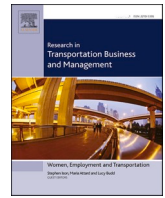


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An accessible and inclusive public transportation management response to COVID-19 through a co-creation process with people with disability. The case of Metro Barcelona

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ABSTRACT

The literature on digitalization and accessibility changes to public transport in response to the COVID-19 pandemic is limited. This paper reports on the urban public transport measures against COVID-19 launched by a Spanish transportation operator, TMB (Transports Metropolitans de Barcelona), to ensure safe journeys where digitalization of services have been intensified. This study responds to the current trend whereby transport operators are quickly digitalizing their transportation services as a response to COVID-19. The outcome of the research is to apply contemporary academic theory to assist transportation managers in designing and enhancing transportation services for this group during the COVID-19 pandemic. While transport operators have improved their services to better address the needs of PwD, these changes are far from universal in approach. At the end of 2020, as part of an academic–industry collaboration with a Spanish transportation operator, 12 PwD, six transport staff members, and two representatives of two disability advocacy associations took part in an inclusive urban transportation research project in the city of Barcelona using the service-dominant (S–D) logic co-creation process with PwD through a comparative approach. Specifically, we assessed the value outcome perceived by PwD in their Metro experience when resources resulting from the co-creation process were digital (Study 1) and when they were a combination of digital and non-digital (Study 2). To examine the PwD experience, a qualitative methodology was employed that incorporated online focus groups, ethnographic techniques and post-experience surveys with participants. Study 2 indicted better outcomes and explained how ensuring the appropriate combination of digital and non-digital resource allocation for PwD can improve the public transport experience. Our findings can be used by public transport policymakers for enhancing accessibility to improve public transport experiences during and after the COVID-19 pandemic by implementing digital and non-digital resources.

1. Introduction

The decision to keep public transport systems open during the COVID-19 pandemic (Beck, Hensher, & Nelson, 2021) is because it is an essential public service (Shibayama, Sandholzer, Laa, & Brezina, 2021), especially for those who are not able to change to other commuting modes such as cars (Cochran, 2020). According to a number of previous studies (Bezyak, Sabella, & Gattis, 2017; Christensen, 2014), access to transport is essential for leading a fulfilling life. However, the prevalence of COVID-19 presents unique risks and challenges for disadvantaged and vulnerable groups, including PwD. These challenges are identified by Cochran (2020) and include a) safe and reliable transport

b) up-to-date information and c) poor transportation service assistance. Moreover, it threatens to add new transportation barriers (Cochran, 2020; Genitsaris, Nalmpantis, Amprasi, & Naniopoulos, 2021) to the transportation experience (creating transportation hesitancy) and, in turn, may intensify social exclusion as PwD could avoid public transportation due to the fear of get infected by COVID-19 in transportation (Lucas, 2006). Therefore, because of PwD's high risk of social exclusion generally (Darcy, 2010, 2012) that has been heightened during the pandemic, there has been a call for further research into resources to improve accessibility in all forms of transportation (Armitage & Nelums, 2020; Cochran, 2020; Genitsaris et al., 2021). As a consequence, service planning and infrastructure need to be revisited (Jenelius &

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Cebecauer, 2020; Mogaji, Adekunle, Aririguzoh, & Oginni, 2022), with more attention being paid to the transportation service provision and performance (Wang, Shen, Abu Ashour, & Dannenberg, 2022). The challenges in public transport services for PwD (Mogaji et al., 2022; Vickerman, 2020; Wang et al., 2022) need to be resolved through innovative and collaborative processes.

Thus, for an inclusive pandemic response (Boyle, Fox, Havercamp, & Zubler, 2020; Cochran, 2020; Douglas, Katikireddi, Taulbut, McKee, & McCartney, 2020; Turk & McDermott, 2020) revisiting transport access barriers is key (Farinloye, Mogaji, Aririguzoh, & Kieu, 2019). Meanwhile there have been numerous recent contributions to the literature (Fageda, Suárez-Alemán, Serebrisky, & Fioravanti, 2018; Mogaji et al., 2022) on the implications of the COVID-19 pandemic for public transport management and policy within specific country contexts (Beck et al., 2021). For example, transport operators have embraced digitalisation and new systems as a quick response to recover value in the transportation experience which if necessary to balance the demand and supply of commuters towards a safer and more responsible transportation system (Budd & Ison, 2020). For instance, with the implementation of new screens displaying occupancy-related information and the use of occupancy tracking system.

