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Digital kiosks and inclusivity: a novel perspective on mobility hubs

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Abstract

Mobility hubs facilitate multimodal transport and have the potential to improve the accessibility and usability of new mobility services. However, in the context of increasing digitalisation, using mobility hubs requires digital literacy or even owning a smartphone. This constraint may result in the exclusion of current and potential users. Digital kiosks might prove to be a solution, as they can facilitate the use of the services found at mobility hubs. Nevertheless, knowledge of how digital kiosks may improve the experience of disadvantaged groups remains limited in the literature. As part of the SmartHubs project, a field test with a digital kiosk was conducted with 105 participants in Brussels (Belgium) and Rotterdam (The Netherlands) to investigate the intention to use it and its usability in the context of mobility hubs. This study adopted a mixed methods approach, combining participant observation and questionnaire surveys. Firstly, participants were asked to accomplish seven tasks with the digital kiosk while being observed by the researchers. Finally, assisted questionnaire surveys were conducted with the same participants, including close-ended, open-ended and socio-demographic questions. The results offer insights into the experience of the users of a digital kiosk in a mobility hub and the differences across specific social groups. These findings may be relevant for decision-makers and practitioners working in urban mobility on subjects such as mobility hubs and shared mobility, and for user interface developers concerned with the inclusivity of digital kiosks.

Keywords Mobility hubs, Digital kiosks, Shared mobility, Digital mobility services, Inclusive transport, Transport equity

1 Introduction

Mobility hubs facilitate multimodal transport and have the potential to improve the accessibility and usability of new mobility services. In recent years, mobility hubs have become more relevant, with several pilot cases and networks deployed across Europe. Using the wide range of services found at mobility hubs and accessing the necessary information to use them often requires digital literacy or even owning a smartphone. The latter is increasingly essential in the context of the digitalisation of transport services, in which alternative access to services without the use of a smartphone application is often lacking [1]. This conflicts with the actual level of digital skills of citizens, resulting in a new form of transport disadvantage, possibly on top of existing ones [2]. In the European Union, 46% of the population aged between 16 and 74 years do not have basic digital skills [3], and, likely, even a higher percentage of the population does not have the required skills to benefit from app-based mobility services. Thus, low levels of digital skills may exacerbate the exclusion of disadvantaged users who cannot conveniently use mobility hubs. In this regard, digital kiosks might be able to counter this because, as publicly available digital devices, they have the potential to facilitate access to mobility hubs and provide

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the necessary information in a simple, interactive and adapted manner. However, the existing literature presents limited knowledge of how digital kiosks can be used by disadvantaged groups.

This paper presents—to our knowledge—the first study to examine the relevance of digital kiosks for disadvantaged groups in the context of mobility hubs. Although previous studies have been conducted on digital kiosks and public transport stations, none were done regarding mobility hubs. Filling this gap is relevant because, unlike traditional transport stops, mobility hubs include services which are often only accessible through digital means [4]. For this, a field test with a digital kiosk was conducted to answer the research question, 'To what extent can digital kiosks be useful to disadvantaged groups in the context of mobility hubs?'. This study aimed to identify the intention of use, the usability and the relevant and missing features. For this, the sample of 105 participants was segmented depending on the native language of the participants, their level of education, and their digital skills.

The remainder of the paper is structured as follows. Section 2 contains a literature review of previous research on mobility hubs, their inclusivity and the role of digital kiosks. Section 3 explains the research design: the data collection methods, sampling, and set-up of the field test. Section 4 presents the findings, while Sect. 5 includes a discussion, conclusions, and a reflection on the study's limitations and further research.

2 Literature review

A mobility hub is a physical location where different public transport and shared mobility services are offered at permanent, dedicated, well-defined and well-visible places, with either a physical or geo-fenced digital boundary. In a hub, users can find shared bikes, cargo bikes, mopeds, e-scooters or cars, public transport stops, ticket vending machines, interactive digital screens and other services, such as parcel lockers, restrooms and shops [4].

In the context of the increasing digitalisation of transport services, individuals who do not own an up-to-date and operating digital device or do not have the necessary digital skills would be excluded from such services. This is particularly problematic regarding shared mobility services because accessing the necessary information to use them as well as booking them is often only possible via a digital device [4]. This barrier adds to other obstacles faced by certain social groups, such as older adults, people with lower education, individuals with a lower income, migrants, or ethnic minorities [2, 5]. To designate these groups, the term "disadvantaged groups" is used, referring to people who are more likely to encounter difficulties travelling and accessing necessary destinations [6, 7]. Such difficulties can increase their vulnerability to some form of exclusion besides the use of the service, such as social exclusion [8].

Regarding shared mobility services, several scholars found that users are predominantly young and highly educated men [9–15]. The intention to use shared mobility services is higher among people with digital skills [11]. Multiple reasons can explain the unequal use of shared mobility services and mobility hubs. However, not having a digital device or lacking digital skills is a major barrier [5].

The inclusivity of mobility hubs regarding digital accessibility relates to the ability to use personal or public digital devices. This is because such devices are required to access the services offered at hubs as well as the information that facilitates access to these services [5]. Digital devices provide access to booking and ticketing services for public transport and shared vehicles, information about departure times of public transport services, availability of shared vehicles, wayfinding information or additional services such as parcel lockers or vending machines. Usually, this is done using a personal device such as a smartphone.

