sample of respondents (N = 370) who also participated in the 2018 MPN survey, 10 % of them stated that they were never using digital travel information in 2018: no navigation system, apps or websites. In 2022, only 4 % of this sample did not use digital technologies to access travel information.

Table 5 shows sources that respondents employ to access travel information for their car or PT trips. It is worth noting that a majority of car and PT users still rely on public information displays too. Nevertheless, as we saw in section 4.1, only a minority of travellers agree that public information displays give sufficient information to be able to travel worry-free.

Within car users, self-reported digital skills are *not* significantly lower among those using non-digital alternatives.[6] Within PT users, self-reported digital skills *are* significantly lower among those using the help of friends, family and staff, but not among those using public information displays.[7]

In total, four in five car and PT travellers use their smartphone to look for travel information. We conducted binary logistic regressions to uncover the profiles of those searching for travel information on their smartphone (Table 6). As expected from previous analyses, age is a significant predictor of smartphone-based travel information use. For each extra year of age, PT users are 3.7 % less likely to use their smartphone to look for travel information and car users 3.6 % less likely.[8] PT users with an academic education are three times more likely to use their smartphone to search for travel information than PT users with a basic, secondary or basic vocational education, as are PT users identifying as women (3.5 times more likely than men). Address density does not have a significant effect on smartphone-based travel information use, even when we do not control for other variables.

PT users who never perform unfamiliar PT trips are significantly (89 %) less likely to search for travel information on their smartphone than people who perform unfamiliar trips once a month or more. The same applies to car users (70 % less likely).

We used our two factors (perception of indispensability and skills) as independent variables here because engagement is the last stage of the process of digital engagement. 'Digital skills and experience' proves to be the most important predictor for both car and PT users. Individuals who are more digitally skilled are more likely to search for travel information via their smartphone. Unsurprisingly, those who perceive digital technologies to be more indispensable are also more likely to look for travel information on their smartphone. As expected, car users with

[5] Age: U = 322594, z = 9582, p = 0.298. Educational levels: $X^2$ (2, $N$ = 1657) = 4.3, $p$ = 0.116. Income levels: $X^2$ (4, $N$ = 1657) = 3.528, $p$ = 0.474.

[6] Family and friends: U = 65597, z = 0.632, p = 0.528. Public information displays: U = 64130, z = 0.175, p = 0.861. Radio: U = 102879, z = 1.823, p = 0.068.

[7] Family and friends: U = 13693.5, z = −4.099, p = 0.000; mean rank 'no use' = 352.95, mean rank 'use' = 246.46. PT staff: U = 9696, z = −4.230, p = 0.000; mean rank 'no use' = 351.78, mean rank 'use' = 226.50. Public information displays: U = 61941.5, z = 1.507, p = 0.132.

[8] When age is entered as a continuous variable, not shown in Table 4; PT: OR (Odds Ratio) = 0.963, CI (Confidence Interval) = 0.943–0.983; car: OR = 0.964, CI = 0.953–0.976.

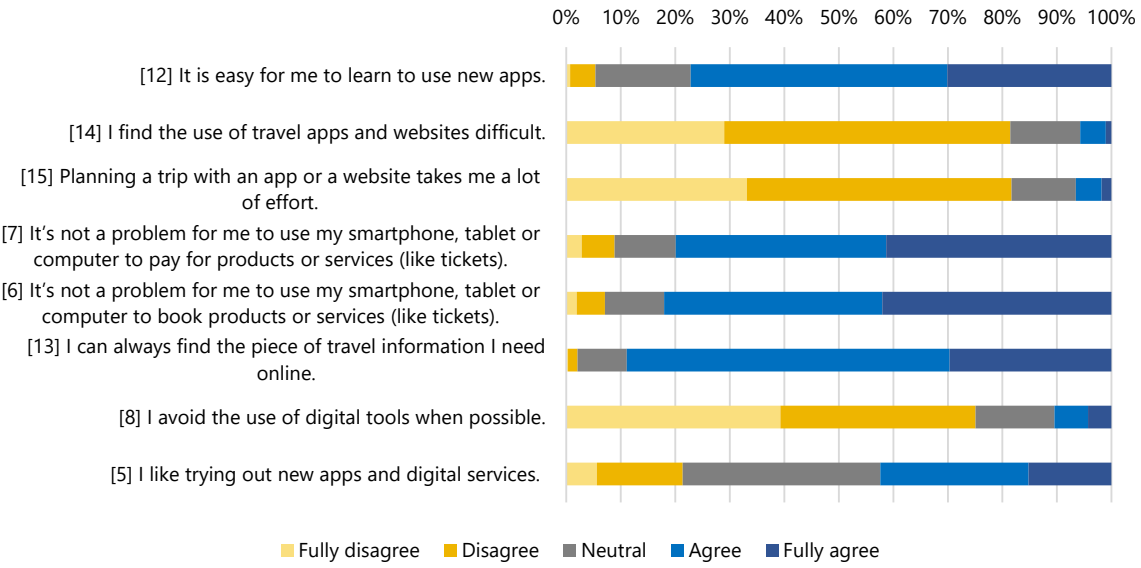



**Fig. 4.** Responses to the statements on skills and experience, sorted according to the EFA results (N = 1,657).

**Table 4**
OLS regression analysis for factor 'Digital skills and experience'. Coefficients statistically significant at 95 % level ($p < 0.05$) in bold font.