Interestingly, the body of literature on public transport experience co-design for PwD has recently grown (Cerdan Chiscano, 2020; Sze & Christensen, 2017), particularly research addressing the increasing interest in the use of new technologies and devices for transportation accessibility (Machala & Havř, 2019; Safronov, Safronov, & Mochalin, 2018; Valderrama-Pineda, 2016). Certainly, digitalisation can make it easier for PwD to navigate public transport systems and has often been recognised as a promising resource for reducing transport barriers facing PwD. Nevertheless, some authors warn that digital resources may have exclusionary effects on PwD, as digitalisation entails a need for specific resources and skills depending on disability type and level of support needs (Darcy, Green, & Maxwell, 2017).

Additionally, others (Nalmpantis, Roukouni, Genitsaris, Stamelou, & Naniopoulos, 2019; Tsafarakis, Gkorezis, Nalmpantis, et al., 2019) have suggested that empirical evidence is needed for better understanding and to develop innovations in transport that meet users' needs. Thus, there is a call for transport operators to include PwD in the planning process (Armitage & Nellums, 2020; Cochran, 2020) to re-design the transport experience through a co-design process to accommodate PwD's needs amidst the pandemic (Amprasi, Genitsaris, Naniopoulos, & Nalmpantis, 2021; Jenelius & Cebecauer, 2020; Mogaji et al., 2022).

Value can be generated through an S—D logic co-creation process (Grönroos & Voima, 2013). The S—D logic process entails collaborating with users to foster mutual learning, which creates a value experience (Vargo & Lusch, 2008) and benefits both users and companies (Busser & Shulga, 2018). Therefore, transport operators should actively collaborate with users in the experience co-design process (Gebauer, Johnson, & Enquist, 2010).

Theories on resource integration suggest that resources already provided by companies to users can be combined to create value (Kleinaltenkamp et al., 2012; Vargo & Lusch, 2008). Furthermore, recent literature has introduced the novel concept of “imposed service innovation” which emerged as companies quickly sought to respond to the COVID-19 pandemic (Heinonen & Strandvik, 2020) so they could continue operating. However, there is a need for empirical evidence to support the design process perspective (Heinonen & Strandvik, 2020), as value co-creation has been proven to create value when the end user is involved (Greenhalgh, Jackson, Shaw, & Janamian, 2016; Heinonen & Strandvik, 2020; Jaakkola & Hakanen, 2013). Therefore, our approach emphasises the importance of including PwD in the design or, more appropriately, the co-design process (Cerdan Chiscano, 2020). This also responds to the call by others (Frow, Nenonen, Payne, & Storbacka, 2015; Heinonen & Strandvik, 2020; Nalmpantis et al., 2019; Tsafarakis et al., 2019 and Wiewiora, Keast, & Brown, 2016) for research into the design process.

With this purpose in mind, using a value co-creation exercise, we will empirically explore the value for PwD of digital and non-digital measures for accessibility implemented by TMB as a response to the COVID-19 pandemic which would not have occurred under normal circumstances (Heinonen & Strandvik, 2020). To do so, we conducted a comparative study, examining whether the use of value co-creation processes with PwD for digital resources created the best value (Study 1) in their public transport experience, or whether a combination of digital and non-digital resources created more value (Study 2). We argue that, although digital technologies can make transportation easier to navigate for PwD, there are certain aspects of digitalisation which need to be combined with non-digital resources in public transport experience design to enhance accessibility (Holstein, Wiesel, Bigby, & Gleeson, 2021).

First, we will review previous literature on public transport, digitalisation, value co-creation and disability. After that, we will describe our methodology. Finally, we will present and discuss our findings and summarise our conclusions and the theoretical and practical implications of our research.