However, publicly available devices can still be useful for people who do not have a functioning personal digital device. In the literature, publicly accessible devices are referred to as interactive kiosks, self-service kiosks or digital information kiosks. In this study, the term digital kiosk refers to publicly available digital devices that provide information and other features for users of transport services in an interactive and individualised manner.

From the scarce literature about digital kiosks in the context of urban mobility, two main strands can be distinguished. Firstly, some scholars investigated the opportunities for digital kiosks to enable interaction and provision of information to improve user experience with transport services [16], especially in the case of multimodal hubs [17]. Secondly, other authors focussed on the relevance and acceptance of digital kiosks. For instance, a study in Istanbul found that most users would like to use the kiosk for route planning, and intuitive and easy-to-use kiosks would improve their experience with public transport [18]. Nonetheless, younger people are more likely to interact with kiosks, while older users would be more likely to look at the screen to read displayed information [19]. The ease of use, perceived performance and the need for consumer interaction impact the acceptance of digital kiosks [20].

Some scholars created guidelines specifically for designing digital kiosks [17]—sometimes even with a user-centric design framework [18]—although the diverse needs of disadvantaged users were not considered. The inclusivity

of digital kiosks has been considered by Maguire [21], who proposed guidelines on user interface design for public digital kiosks, and Veijalainen [22], who identified general design principles. Furthermore, some authors studied the needs and barriers encountered by older people and people with impairments [21, 23, 24]. The main conclusions of such studies were that kiosks can be made more inclusive by adopting a user-centric approach that includes disadvantaged people in the design process and by increasing the sophistication and data analysis of the kiosk. The latter would allow for the adaption of the user experience to the abilities of users, simplifying the interaction needed and anticipating potential mistakes. In this regard, recent research has identified how universal design principles could be applied to digital mobility services to make them more accessible to disadvantaged people. A service evaluation tool and design guidelines were developed to foster a more inclusive design. However, these efforts focused on smartphone-based services and not digital kiosks [25, 26].

As there has been limited research on the inclusivity of digital kiosks, this review has also considered literature about the needs of disadvantaged groups concerning ticket vending machines. Within this strand of literature, some scholars focussed on the development of barrier-free ticket vending machines [27–29]. They highlighted the need to adapt the position of each element of the kiosk to the abilities of people with impairments, such as wheelchair users. They also stressed the need to include features that enable people with visual impairments to use machines. A simplified menu display with body language service and voice recognition, as well as a feature that automatically detects the disability level of the user, were recommended to increase the success rate of users with impairments [27].

Within the literature about ticket vending machines, some studies focussed on the usability for specific groups, such as older adults [30, 31] or foreigners [32]. The results suggested that the simple integration of a short video with instructions or a task-oriented wizard design can make the use of the machines easier. Lastly, some scholars stated that adopting a user-centric design approach enables the identification of the needs of disadvantaged users and, therefore, the development of more inclusive machines [29, 33]. The latter highlighted that the emotional experience when using the machine must be considered because a positive experience will encourage widespread and recurrent use.

The literature included in this review suggests that barrier-free and user-centric digital devices may increase the inclusivity of transport services. However, as the research on mobility hubs is relatively new, the extent to which digital kiosks can be useful to disadvantaged groups in the context of mobility hubs has not been studied yet. To fill this knowledge gap, this study focuses on three disadvantaged groups that encounter difficulties accessing the necessary information to use mobility hubs: people with low education, low literacy of the official local languages and low digital skills [5].

3 Research design

Data was collected in Brussels (Belgium), and Rotterdam (Netherlands) to investigate digital kiosks in the context of mobility hubs. These cities were selected because they are developing networks of mobility hubs as part of their transport infrastructure [34], and such kiosks would be new to most users. The following section describes the data collection methods applied in this study, the sample of participants, and the set-up of the field test.

3.1 Methodology

This study applied three methods to collect data on how participants used digital kiosks. The methods were chosen by reviewing previous studies on digital kiosks or ticket vending machines. Several scholars aiming to gain insights into the performance of users conducted field tests in which participants tested a device [35–38]. Questionnaire surveys were also broadly used [19, 36, 39, 40], as well as observations of the participants testing the devices [18, 37, 38].

Furthermore, transport scholars who investigated the usability of devices or applications most often used surveys, but field tests and interviews were also used [41]. Field tests are considered the most realistic and, thus, more adequate than lab-based tests [42]. To assess usability, they investigated the efficiency, effectiveness and satisfaction of a solution in a specific context [41, 43].

Based on this, a mixed-methods approach was adopted. Firstly, participants in this study were asked to test the digital kiosk by conducting a set of seven predefined tasks. Participants were asked to look for the next departure time for a tram, bus, or metro lines; to look for information and book shared transport services—shared bicycles in both locations and shared cars in Brussels or shared mopeds in Rotterdam; to look for what additional services are found in the hub; to look up the walking time to a specific location; and to look for more information about the digital kiosk. Destinations of public transport services and real-time information were changed depending on the location where the field test took place.

The researchers observed participants conducting each task to evaluate their performance. These observations (see Appendix 1) aimed at identifying the difficulties and reactions encountered by participants, the time they took to complete the tasks, and the number of tasks successfully achieved.