| Variable | Levels | Digital skills and experience | |
|---|---|---|---|
| | | Unst. B | Sig. |
| Intercept | | **−0.659** | **0.000** |
| *Sociodemographic and socioeconomic variables* | | | |
| Gender | Men | – | – |
| | Women | **−0.114** | **0.007** |
| Age | 18–34 | – | – |
| | 35–49 | **−0.258** | **0.000** |
| | 50–64 | **−0.540** | **0.000** |
| | 65 and older | **−0.921** | **0.000** |
| Education | Basic, secondary, and basic vocational | – | – |
| | (Advanced) vocational and college | **0.289** | **0.000** |
| | University (academic education) | **0.378** | **0.000** |
| Household income | Below modal | – | – |
| | Modal | 0.121 | 0.069 |
| | Between modal and twice modal | **0.186** | **0.001** |
| | Twice modal and more | **0.152** | **0.020** |
| | Does not know or want to say | −0.003 | 0.969 |
| *Mobility-related variables* | | | |
| Car use frequency | 4 times a week or more | – | – |
| | Once to 3 times a week | **−0.151** | **0.002** |
| | Between once and 3 times a month | **−0.185** | **0.013** |
| | Between once and 11 times a year | −0.143 | 0.160 |
| | Never | **−0.228** | **0.034** |
| PT use frequency | Once a week or more | – | – |
| | Between once and 3 times a month | −0.119 | 0.135 |
| | Between once and 11 times a year | **−0.151** | **0.019** |
| | Never | **−0.255** | **0.000** |
| Owning a personal PT smartcard | No | – | – |
| | Yes | **0.136** | **0.006** |
| *Technology-related variable* | | | |
| Number of possessed types of technological devices | | **0.342** | **0.000** |
| *Model statistics* | | | |
| N | | 1657 | |
| $R^2$ | | 0.226 | |
| Adjusted $R^2$ | | 0.217 | |

**Table 5**
Travel information sources used by Dutch car and PT users in 2022 (multiple answers possible).

| Travel information source | Car users (N = 972) | PT users (N = 685) |
|---|---|---|
| Navigation system (built-in or separate device, not a smartphone) | 62 % | n.a. |
| Smartphone (such as apps) | 74 % | 90 % |
| Tablet | 7 % | 14 % |
| Desktop, PC or laptop | 21 % | 39 % |
| Family, friends or people I travel with look for digital travel information for me | 18 % | 10 % |
| Public information displays: signs (along the road, at the station…) or maps | 68 % | 56 % |
| Radio with traffic information integrated in the car | 30 % | n.a. |
| PT staff or calling 9292 (travel information number) | n.a. | 7 % |
| Other travellers (not in my company) | n.a. | 2 % |
| *No travel information needed (exclusive)* | *2 %* | *2 %* |

access to a real-time navigation system are less likely to use their smartphone to search for travel information.

The 'digital skills and experience' factor has a mediation effect. Income no longer contributes significantly to explaining smartphone-based travel information use once we control for digital skills and experience (otherwise, PT users from households earning less than modal were found to be significantly less likely to use smartphone-based travel information). The contributions of education level, age and frequency of unfamiliar trips also diminish after controlling for digital skills and experience. Our result is not surprising: digital skills have been repeatedly found to be the strongest predictor for usage, cancelling out the effect of most other variables that were previously statistically significant (Dodel & Hernandez, 2025; Helsper, 2021; Van Deursen et al., 2017). This mediating effect is much less present in the model with car users; the strengths of the relationships between education level and income also slightly diminish after controlling for digital skills and experience, but they were not significant in the first place anyway.

Age, income and education level appear to be contributing less to explaining the dependent variable once we add the 'perception of indispensability' factor, but the odds ratios only slightly reduce and there is no change in significance levels.

**Table 6**
Binary logistic regression analyses about usage of the smartphone to look for travel information. Coefficients statistically significant at 95 % level ($p < 0.05$) in bold font.