2. Theoretical background: COVID-19, accessible public transport, S—D logic, and digitalisation

Armitage and Nellums (2020) suggest transport planners need to consider the access needs of PwD in transportation in during the COVID-19 pandemic by including them in the planning process co-creation is a user-centred collaboration approach (Payne, Storbacka, & Frow, 2008; Sanders & Stappers, 2008) aimed at designing a service or a product by stakeholders and users by creating joint value through collaboration (Vargo & Lusch, 2008). Co-creation involves active and continuing interaction among stakeholders and users (Randall, Gravier, & Prybutok, 2011). Interestingly, Narver, Slater, and MacLachlan (2004) found that adopting a co-creation process led to better understanding of customer needs, enhanced decision making, reduced costs, customized services and products and increased product quality. While the co-creation process is often used in urban planning, its use in relation to public transport is not widespread (Nalmpantis et al., 2019).

The COVID-19 pandemic has had a huge impact on public transport in Spain and elsewhere, necessitating a range of measures to mitigate impact (Eisenmann, Nobis, Kolarova, Lenz, & Winkler, 2021). One example operational is the use of contactless systems for paying fares and digital resources to prevent crowding by using seat allocation systems (Cochran, 2020; Weiner & Armenta, 2020). Gkiotsalitis and Cats (2021) suggest re-designing systems and allocating new resources to manage crowding and demand, since according to Tirachini and Cats (2020), crowding management using digital and non-digital resources is a priority for public transport management due to the need to maintain social distancing during the pandemic.

Interestingly, Vickerman (2020) suggests more personalized service delivery resources to allow trip planning, for example by providing information about crowding in real time. Importantly, as a result of the current pandemic and future disruptions related to new pandemics and natural disasters, organisations have been forced to rethink how they design their services (Heinonen & Strandvik, 2020), prompting them to develop new digital products and services. However, digitalisation is a challenge for both public transport operators and PwD. For instance, users may feel anxious when internet connectivity occasionally fails in the underground and they are struggling to navigate the web of lines and stops. Despite advances in universal design – “the systemic process of adapting and creating new products and services for all” (Story, 2001, p.32) – and regulations on accessibility standards, more empirical evidence is needed in the contribution of digitalization to accessibility in transportation. Therefore, transport operators must strive to co-create digital resources with users with different types of disability (Koh-tamäki, Parida, Oghazi, & Baines, 2019; Sjödin, Parida, Kohtamäki, & Wincent, 2020). Embracing value co-creation in the digitalisation

process means gaining a better understanding of user practices and behaviour in regard to digital products and services.

Digital products, services and facilities developed using a co-creation process better fulfil users' personal needs (Machala & Havír, 2019; Pieters & Jansen, 2017). A handful of studies have previously researched the co-creation process in the field of public transport (Heidenreich, Wittkowski, Handrich, & Falk, 2014; Machala & Havír, 2019; Nunes, Galvão, & Falcão, 2014) and found that engaging in idea generation with PwD can be challenging for transport operators. Voorberg, Bekkers, Timeus, Tonurist, and Tummers (2017) introduced the concept of public service co-creation as a process of engagement with users, considering them important partners who leverage their own resources, skills and competencies to add value to the process. Therefore, as a management tool, value co-creation has the potential to help transport operators design positive experiences with customers including PwD (Cerdan Chiscano, 2020).

The framework provided by Payne et al. (2008) for managing encounters with users through mutual collaboration, interaction and benefit is helpful in bringing new components into the design process under the S—D logic framework. Payne et al. (2008) identify three encounters resulting from the value co-creation process: communication, usage and service. Communication refers to a company's interactions and dealings with users. Usage refers to how a company's products, services and facilities are used and how users are supported in using them. Lastly, service refers to users' interactions with staff and other users in a shared service environment. In addition, previous studies have proposed a taxonomy of value outcomes of the value co-creation process: (1) social; (2) emotional (see, for example, Schau, Muñoz, & Arnould, 2009); and (3) functional (Harris & Baron, 2004).