Secondly, once the participants had used the kiosk and become familiar with it, they were asked to rate their experience through a short satisfaction survey found in the kiosk (see Appendix 2). Participants were asked to rate their intention of using it in the future, the usefulness and usability of the digital kiosk according to their needs, and its main features.

Finally, participants completed an assisted questionnaire survey with a researcher (see Appendix 3). They were asked nine questions, of which seven were open-ended. The researchers asked about previous experiences with similar devices, their experience during the test, the perceived usefulness of the kiosk, and potential improvements and missing functionalities. Several additional questions were aimed at learning about the travel behaviour of the participants, their level of digital skills, and their demographic characteristics. Participants were free to answer any of the questions, resulting in a lower response rate in the open-ended questions that required further elaboration.

To answer the research questions, the analysis first looked at the general results and secondly at the results of specific groups. The quantitative data was analysed through a descriptive approach, and the qualitative data was analysed through inductive coding. The latter allowed the researchers to identify categories within the data obtained in the open-ended questions. All answers to the open-ended questions were reviewed again, filtering and reorganising them using categories.

3.2 Sample

Participants were recruited on-site in four different locations: three in Anderlecht (Brussels) and one in Rotterdam. The researchers looked for people passing by or conducting an activity inside the buildings where the study was conducted. They were informed about the study and invited to participate.

The sample of participants was chosen according to the type of performance test conducted for the study: a guided test with seven predefined tasks. As similar studies found in the literature included a sample of no more than 71 participants [18, 32, 36, 38], 100 participants was considered an adequate sample for this study. Furthermore, the sample had to include the disadvantaged groups considered in this study: people with low education, low literacy of the official local language(s) and low digital skills. For this, the following quotas were targeted:

- 50% of participants should have a low level of education.
- 50% of participants should not be a native speaker of the official local languages (French and/or Dutch).
- At least 50% of participants should have a low level of digital skills.

Additionally, a minimum of 50% of participants indicating their gender as women and 10% being over 60 were also targeted. This aimed at ensuring the participation of groups that, although demographically relevant, have traditionally suffered from transport disadvantages [6].

In total, 105 participants tested the digital kiosk (see Table 1): 50 in Anderlecht and 55 in Rotterdam. Most participants were women (64%), and the Belgian sample contained more women than the Dutch one (72% vs. 56%). The testers were, on average, 40 years old, with the Dutch sample being skewed slightly towards a younger population than the Belgian sample. Most of the participants had a low level of education (46%) because their highest schooling was a secondary degree. Half of the sample completed the tasks in their mother tongue, which was one of the available languages in the kiosk. Here, a significant difference was found between the Anderlecht and Rotterdam data: in the former case, 62% of the testers were non-native speakers of the local languages, whereas in the latter case, it was 39%. In both the Belgian and Dutch samples, the vast majority of testers had lived in the respective testing cities for over two years, being familiar to a certain extent with the local transport network. Lastly, although nearly all of the testers owned a smartphone, 74 participants were considered to have low digital skills. In this study, participants were considered to have low digital skills if they had never used their smartphones to scan a QR code, book a transport service, and make online payments.

3.3 Set-up of the field test

In order to test to which extent digital kiosks can facilitate the use of mobility hubs, a field test was designed with a digital kiosk (see Fig. 1). The software and the interface were developed by Mpact, and the kiosk (hardware) was developed by Infopunt Publieke Ruimte, two Belgian nonprofit organisations. Through language buttons in the lower right-hand corner, testers could switch between Dutch and English, and in Brussels, French was also available.

The digital kiosk was tested in two neighbourhoods: Kuregem in Anderlecht (Brussels) and Zuidplein in Rotterdam. In Brussels, the tests took place for seven days between October and November, and in Rotterdam, the tests took place for one week at the beginning of December. Testers were recruited on-site in both locations. In Brussels, three testing days were held at a local community centre and two days at a municipal building where

Table 1 Socio-demographics of participants (number-percentage of respondents within the sample)

	Full sample		Belgian sample		Dutch sample	
Women	67	64%	36	72%	31	56%
Men	38	36%	14	28%	24	44%
Median age	38	–	39	–	36	–
< 20 years	11	11%	2	4%	9	16%
20–29 years	19	18%	8	17%	11	20%
30–39 years	26	25%	15	31%	11	20%
40–49 years	15	15%	10	21%	5	9%
50–59 years	17	17%	7	15%	10	18%
60–69 years	8	8%	1	2%	7	13%
> 69 years	7	7%	5	10%	2	4%
Completed primary school	16	15%	11	22%	5	9%
Completed secondary school	33	31%	14	28%	19	35%
Completed post-secondary school	46	44%	23	46%	23	41%
Native speaker of the local language(s)	52	50%	19	38%	33	61%
Non-native speaker of the local language(s)	51	50%	31	62%	20	39%
Have a smartphone	97	92%	47	94%	50	91%
Do not have a smartphone	8	8%	3	6%	5	9%