| Variable | Levels | Dependent variables | | | | | |
|---|---|---|---|---|---|---|---|
| | | Use of the smartphone to look for travel information among PT users | | | Use of the smartphone to look for travel information among car users | | |
| | | Odds Ratio (OR) | 95 % Confidence Interval (CI) (lower) | 95 % Confidence Interval (CI) (upper) | Odds Ratio (OR) | 95 % Confidence Interval (CI) (lower) | 95 % Confidence Interval (CI) (upper) |
| *Sociodemographic and −economic variables* | | | | | | | |
| Gender | Men | – | – | – | – | – | – |
| | Women | **3.517** | **1.692** | **7.311** | 0.842 | 0.586 | 1.210 |
| Age | 18–34 | – | – | – | – | – | – |
| | 35–49 | 0.370 | 0.106 | 1.289 | 0.718 | 0.393 | 1.311 |
| | 50–64 | **0.211** | **0.069** | **0.640** | **0.301** | **0.172** | **0.527** |
| | 65 and older | **0.144** | **0.045** | **0.461** | **0.173** | **0.094** | **0.318** |
| Education | Basic, secondary and basic vocational | – | – | – | – | – | – |
| | (Advanced) vocational and college | 1.813 | 0.749 | 4.389 | 1.036 | 0.616 | 1.742 |
| | University (academic education) | **2.865** | **1.137** | **7.221** | 0.748 | 0.443 | 1.266 |
| Household income | Below modal | – | – | – | – | – | – |
| | Modal | 3.402 | 0.978 | 11.830 | 1.217 | 0.689 | 2.152 |
| | Between modal and twice modal | 2.090 | 0.821 | 5.319 | 0.880 | 0.535 | 1.448 |
| | Twice modal and more | 2.084 | 0.768 | 5.650 | 1.656 | 0.908 | 3.021 |
| | Does not know or want to say | **5.745** | **1.396** | **23.646** | 0.981 | 0.531 | 1.811 |
| Address density | Very high (>2,500 addresses/km$^2$) | – | – | – | – | – | – |
| | High (1,500–2,500 addresses/km$^2$) | 0.497 | 0.221 | 1.115 | 0.868 | 0.539 | 1.398 |
| | Moderate (1,000–1,500 addresses/km$^2$) | 1.318 | 0.339 | 5.128 | 0.808 | 0.462 | 1.414 |
| | Low (<1,000 addresses/km$^2$) | 0.904 | 0.336 | 2.436 | 0.934 | 0.572 | 1.525 |
| *Mobility-related variables* | | | | | | | |
| Car use frequency | 4 times a week or more | | | | – | – | – |
| | Once to 3 times a week | | | | 1.228 | 0.812 | 1.857 |
| | Between once and 3 times a month | | | | 0.720 | 0.421 | 1.232 |
| | Between once and 11 times a year | | | | 0.650 | 0.222 | 1.904 |
| Frequency of unfamiliar trips with the car | Once a month or more | | | | – | – | – |
| | Between 6 and 11 times a year | | | | 0.770 | 0.494 | 1.200 |
| | Between once and 5 times a year | | | | 0.754 | 0.468 | 1.213 |
| | Never | | | | **0.267** | **0.118** | **0.604** |
| PT use frequency | Once a week or more | – | – | – | | | |
| | Between once and 3 times a month | 1.122 | 0.414 | 3.045 | | | |
| | Between once and 11 times a year | 1.410 | 0.561 | 3.542 | | | |
| Frequency of unfamiliar trips with PT | Once a month or more | – | – | – | | | |
| | Between 6 and 11 times a year | 0.715 | 0.177 | 2.883 | | | |
| | Between once and 5 times a year | 0.918 | 0.240 | 3.505 | | | |
| | Never | **0.132** | **0.032** | **0.539** | | | |
| *Technology-related variables* | | | | | | | |
| Perception of indispensability of digital technologies in transport | | **1.826** | **1.222** | **2.730** | **1.752** | **1.422** | **2.158** |
| Digital skills and experience | | **3.437** | **2.335** | **5.060** | **2.391** | **1.924** | **2.970** |
| Access to a real-time navigation system | No | | | | – | – | – |
| | Yes | | | | **0.281** | **0.157** | **0.505** |
| Constant | | **15.946** | | | **15.642** | | |
| *Model statistics* | | | | | | | |
| N | | 678 | | | 951 | | |
| Log-Likelihood | | 263.845 | | | 817.539 | | |
| R2 (Cox-Snell) | | 0.235 | | | 0.274 | | |
| R2 (Nagelkerke) | | 0.490 | | | 0.399 | | |

## 5. Conclusions, discussion and further research

This article explored the process of digital engagement of car and public transport travellers as well as perceptions around the indispensability of digital technologies in transport. We based our results on a survey conducted in 2022 in the Netherlands among representative samples of PT users (N = 685) and car users (N = 972). Our questionnaire focused specifically on the smartphone and on digital travel information services. Our approach enables us to establish connections between socioeconomic variables, sociodemographic variables, travel behaviour and digital access. Furthermore, a sub-sample (N = 370) had taken part in a survey in 2018 with a few similar or comparable questions/statements, which allowed use to examine evolutions over a period of 4 years.

### 5.1. Differences in four years' time

Between 2018 and 2022, the share of people *not* relying on digital travel information has reduced from 10 % to 4 %, while smartphone ownership has increased from 88 % to 97 %. Booking and paying for products and services has also become more common. As such, there is clear evidence of travellers getting more used to digital technologies in just four years' time. The COVID-19 pandemic is likely to have played a role in these changes and there is no guarantee that the same pace will keep on, nor that *everyone* will eventually get used to new digital services. We were not able to compare more aspects of digital access because the dataset used in 2018 had different purposes than our study.

### 5.2. Perception of indispensability of digital technologies

Another noteworthy aspect of our study is our focus on *perceptions around indispensability*. Digital technologies have become embedded in travelling practices: almost three quarters of car and PT users think that travelling is more difficult nowadays without a smartphone. However, viable alternatives do exist and are still used by a majority of car and PT users. PT travellers using the help of friends and family or PT staff to look for travel information are more likely to report lower digital skills. In contrast, traditional communication channels such as signs along the road or in public transport are *not* more likely to be used by car or PT users reporting lower digital skills. Nevertheless, they are not deemed sufficient anymore to travel worry-free.

It would have been highly valuable to compare how current perceptions of indispensability contrast with previous ones. However, we do not have access to such data. Nevertheless, literature from the past decades provides interesting landmarks. For instance, ethnographic research carried out in 2005 among young professionals in London, Tokyo and Los Angeles showed that back then, a mobile phone was 'just' a mobile phone. Most city residents were also carrying things like music players, maps and PT passes in their purses (Ito et al., 2008). Then, the release of the iPhone in 2007 started to change that, such that a few years later, Line et al. (2011, p. 1497) already argued that: "the development of the mobile phone continues to move it beyond being a device only for phone calls and texts with the offer of connectivity between people, entertainment, and access to information via mobile internet/GPS on the move across modes. In terms of travelling, the discourses of safety and emergency embedded in the rationale for carrying the phone suggest people travel more confidently (or even carefree)".

While we only measured perceptions, they contribute to shaping reality. The contemporary expectation for everyone to carry a smartphone and be skilled enough to use it can put those (temporarily) without (the required hardware/skills) at a disadvantage by making them invisible. Our survey did not investigate this aspect, but interviews conducted by Durand et al. (2023b) among individuals at risk of exclusion due to digitalisation in public transport in the Netherlands showed how the perceptions we measured in the present study can play out. Public transport staff sometimes expect travellers to be able to look for travel information independently on their digital devices. Travellers mistakenly believe that non-digital alternatives (to request money back after a disruption, for instance) have completely disappeared given their relative invisibility, meaning that those who would need to access them may not know of their existence.