More recently, Heinonen and Strandvik (2020) introduced the concept of "imposed service innovations" to describe innovations that companies rapidly adopted in response to the COVID-19 pandemic which would not have emerged under normal circumstances. The authors proposed a taxonomy of such innovations, which included the following thematic categories: (1) delivery innovations, which include contactless or remote delivery; (2) physical distancing innovations, whereby companies seek to ensure the implementation of health and safety measures; (3) technology and digital innovations; (4) professional consultation innovations, such as the new video or text chat systems created by many companies to provide guidance and support to users engaging in self-service; (5) social connection innovations, which socially connect individuals and foster a collective sense of togetherness; (6) education innovations; and (7) public innovations, which are public sector responses to the pandemic with a special focus on the needs of the most vulnerable.

Drawing on this theoretical background, we pose the following research questions (RQ):

RQ1. : What were the main service encounter innovations that emerged in response to the COVID-19 pandemic to address public transport accessibility for PwD?

RQ2. : What service encounter innovations bring the best value to PwD's public transport experience, including the digital experience or the combination of the digital and non-digital experience?

3. Research design

TMB, the main public transport operator in Barcelona, Spain, launched its "urban public transport measures against COVID-19" in 2020 to ensure a safe journey for passengers. The Barcelona Metro service has 8 lines 165 stations, and 165 trains run at peak times, facilitating 425 million trips annually (see: <https://www.tmb.cat/en/home>). The Barcelona metro network is a European leader in accessibility. All of TMB's measures with respect to accessibility are reflected in its Accessibility Master Plan. The plan outlines measures aimed at ensuring equal access to public transportation. The major measures as a

response to COVID-19 taken by TMB included:

- a) Introducing new ways of communicating real-time information on service occupancy and crowding (Gkiotsalitis & Cats, 2021; Tirachini & Cats, 2020; Vickerman, 2020).
- b) reinforcing staff service support to ensure the implementation and monitoring of COVID-19 public health measures (Tirachini & Cats, 2020).
- c) re-designing infrastructure (Jenelius & Cebecauer, 2020; Mogaji et al., 2022).

Our research aims to explore TMB's responses to the COVID-19 pandemic using a value co-creation process in the city of Barcelona to design digital and non-digital resources for PwD. Specifically, we were interested in exploring which specific digital and non-digital measures emerged using a value co-creation exercise, which had positive accessibility impacts. Firstly, we identified the digital and non-digital measures (Heinonen & Strandvik, 2020) for accessibility that emerged as a result of the value co-creation exercise. Then, peer collaboration was undertaken between the stakeholders (six staff members, two representatives of associations for PwD and 12 PwD), and the researcher to explore the accessibility experience (positive or negative) for PwD. The stakeholders involved were six staff members, two representatives from PwD organisations (Dincat and the Municipal Institute for People with Disabilities (IMPD)), and 12 participants with disabilities.

Two studies were carried out to provide a comparison:

- Study 1 aimed to explore how exclusively digital resources contributed to the creation of value in PwD's accessible Metro experience.
- Study 2 aimed to explore how the combination of digital and non-digital resources contributed to the creation of value in PwD's accessible Metro experience.

3.1. Research project design

Fig. 1 shows the project phases.

3.1.1. Project phases

Studies 1 was carried out between December 2020– July 2021 and Study 2 between March 2021–July 2021, and followed an identical methodology, consisting of the following phases:

- o *Phase 1.* Online focus groups and encounters. One researcher and two assistant researchers ran four online focus groups with stakeholders (six staff members, two representatives of associations for PwD and 12 PwD) to generate new ideas related to the measures of the TMB program called 'Urban public transport measures against COVID-19'.
 - Study 1 involved two focus groups comprised of stakeholders, brainstorming ideas regarding the use of digital resources exclusively.
 - Study 2 involved two focus groups comprised of stakeholders brainstorming ideas regarding the use of both digital and non-digital resources.
 - o Phase 2 – adjustments and audit: in Phase 2, selected ideas emerging from the focus groups were developed and implemented by TMB to improve the PwD public transport experience. The researcher was invited to the TMB control area to access video observations of the settings (carriage, platforms, lifts ect...)
 - o After identifying the most meritorious ideas from the stakeholders in the focus groups in Phase 1, the transportation operator implemented these ideas, mostly by making adjustments to products and services to improve PwD experience. This included staff training in providing support on the use of digital services for PwD, the installation of intercom systems on platforms and trains, etc. The researcher visited the TMB control area, spoke with TMB staff