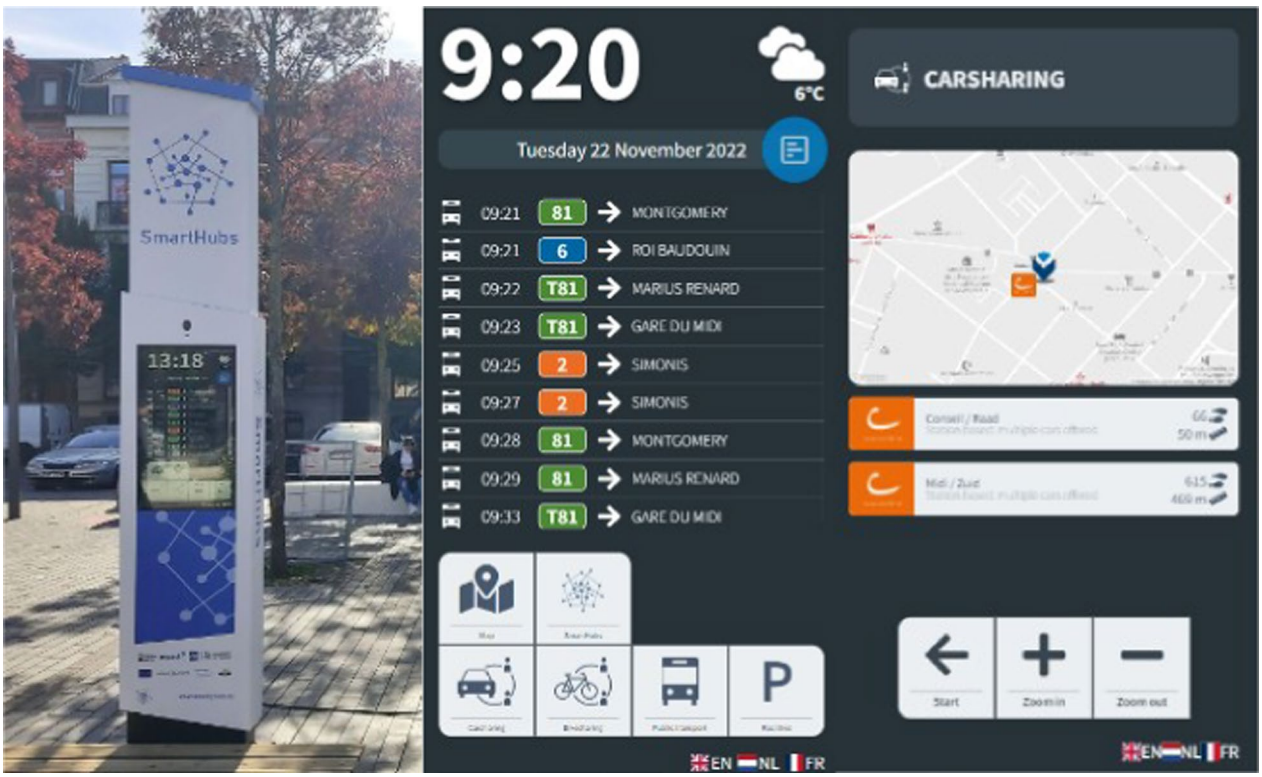


Fig. 1 Left: the digital kiosk in Anderlecht—middle: starting screen of the digital kiosk—right: detailed page on carsharing. Source: authors' own

social and cultural activities were organised. Two other days of testing took place outdoors at Raadsplein/Place du Conseil, the central square of the neighbourhood. In Rotterdam, the pillar testing took place at the service point of the RET, the local public transport provider. Visitors of the service point, who mostly visited the location to charge their public transport card (OV-chipkaart) or ask for directions, were asked to participate in the test.

Beforehand, the six testing days were promoted via social media, posters, and flyers at the service point and in local community centres.

The first location of the field test, Kuregem (Cureghem in French spelling), is a neighbourhood located just outside the centre of Brussels and close to the largest railway station in Belgium. Many shared, and sustainable modes are available, such as the tram, bus, metro shared cars, and shared bicycles. Nonetheless, the levels of nitrogen dioxide are among the highest in the Region, being twice or thrice as high as the maximum recommended by the World Health Organisation [44]. As shown in Table 2, Kuregem is one of the most densely populated parts of Brussels and Belgium; the median taxable income is among the lowest in the capital, and more than a quarter of the population is unemployed. Higher levels of poverty and unemployment can be found [45] in this area, which also hosts a higher share of people without Belgian nationality (European Union, Turkey, Northern Africa, Sub-Sahara) than the regional average [46]. Moreover, figures for the municipality of Anderlecht indicate that around 47% of the residents with a Belgian ID card have non-Belgian origins [47]. The share of people above 25 with a higher education degree is also much lower than the regional average: 16% in Anderlecht compared to 28% in Brussels [48].

The second location of the field test, Zuidplein, is an important public transportation node within the city of Rotterdam, the second-largest municipality in The Netherlands. The station offers a wide range of bus and metro lines and houses one of the largest shopping malls in the city. Although parking shared vehicles is prohibited [49], the municipality placed a temporary micro-hub within walking distance of the station. Zuidplein is located within the Charlois district but also serves the nearby Feijenoord district. These two districts in the southern part of Rotterdam are relatively disadvantaged compared to the rest of the city. The municipality of Rotterdam and the national government acknowledged in 2010 that the situation in the south of Rotterdam needed to improve, resulting in a national intervention program that invested in education, work and safety [50]. Still, as shown in Table 3, the area has a large share of people with household incomes below average and relatively lower educational levels.

4 Findings

The results are structured in three sub-sections, according to the main elements investigated in this study: the intention of use, the usability and the relevant functionalities of the digital kiosk. The three sub-sections are informed by the data collected in the satisfaction survey and the assisted questionnaire surveys. The observations are used to elaborate on the usability of the kiosk.