### 5.3. Disparities in digital engagement

In terms of digital engagement, our survey shows that in 2022, consulting travel information via privately owned digital devices was widespread in the Netherlands. At most 80 % of car and PT users relied at least from time to time on their smartphone to look for travel information. However, even respondents of an online panel are not homogenous in their digital access. At least 5 % of Dutch car and PT users either cannot use a smartphone because they do not have one, or run into issues pertaining to mobile data, battery and storage when using it. Besides, at least 10 % struggle with various aspects of digital skills applied in transport. Older adults, people in households with an income below modal, people with a basic, secondary and basic vocational education level and women are more likely to report lower digital skills and experience in transport, confirming previous findings (Goodman-Deane et al., 2021; Groth, 2019; Zhang et al., 2020). This also confirms that disparities in access to and engagement with digital technologies is patterned along the lines of socioeconomic disparities (Durand et al., 2022).

The same individuals are less likely to use a smartphone for travel information purposes, as also shown by Tao et al. (2024) recently. In fact, our study shows that digital skills are a strong predictor for the use of smartphone-based travel information services and mediate the relationship between this latter variable on the one hand, and income, education level, age and frequency of unfamiliar trips on the other hand. This mediation effect has also been recently demonstrated by Dodel and Hernandez (2025) in a Uruguayan context, and is therefore likely at play in other contexts. Perceptions of indispensability also predict the use of the smartphone, but to a lesser extent than digital skills.

From a transportation equity perspective, the inability to take advantage of technologies may constitute a barrier to accessibility (Bruno et al., 2024; Luz & Portugal, 2021). Accessibility is defined as the potential to reach spatially distributed opportunities (Vecchio & Martens, 2021), and is shaped by the interactions between transport systems, land use and individual attributes (Páez et al., 2012; Van Wee et al., 2013). Indeed, it is not directly the access to and engagement with digital technologies that matter the most, but it is the opportunities that people may or may not be able to access that matter (Helsper, 2021).

Although car and PT users do not differ significantly in their perception of indispensability of digital technologies, our study reveals other differences between both populations in terms of digital access. In general, car users are less reliant on a smartphone than PT users, as many cars are equipped with a navigation system nowadays (Dicke-Ogenia et al., 2022). Interestingly, a majority of car users in the Netherlands rely on a smartphone *and* a navigation system (built-in or as a separate device). Our survey does not allow us to know if that happens at the same time or not. Furthermore, we see hints that smartphone-based travel information does not require the same (level of) digital skills between PT and car users. Digital skills among PT users are higher than among car users, while these samples do not differ significantly in terms of age and education levels, two key predictors of digital skills (Van Dijk, 2019).

### 5.4. Implications and transferability of the findings

This latter finding has implications for policymakers and researchers in and outside of the Netherlands seeking pathways to decarbonise the passenger transport sector: low digital skills might be a barrier to switching from the car to public transport. One of the limitations of our study consists in the way we measured digital skills (see below), but

even a low self-reported (perceived) level of digital skills can be a barrier. This potential barrier is particularly important to take into account as digital transformations in transport services are often depicted as having a central role to play in a shift towards more sustainable mobility patterns (Dutch Ministry of Infrastructure and Water Management, 2019; Groth, 2019; Manders & Klaassen, 2019).

Also, it should not be assumed that everyone can use digital travel information services purely based on a very high smartphone ownership rate. This insight is particularly relevant at a time when many digital services use access to digital travel information as a groundwork (Durand et al., 2018; Lyons et al., 2019; Sochor et al., 2017). Countries, regions or cities where digital technologies are perceived as less indispensable – i.e., where non-digital options are still relatively available – can also find the results from this article insightful. It can help them realise and prevent potentially unintended consequences of a commitment to more digitalisation. We also refer to Durand et al. (2023c) for solutions to foster an inclusive public transport system in the digital era.

### 5.5. Future research recommendations

Future studies should build on this research and address its limitations. Firstly, we encourage researchers to use and refine the statements we have used to capture perceptions of indispensability. It would be interesting to be able to compare results with other countries or places. Obviously, these statements only reflect perceptions, and we recommend pairing them with a good understanding of the context and the extent to which the (transport) system has become/been designed 'digital-by-default' (Yates et al., 2015); this is what makes the qualitative study by Durand et al. (2023b) complementary with the present study.

Secondly, a limitation in our study consists of the way we have measured skills. Self-assessments of skills are known to lead to overrating and underrating (Hargittai, 2009; Van Deursen & Van Dijk, 2010). Nevertheless, they remain one of the most prevalent ways to measure digital skills (Van Deursen et al., 2014). Performance tests could be used in future research (see e.g. Goodman-Deane et al. (2021) and Goodman-Deane et al. (2024) for inspiration), but tasks need to be carefully calibrated.

Thirdly, it is important to note that our regression analyses do not allow us to draw conclusions on the exact causal relationships between variables. For instance, people might be developing skills as they use digital travel information, but we cannot confirm this. An approach via Directed Acyclic Graphs (DAGs) might be helpful to shed light on these aspects.

## CRediT authorship contribution statement

**Anne Durand:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Marije Hamersma:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Niels van Oort:** Writing – review & editing, Methodology, Conceptualization. **Serge Hoogendoorn:** Writing – review & editing, Methodology, Conceptualization.

## Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgements

This article is part of a joint PhD research project of the KiM Netherlands Institute for Transport Policy Analysis (Ministry of Infrastructure and Water Management) and the Smart Public Transport Lab at TU Delft. This article builds on a Dutch report published by KiM Netherlands Institute for Transport Policy Analysis (Durand et al., 2023a), and the authors thank KiM colleagues for their valuable feedback on this study.

## Appendix A

**Table A1**
Representativeness of the sample of car users.

| Variable | | Car users Dutch national travel survey (ODiN), 2022 | Car users MPN after weighing (N = 972), 2022 |
|---|---|---|---|
| Gender | Men | 49.5 % | 49.6 % |
| | Women | 50.5 % | 50.4 % |
| | Non-binary or gender diverse | – | – |
| | Prefer not to disclose | – | – |
| Age | 18–24 | 8.8 % | 8.2 % |
| | 25–34 | 16.1 % | 17 % |
| | 35–44 | 17.4 % | 18.5 % |
| | 45–54 | 19.2 % | 19.7 % |
| | 55–64 | 19 % | 18.8 % |
| | 65 and older | 19.5 % | 17.9 % |
| Education | Basic, secondary and basic vocational | 16 % | 16.2 % |
| | (Advanced) vocational and college | 34.8 % | 35 % |
| | University (academic education) | 49.1 % | 48.8 % |
| Car use frequency | 4 times or more per week | 42 % | 42 % |
| | Once to 3 times a week | 40.2 % | 40.2 % |
| | Once to three times per month | 14.8 % | 14.8 % |
| | Between 6 and 11 times per year | 3 % | 3 % |

**Table A2**
Representativeness of the sample of PT users.

| Variable | | PT users Dutch national travel survey (ODiN), 2022 | PT users MPN after weighing (N = 685), 2022 |
|---|---|---|---|
| Gender | Men | 45.9 % | 42.6 % |
| | Women | 54.1 % | 57.4 % |
| | Non-binary or gender diverse | – | – |
| | Prefer not to disclose | – | – |
| Age | 18–24 | 17.6 % | 15.5 % |
| | 25–34 | 19.8 % | 20.5 % |
| | 35–44 | 16.1 % | 16.7 % |
| | 45–54 | 15.5 % | 15.5 % |
| | 55–64 | 15 % | 15.9 % |
| | 65 and older | 16 % | 15.9 % |
| Education | Basic, secondary and basic vocational | 13.3 % | 12.6 % |
| | (Advanced) vocational and college | 32.2 % | 32.6 % |
| | University (academic education) | 54.5 % | 54.8 % |
| PT use frequency | 4 times or more per week | 9.2 % | 9.2 % |
| | Once to 3 times a week | 17.8 % | 17.8 % |
| | Once to three times per month | 23 % | 23 % |
| | Between 6 and 11 times per year | 50 % | 50 % |

## Appendix B

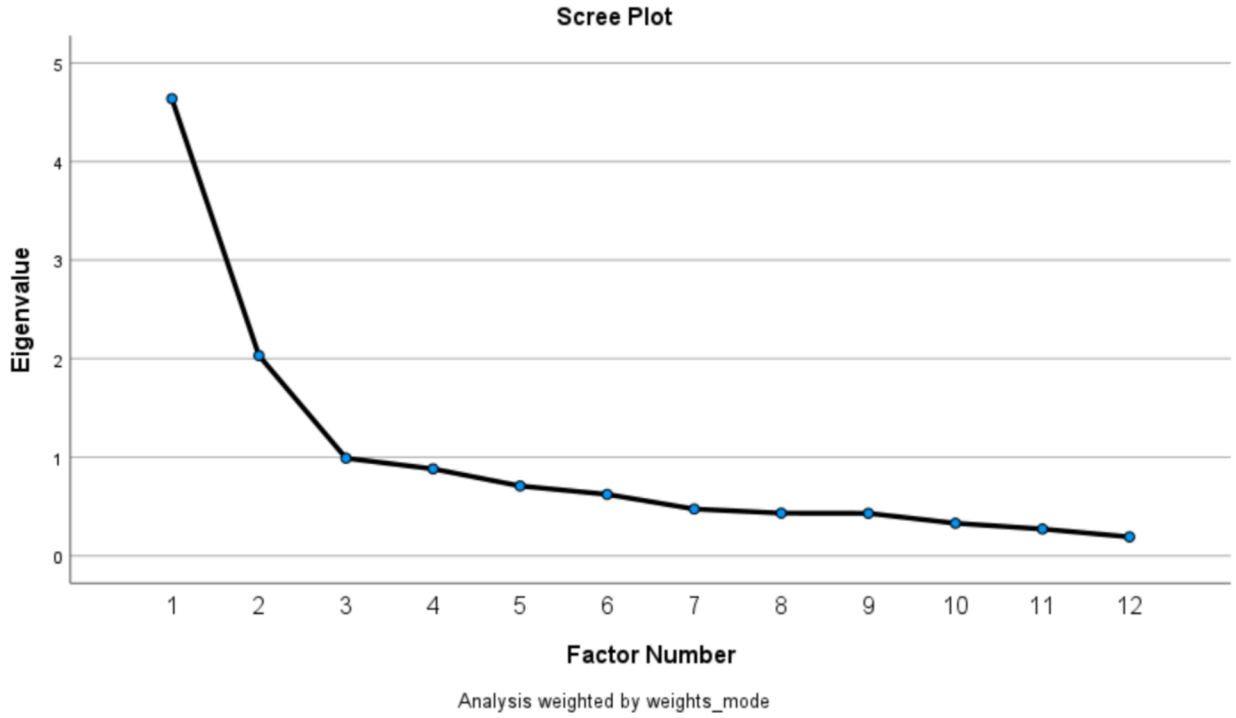



**Fig. B1.** Scree plot of the Exploratory Factor Analysis.

## Data availability

The data that has been used is confidential. Access conditions and procedures to use the Mobility Panel Netherlands can be found at https://www.mpndata.nl/.