4.1 Intention of use

85% of the participants had never interacted with a digital kiosk before, and this was similar for participants with low and high levels of digital skills. Participants who had used a digital kiosk before had rarely used it for transportation, and most of them had only used it in exceptional situations. Almost every participant who had used

Table 2 Demographics at the Anderlecht living lab in Brussels [45, 46]

	Kuregem	Brussels capital region
Population density (inhabitants/km^2)	20 679	7 501
Median taxable yearly income	€ 15 518	€ 19 723
Share of inhabitants with non-Belgian nationality (European Union, Turkey, North Africa, Sub-Sahara)	34,8%	29,1%
+25-year-olds with a higher education degree (Anderlecht)	16.3%	28.1%

Table 3 Demographics at the Rotterdam living lab [54–56]

	Charlois	Feijenoord	Rotterdam
Population density (inhabitants/km^2)	6 225	11 767	3 001
Median taxable yearly income	€ 26 600	€ 28 400	€ 32 700
Share of inhabitants with a migration background (European Union, Suriname, Turkey, North Africa, etc.)	68,9%	69,3%	53,7%
Inhabitants (15–75y) with a higher education degree	18,0%	23,6%	31,0%

a digital kiosk before (15%) would like to use it again in a mobility hub.

The participants of the field test had a positive experience with the digital kiosk. Overall, most participants (71%) stated that they would use the digital kiosk in the future. Interestingly, participants with low digital skills were not less likely to use the digital pillar than more digitally skilled participants (see Table 4). However, participants with lower education and non-native speakers of the official local languages were more likely to use the digital kiosk than those with higher education and native speakers.

Considering the complete sample of participants, 87% of participants regarded the digital kiosk as useful. Additionally, 82% of participants were positive that the kiosk could help them to use mobility services such as public transportation (e.g., by providing information on departure times and schedules of services) and, to a lesser extent, shared mobility. People with lower education or non-native speakers of the local language did not rate the usefulness of the digital kiosk very differently than participants who did not belong to these groups. Nonetheless, people with lower levels of digital skills consider the kiosk less useful than people with higher levels of digital skills (see Table 4).

Through the open-ended questions, participants were asked to explain why they would or would not use the digital kiosk. Among the reasons for using the kiosk, using it to substitute the smartphone when it is not functioning properly (e.g., no internet connection or Wifi) was the most referred to (n = 10). Some participants (n = 8) stated they would use the kiosk to easily obtain information about the transport services found at the hub. Several participants stated they would use the kiosk only for specific functions, such as looking up departure times and schedules (n = 7) or checking the map and wayfinding in the hub (n = 4). Moreover, the participants who stated they would use the kiosk to check departure times and schedules of public transport services were found to be less digitally skilled.

Several participants (n = 8) indicated they would use the digital kiosk irregularly when they were unfamiliar with the location of the mobility hub or the trip or had no other information sources. The participants who stated they would use the kiosk regularly (n = 4) belong to the group with low digital skills. Furthermore, 22% of the participants indicated they would not use the digital kiosk. The preference to use their smartphone (n = 4) and the kiosk being inconvenient or difficult to use (n = 3) were the reasons given by participants. Moreover, the latter was only stated by people with low digital skills.

4.2 Usability

Concerning the tasks participants were asked to conduct, 66% could not complete one or more tasks. Their performance was rated as poor when participants succeeded with four or fewer tasks, fair when participants succeeded in 5 or 6 tasks, and good if they completed all tasks (see Fig. 2). Participants with lower digital skills encountered more difficulties in performing all tasks, and their success rate was lower than for the rest of the participants: 74% of participants with lower digital skills failed one or more tasks, whilst 45% of participants with higher digital skills did.

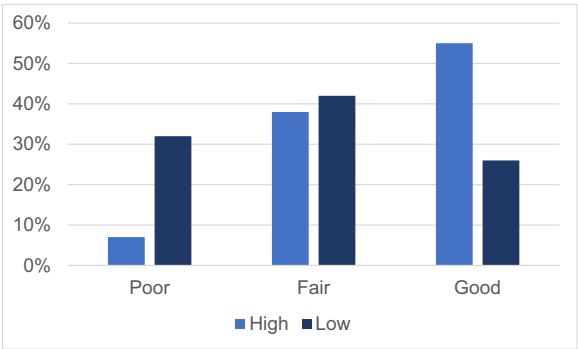


Fig. 2 Test performance comparison: high digital skills—low digital skills

Table 4 The likelihood of using the kiosk and its perceived usefulness depending on the literacy of the local language, the level of education and digital skills of the participant

	Literacy local language			Level of education			Level of digital skills		
	Native (%)	Non-native (%)	Diff. (%)	Low (%)	High (%)	Diff. (%)	Low (%)	High (%)	Diff. (%)
Not likely to use it again	33	28	5	22	33	**11**	30	28	2
Likely to use it again	67	73	5	78	67	**11**	70	72	2
Not useful	12	14	2	10	11	1	15	7	**8**
Useful	89	86	2	90	89	1	85	93	**8**

The difference among groups is indicated in the column 'Diff.' In bold letters, the most significant differences are highlighted

Moreover, people with low digital skills, non-native speakers of the local language, and people with lower education levels needed more time to complete the tasks. Lower digitally skilled people needed, on average, 12% more time to complete all tasks compared to higher digitally skilled. Overall, participants with lower digital skills and non-native speakers of the local language rated the ease of using the kiosk less positively than the rest (see Table 5). The difference between participants with low and high levels of education was insignificant.

The tasks with a lower success rate—where less than 75% of participants succeeded—indicate what elements of the kiosk should be improved. In the most challenging task—49 out of 105 participants failed—participants were asked to find the walking time to a specific location using the map feature. Participants struggled with finding the right location on the map because they failed to zoom or pan the map. Another reason for failure was that some locations were hidden behind map symbols, showing the need to improve the map interface (e.g., sizes of fonts, icons, and colours). Overall, the map was too difficult to use for participants with low digital skills and overwhelming for participants who did not have experience with interactive maps.

Finding information on facilities at the hub was considered a difficult task. Over 30 participants selected the wrong button on the kiosk, which suggests that the 'facilities' button was not self-explanatory enough. Likewise, 20% of the participants did not successfully complete the tasks related to renting a shared vehicle. Several participants did not find out that a second click on a specific place on the page was needed to find rental information. Through the open-ended questions, participants pointed out, among other issues, that they struggled with the complexity of the map (n = 25) and finding the right buttons (n = 11). The participants who stated that they struggled with the meaning of the pictograms (n = 6) and the concept of shared mobility (n = 6) belonged to the group with low digital skills.

Participants mentioned multiple points of improvement, mostly regarding the usability of the kiosk, and some participants (n = 8) explicitly referred to the map. Overall, the need for a simplified and more straightforward interface was highlighted by some participants (n = 6), as well as more precise and easily recognisable pictograms (n = 6). To improve the experience for non-native speakers, some participants (n = 8) stated that other language options should be available. Furthermore, an interface with less text, improved colours, and font size would increase the usability of some disadvantaged groups and people with low digital skills.

4.3 Functionalities

After completing the tasks, participants were asked which function they considered most useful among those unrelated to accessing shared mobility services. The real-time departure information was voted the most useful functionality (54% of participants), ahead of the map (28%) and the overview of the facilities (18%). Real-time information was highly appreciated and commonly referred to by participants when they explained why they considered the kiosk useful.

Additionally, 66% of participants stated that they would use the digital kiosk to buy public or shared transportation tickets. This is related to the findings on missing functionalities, as several participants stated they missed the option to purchase a ticket (n = 13) or a trip planning feature (n = 5). Public transportation was primarily mentioned as the service for which participants would like to buy a ticket (n = 26), followed by shared mobility in general (n = 10). When looking at the group of people with low digital skills, the proportion of participants that would use the digital kiosk to book a shared mobility service was slightly higher than those with higher digital skills. On the other hand, participants who did not want to buy a ticket via the kiosk stated that they would rather use their phone (n = 4) or did not need to purchase tickets because they already owned a yearly pass (n = 9).

Table 5 The ease of use of the kiosk depending on the literacy of the local language, the level of education and the level of digital skills of the participants

	Literacy local language			Level of education			Level of digital skills		
	Native (%)	Non-native (%)	Diff. (%)	Low (%)	High (%)	Diff. (%)	Low (%)	High (%)	Diff. (%)
Not easy to use	21	33	**12**	24	26	2	32	14	**18**
Easy to use	79	67	**12**	76	74	2	68	86	**18**

The difference among groups is indicated in the column 'Diff.' In bold letters, the most significant differences are highlighted

5 Conclusions

This study aimed to answer the research question "To what extent can digital kiosks be useful to disadvantaged groups in the context of mobility hubs?" by investigating the intention of using and the usability of digital kiosks through two field tests undertaken with 105 participants in Brussels (Belgium), and Rotterdam (The Netherlands). The disadvantaged groups considered in the study were people with low education, low literacy of the official local languages and low digital skills. The results show that digital kiosks would be useful for such groups. Furthermore, most participants with low digital skills and non-native speakers of the official local languages mentioned that the kiosk was easy to use. This may indicate that digital kiosks at mobility hubs do not per se increase the exclusion of the disadvantaged groups considered in this research. On the contrary, digital kiosks are an additional option in a context where transport services are often provided only via smartphones.

Nevertheless, the information provided by digital kiosks must be simple and self-explanatory to all users, including those of public transport, shared mobility, and other services of the mobility hub. For this, the colours and size of elements and fonts must be purposely chosen, and the meaning of the pictograms and buttons must be understandable by all users. The latter allows them to know where to click at each moment, as identified in previous research [51]. Similarly, several scholars stated that it is necessary to develop user-friendly interfaces to decrease the difficulties encountered by users with low technological ability [21, 23, 24, 29]. In this regard, Basu et al. [52] highlighted the need to adopt universal design principles for digital mobility services to ensure inclusivity. How the information is presented and integrated with shared mobility solutions is key to overcoming transport disadvantages [53]. Lastly, the use of maps should be critically considered, as this feature was found to be problematic, particularly for low digitally skilled people. Besides, maps can be misleading when incomplete or difficult to read.

The results of this study fill the gap identified in the literature by acknowledging the relevance of digital kiosks for disadvantaged groups. Moreover, they offer new insights regarding three disadvantaged groups previously overlooked in the literature on digital kiosks. Nevertheless, these findings do not indicate that a digital kiosk is the preferred option for accessing mobility hubs. For instance, some participants stated that the real-time information and ticket vending options were important to them, and other participants did have a smartphone and were digitally skilled. Perhaps, for such groups, other solutions, such as an information screen, ticket vending machine, or training on how to operate the necessary apps to use a mobility hub, are more suitable.