## References

Alonso-González, M.J., Hoogendoorn-Lanser, S., van Oort, N., Cats, O., Hoogendoorn, S., 2020. Drivers and barriers in adopting Mobility as a Service (MaaS) – A latent class cluster analysis of attitudes. Transp. Res. A Policy Pract. 132, 378–401. https://doi.org/10.1016/j.tra.2019.11.022.

Astroza, S., Garikapati, V.M., Bhat, C.R., Pendyala, R.M., Lavieri, P.S., Dias, F.F., 2017. Analysis of the impact of technology use on multimodality and activity travel characteristics. Transp. Res. Rec. 2666 (1), 19–28. https://doi.org/10.3141/2666-03.

Ben-Elia, E., Avineri, E., 2015. Response to travel information: A behavioural review. Transp. Rev. 35 (3), 352–377. https://doi.org/10.1080/01441647.2015.1015471.

Berggren, U., Johnsson, C., Svensson, H., Wretstrand, A., 2019. Exploring waiting times in public transport through a semi-automated dedicated smartphone app survey. Travel Behav. Soc. 15. https://doi.org/10.1016/j.tbs.2018.11.002.

Bruno, M., Kouwenberg, M., Van Oort, N., 2024. Addressing transport related social exclusion through transportation policy: A novel evaluation method applied to the Amsterdam Transport Region. Transp. Res. Interdiscip. Perspect. 26, 101177. https://doi.org/10.1016/j.trip.2024.101177.

Caiati, V. (2018). Innovation Adoption And Diffusion in Transportation: Modelling the long-term demand for new mobility services based on platform technology 97th Annual Meeting of the Transportation Research Board (TRB), Washington D.C., United States.

Chorus, C.G., Arentze, T.A., Timmermans, H.J.P., Molin, E.J.E., Van Wee, B., 2007. Travelers' Need for Information in Traffic and Transit: Results from a Web Survey.

J. Intell. Transp. Syst. 11 (2), 57–67. https://doi.org/10.1080/15472450701293841.
Dicke-Ogenia, M., Schotman, R., Bigalke, S., & van Huffelen, T. (2022). *Monitor wegverkeergerelateerde informatiediensten. [Monitor road traffic-related information services.]*.
Dodel, M., Hernandez, D., 2025. Smarter but more unequal transport? How socioeconomic and digital inequalities hinder adoption of mobility apps in the Global South. Travel Behav. Soc. 38, 100911. https://doi.org/10.1016/j.tbs.2024.100911.
Durand, A., Harms, L., Hoogendoorn-Lanser, S., & Zijlstra, T. (2018). *Mobility-as-a-Service and changes in travel preferences and travel behaviour: a literature review*. KiM Netherlands Institute for Transport Policy Analysis.
Durand, A., Hamersma, M., & Rienstra, S. (2023a). *Digitale reisinformatie: Gebruik en gepercipieerde effecten bij auto- en ov-reizen. [Digital travel information: use and perceived effects for car and public transport trips]*. KiM Netherlands Institute for Transport Policy Analysis.
Durand, A., Zijlstra, T., Van Oort, N., Hoogendoorn-Lanser, S., Hoogendoorn, S., 2022. Access denied? Digital inequality in transport services. Transp. Rev. 42 (1), 32–57. https://doi.org/10.1080/01441647.2021.1923584.
Durand, A., Zijlstra, T., Hamersma, M., van Oort, N., Hoogendoorn-Lanser, S., Hoogendoorn, S., 2023b. "Who can I ask for help?": Mechanisms behind digital inequality in public transport. Cities 137, 104335. https://doi.org/10.1016/j.cities.2023.104335.
Durand, A., Zijlstra, T., Hamersma, M., van Oort, N., Hoogendoorn, S., Hoogendoorn-Lanser, S., 2023c. Fostering an inclusive public transport system in the digital era: An interdisciplinary approach. Transp. Res. Interdiscip. Perspect. 22, 100968. https://doi.org/10.1016/j.trip.2023.100968.
Dutch Ministry of Infrastructure and Water Management. (2019). *Schets Mobiliteit naar 2040: veilig, robuust, duurzaam.* [Outline Mobility to 2040: safe, robust, sustainable.].
European Commission. (2022). *Digital Economy and Society Index (DESI) 2022*.
Farag, S., Lyons, G., 2012. To use or not to use? An empirical study of pre-trip public transport information for business and leisure trips and comparison with car travel. Transp. Policy 20, 82–92. https://doi.org/10.1016/j.tranpol.2011.03.007.
Field, A., 2018. Discovering statistics using IBM SPSS statistics. Sage.
Gaskin, C.J., Happell, B., 2014. On exploratory factor analysis: A review of recent evidence, an assessment of current practice, and recommendations for future use. Int. J. Nurs. Stud. 51 (3), 511–521. https://doi.org/10.1016/j.ijnurstu.2013.10.005.
Geržinič, N., van Oort, N., Hoogendoorn-Lanser, S., Cats, O., Hoogendoorn, S., 2023. Potential of on-demand services for urban travel. Transportation 50 (4), 1289–1321. https://doi.org/10.1007/s11116-022-10278-9.
Golub, A., Satterfield, V., Serritella, M., Singh, J., Phillips, S., 2019. Assessing the barriers to equity in smart mobility systems: A case study of Portland, Oregon. *Case Studies on Transport Policy* 7 (4), 689–697. https://doi.org/10.1016/j.cstp.2019.10.002.
Golub, A., Brown, A., Brakewood, C., MacArthur, J., Lee, S., Ziedan, A., 2022. Equity and exclusion issues in cashless fare payment systems for public transportation. Transp. Res. Interdiscip. Perspect. 15, 100628. https://doi.org/10.1016/j.trip.2022.100628.
Goodman-Deane, J., Kluge, J., Roca Bosch, E., Nesterova, N., Bradley, M., Waller, S., Hoeke, L., Clarkson, P.J., 2021. Toward Inclusive Digital Mobility Services: a Population Perspective. Interact. Comput. 33 (4), 426–441. https://doi.org/10.1093/iwc/iwac014.
Goodman-Deane, J., Waller, S., Bradley, M., Clarkson, P.J., Lazzarini, B., Roca Bosch, E., Gaggi, S., 2024. User factors affecting the use of digital services in five European regions and countries. Sci. Data 11 (1), 468. https://doi.org/10.1038/s41597-024-03318-9.
Goswami, A., Dutta, S., 2015. Gender differences in technology usage—A literature review. Open Journal of Business and Management 4 (1), 51–59. https://doi.org/10.4236/ojbm.2016.41006.
Groth, S., 2019. Multimodal divide: Reproduction of transport poverty in smart mobility trends. Transp. Res. A Policy Pract. 125, 56–71. https://doi.org/10.1016/j.tra.2019.04.018.
Hargittai, E., 2009. An update on survey measures of web-oriented digital literacy. Soc. Sci. Comput. Rev. 27 (1), 130–137. https://doi.org/10.1177/0894439308318213.
Helsper, E.J., 2021. The Digital Disconnect: The Social Causes and Consequences of Digital Inequalities. Sage Publications.
Hoogendoorn-Lanser, S., Schaap, N.T.W., Olde Kalter, M.-J., 2015. The Netherlands Mobility Panel: An Innovative Design Approach for Web-based Longitudinal Travel Data Collection. Transp. Res. Procedia 11, 311–329. https://doi.org/10.1016/j.trpro.2015.12.027.
Ito, M., Okabe, D., Anderson, K., 2008. Portable Objects in Three Global Cities: The Personalization of Urban Places. In: Ling, R., Campbell, S.W. (Eds.), The Reconstruction of Space and Time: Mobile Communication Practices. Transaction Publishers, pp. 67–88.
Jamal, S., Habib, M.A., 2020. Smartphone and daily travel: How the use of smartphone applications affect travel decisions. Sustain. Cities Soc. 53, 101939. https://doi.org/10.1016/j.scs.2019.101939.
Kaiser, H.F., Rice, J., 1974. Little Jiffy, Mark IV. Educ. Psychol. Meas. 34 (1), 111–117. https://doi.org/10.1177/001316447403400115.
Keseru, I., Randhahn, A., 2023. Towards User-Centric Transport in Europe 3: Making Digital Mobility Inclusive and Accessible. Springer Nature. https://doi.org/10.1007/978-3-031-26155-8.
Line, T., Jain, J., Lyons, G., 2011. The role of ICTs in everyday mobile lives. J. Transp. Geogr. 19 (6), 1490–1499. https://doi.org/10.1016/j.jtrangeo.2010.07.002.
Lupač, P., 2018. Beyond the Digital Divide: Contextualizing the Information Society. Emerald Publishing Limited. https://doi.org/10.1108/9781787565470.
Luz, G., Portugal, L., 2021. Understanding transport-related social exclusion through the lens of capabilities approach. Transp. Rev. 1–23. https://doi.org/10.1080/01441647.2021.2005183.
Lyons, G., Hammond, P., Mackay, K., 2019. The importance of user perspective in the evolution of MaaS. Transp. Res. A Policy Pract. 121, 22–36. https://doi.org/10.1016/j.tra.2018.12.010.