This study has several limitations that prevent a precise determination of whether digital kiosks facilitate the use of mobility hubs. Firstly, the number of participants is too low to make a reliable statistical analysis. Secondly, participants were asked to express their preferences concerning a device and specific services that they were not familiar with. This may lead to a certain degree of mismatch with the actual use that people would make of the digital kiosk once they are familiar with it. Although all surveys were conducted after participants had tested the kiosk to overcome this, the long-term behaviour remains unknown. Thirdly, the kiosk was not fully integrated with the systems of the shared mobility providers, and it was impossible to ask participants to complete the booking of a service or pay for it.

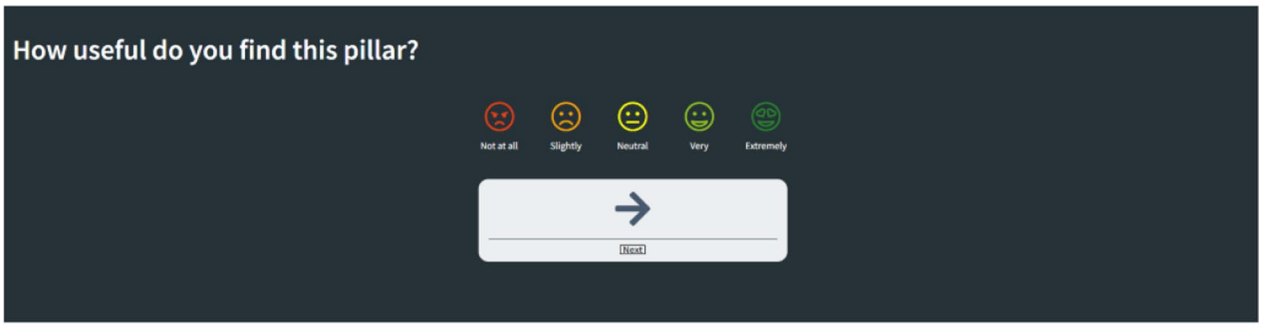
Further research could thoroughly investigate to what extent digital kiosks enable the use of mobility hubs in the long term by testing more integrated devices and studying how they are used throughout time. Moreover, the findings of this study also show how familiarity with and ownership of digital devices, as well as the level of digital skills, are increasingly important barriers preventing individuals from using transport services. Further research could investigate what form of segmentation by the level of digital skills is more relevant to transport studies. Lastly, further research could investigate which features are best to include in a digital kiosk and which should be provided on different information media or interfaces.