Manders, T., Klaassen, E., 2019. Unpacking the Smart Mobility Concept in the Dutch Context Based on a Text Mining Approach. Sustainability 11 (23). https://doi.org/10.3390/su11236583.
Mariën, I., Heyman, R., Salemink, K., Van Audenhove, L., 2016. Digital by Default: Consequences, Casualties and Coping strategies. In: Social Inequalities, Media and Communication: Theory and Roots. Rowman and Littlefield, pp. 167–188.
Páez, A., Scott, D.M., Morency, C., 2012. Measuring accessibility: positive and normative implementations of various accessibility indicators. J. Transp. Geogr. 25, 141–153. https://doi.org/10.1016/j.jtrangeo.2012.03.016.
Pick, J., & Sarkar, A. (2016). *Theories of the Digital Divide: Critical Comparison* 49th Hawaii International Conference on System Sciences (HICSS).
Ravensbergen, L., Van Liefferinge, M., Isabella, J., Merrina, Z., El-Geneidy, A., 2022. Accessibility by public transport for older adults: a systematic review. J. Transp. Geogr. 103, 103408. https://doi.org/10.1016/j.jtrangeo.2022.103408.
Schmitt, L., Delbosc, A., Currie, G., 2019. Learning to use transit services: adapting to unfamiliar transit travel. Transportation. https://doi.org/10.1007/s11116-018-9880-9.
Schreiber, J.B., 2021. Issues and recommendations for exploratory factor analysis and principal component analysis. Res. Soc. Adm. Pharm. 17 (5), 1004–1011. https://doi.org/10.1016/j.sapharm.2020.07.027.
Sell, A., Mezei, J., Walden, P., 2014. An attitude-based latent class segmentation analysis of mobile phone users. Telematics Inform. 31 (2), 209–219. https://doi.org/10.1016/j.tele.2013.08.004.
Sin, F., Berger, S., Kim, I.-J., Yoon, D., 2021. Digital social interaction in older adults during the COVID-19 pandemic. Proc. ACM. Hum. Comput. Interact. 5 (CSCW2), 1–20. https://doi.org/10.1145/3479524.
Sochor, J., Arby, H., Karlsson, I.C.M., Sarasini, S., 2017. A topological approach to Mobility as a Service: A proposed tool for understanding requirements and effects, and for aiding the integration of social goals. 1st International Conference on Mobility-as-a-Service.
Statistics Netherlands. (2023a). *Digital proficiency continues to rise*. Retrieved April 27th, 2024 from https://www.cbs.nl/en-gb/news/2023/45/digital-proficiency-continues-to-rise.
Statistics Netherlands. (2023b). *ICT-gebruik bij personen [ICT use among persons]*. Retrieved April 27th, 2024 from https://longreads.cbs.nl/ict-kennis-en-economie-2023/ict-gebruik-bij-personen/.
Statistics Netherlands. (2024). *Dutch National Travel survey*. Retrieved April 27th, 2024 from https://www.cbs.nl/en-gb/our-services/methods/surveys/brief-survey-description/dutch-national-travel-survey.
Tao, S., Kamruzzaman, L., Ma, J., 2024. Transport disadvantage and social inclusion: Exploring the role of smartphone use for transport purposes. Transp. Res. A Policy Pract. 189, 104240. https://doi.org/10.1016/j.tra.2024.104240.
Un, P., Adelé, S., Vallet, F., Burkhardt, J.-M., 2022. How Does My Train Line Run? Elicitation of Six Information-Seeking Profiles of Regular Suburban Train Users. Sustainability 14 (5), 2665. https://doi.org/10.3390/su14052665.
Van Acker, V., Ho, L., Mulley, C., 2021. "Satisfaction lies in the effort". Is Gandhi's quote also true for satisfaction with commuting? Transp. Res. A Policy Pract. 151, 214–227. https://doi.org/10.1016/j.tra.2021.07.010.
Van Deursen, A., Helsper, E. J., & Eynon, R. (2014). Measuring digital skills. From Digital Skills to Tangible Outcomes project report.
Van Deursen, A.J.A.M., Helsper, E.J., Eynon, R., Van Dijk, J., 2017. The compoundness and sequentiality of digital inequality. Int. J. Commun. 11, 452–473.
Van Deursen, A.J.A.M., Van Dijk, J., 2010. Internet skills and the digital divide. New Media Soc. 13 (6), 893–911. https://doi.org/10.1177/1461444810386774.
Van Deursen, A.J.A.M., Van Dijk, J., 2018. The first-level digital divide shifts from inequalities in physical access to inequalities in material access. New Media Soc. 21 (2), 1–22. https://doi.org/10.1177/1461444818797082.
Van Deursen, A. (2023). *Trendrapport Digitale Inclusie 2023*.
Van Dijk, J.A.G.M., 2005. The Deepening Divide: Inequality in the information society. Sage Publications. https://doi.org/10.4135/9781452229812.
Van Dijk, J.A.G.M., 2019. The Digital Divide. Polity Press.
Van Dijk, J. A. G. M., & Van Deursen, A. J. A. M. (2014). *Digital Skills: Unlocking the Information Society*. Palgrave Macmillan.
Van Wee, B., Geurs, K., Chorus, C., 2013. Information, communication, travel behavior and accessibility. J. Transp. Land Use 6 (3), 1–16. https://doi.org/10.5198/jtlu.v6i3.282.
Vecchio, G., Martens, K., 2021. Accessibility and the Capabilities Approach: a review of the literature and proposal for conceptual advancements. Transp. Rev. 41 (6), 833–854. https://doi.org/10.1080/01441647.2021.1931551.
Vrščaj, D., Nyholm, S., Verbong, G.P.J., 2020. Smart mobility innovation policy as boundary work: identifying the challenges of user involvement. Transp. Rev. 1–20. https://doi.org/10.1080/01441647.2020.1829743.
Williams, B., Onsman, A., Brown, T., 2010. Exploratory factor analysis: A five-step guide for novices. Australasian Journal of Paramedicine 8, 1–13. https://doi.org/10.33151/ajp.8.3.93.
Yates, S.J., Kirby, J., Lockley, E., 2015. 'Digital-by-default': reinforcing exclusion through technology. In: Foster, L., Brunton, A., Deeming, C., Haux, T. (Eds.), In Defense of Welfare 2. Social Policy Association, pp. 158–161.
Yigitcanlar, T., Downie, A.T., Mathews, S., Fatima, S., MacPherson, J., Behara, K.N., Paz, A., 2024. Digital technologies of transportation-related communication: Review

and the state-of-the-art. Transp. Res. Interdiscip. Perspect. 23, 100987. https://doi.org/10.1016/j.trip.2023.100987.

Zhang, M., Zhao, P., Qiao, S., 2020. Smartness-induced transport inequality: Privacy concern, lacking knowledge of smartphone use and unequal access to transport information. Transp. Policy 99, 175–185. https://doi.org/10.1016/j.tranpol.2020.08.016.

Zijlstra, T., Durand, A., Hoogendoorn-Lanser, S., Harms, L., 2020. Early adopters of Mobility-as-a-Service in the Netherlands. Transp. Policy 97, 197–209. https://doi.org/10.1016/j.tranpol.2020.07.019.