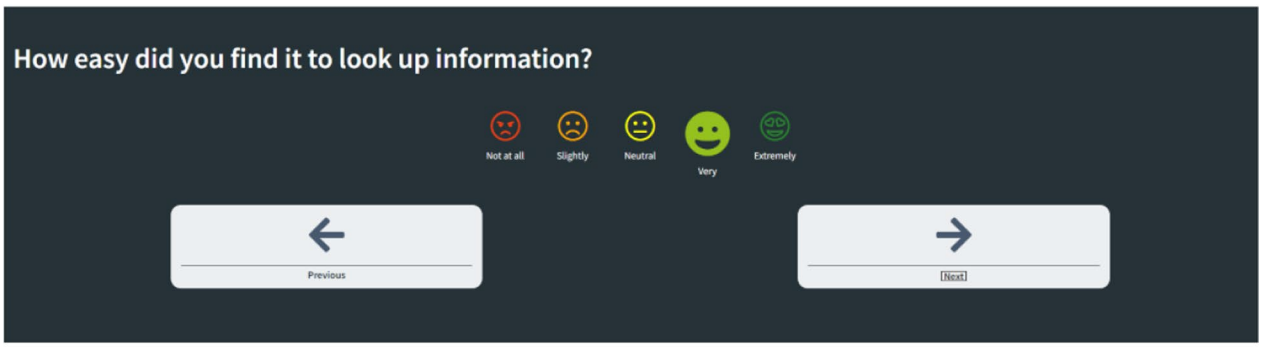
Appendix 1

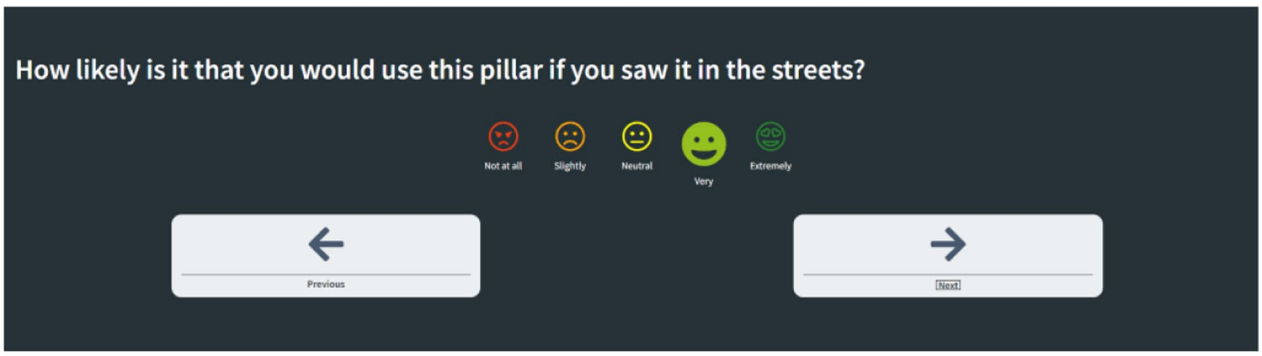
Observation protocol

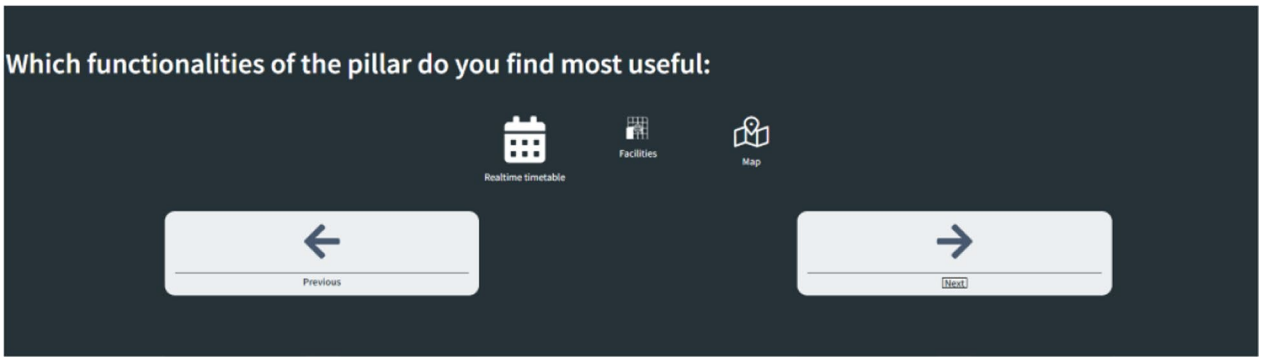
ID participant	
Initials observer	
Date	
Start time	
End time	
Assignment type	A / B
OBSERVATIONS	**CODING**
Steps that participant struggled with; errors made; reactions and comments by participant concerning each assignment (1-7).	
1.	
2.	
3.	
4.	
5.	
6.	
7.	

Appendix 2
Digital satisfaction survey









Appendix 3

Assisted questionnaire survey

Questions

- Have you ever **used a digital information kiosk before** similar to the one you just tested?

Y / N

- If yes, where/how often?

- Do you **intend to use** these types of kiosks in the future? (Y / N)

  If yes, how? (when/how many times/for which types of purposes?)
  If not, what makes you refrain from using them?

- Do you think this kiosk can **help you to use mobility services** (e.g. public transit, shared bikes, shared scooters)? (Y/N)

  If yes, which services become easier to use?
  If no, why?

- What did you **struggle** with? (e.g. too many options, selecting options, understanding information, language, etc.)
- How would you **improve** this kiosk?
- Which **functions** do you miss?
- Would you **buy a ticket** for public or shared transport via the kiosk if that were possible? (Y/N)

  If yes, for which services would you buy a ticket?
  If no, why?

- Which of the following mobility modes do you use at least **once a month**:

  Public transport (bus, tram, metro, train)
  Private bicycle
  Private car
  Shared mobility

  Taxi or Uber
  Shared car (Cambio, Poppy)
  Shared bicycle (Villo!, JUMP)
  Shared moped (Felyx)
  Shared scooter (JUMP, Lime, Pony, VOI,..)

- Do you have a **smartphone**? (Y/N)

- If, yes

  Using an app on your smartphone to **plan a trip by your own means of transport**, like the car or bicycle (for instance Google Maps)
  Using an app on your smartphone to **plan a trip by public transport** (for instance the apps of STIB or SNCB)
  Using an app on your smartphone to **reserve a means of transport** as you do with, for example, a shared car (cambio, Poppy) or a shared bike (Villo!)?
  Online payments
  Scanning **QR codes**

Demographic data

- How old are you?

_____

- Do you consider yourself as…

  Male
  Female
  Other
  Prefer not to say

- What is your highest degree?

  None
  Primary school
  Secondary school
  Post-secondary
  Prefer not to say

- What is your native language?

Have you been living in Brussels for more than 2 years? (Y/N).

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Author contributions
LM contributed to the conceptualisation, investigation, formal analysis, methodology and writing of the manuscript. KG contributed to the investigation, formal analysis and writing. JB contributed to the investigation and writing. AG contributed to the investigation and review of the manuscript. KM contributed to the conceptualisation, methodology and review of the manuscript. IK and KG contributed to the conceptualisation and review of the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
The data that support the findings of this study are available on request from the corresponding author, Lluis Martinez.

Declarations

Ethics approval and consent to participate
The participants involved in this study were residents of the neighborhood who were recruited in the street. They agreed to participate anonymously after being informed about the aim and implications of the study. Although some questions were asked to identify the level of digital skills, education, migration background and age, the sample was not specifically targeting social groups for which ethical approval would be required.

Competing interests
No financial, or personal interest or belief could have affected the objectivity of the study. Although the author JB is an employee of the non-profit organisation that has developed the type of technology being assessed, his contribution does not relate to the research design, the analysis of the data, the explanation of the findings and the conclusions.

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