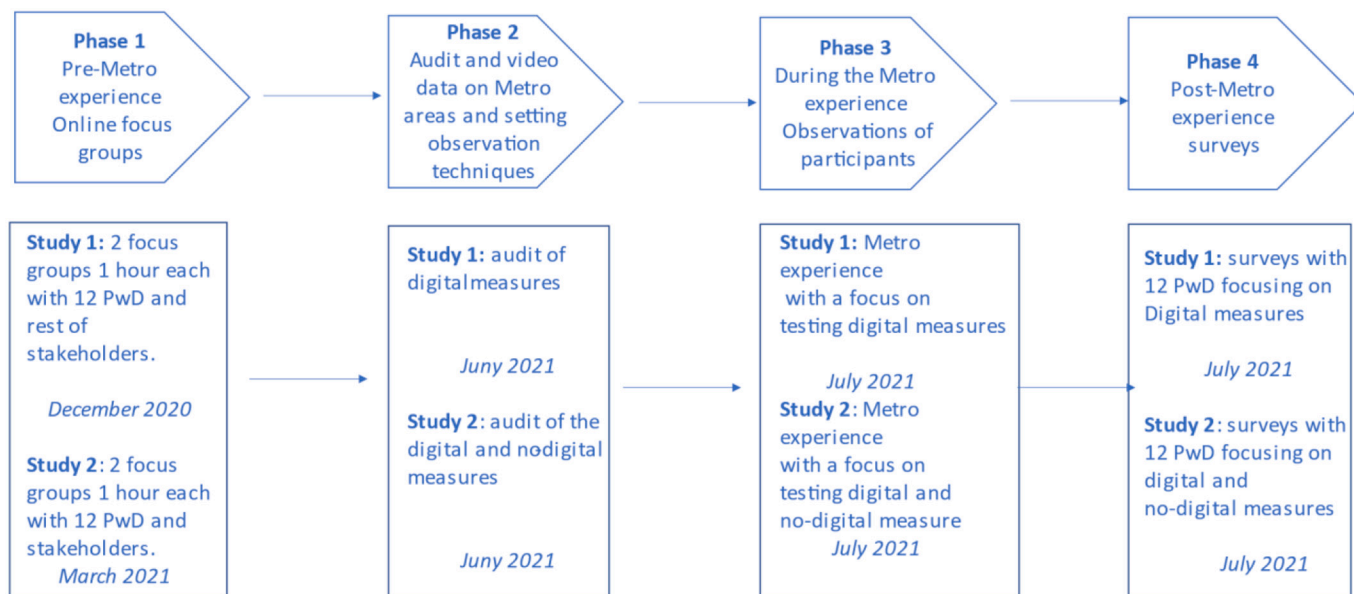


Fig. 1. Project phases.

and was privy to documentation on accessibility provided by TMB, and thus had plenty of access to data in this respect. Specifically:

- Study 1: The researcher audited the feasibility of the ideas emerging from the focus groups of Study 1 with a focus on digital measures to verify their level of compliance with the principles of universal design (Centre for Universal Design, 1997).
 - Study 2: The researcher audited the feasibility of the ideas emerging from the focus groups of Study 2 with a focus on digital and non-digital measures to verify their level of compliance with the principles of universal design (Centre for Universal Design, 1997).
- o Phase 3: in Phase 3, 12 participants with disability and the rest of the stakeholders (six staff members and two representatives of associations for PwD) and the researchers took part in the new Metro experience. PwD tested the convenience of the innovations that emerged in Phase 1 and were implemented in Phase 2. The researchers observed and took notes on their behaviours, feelings and opinions. The visit had two different proposes:
- Study 1: to explore the newly-implemented digital resources.
 - Study 2: to explore the combination of newly-implemented digital and non-digital resources.
- o Phase 4 – post-experience surveys: in Phase 4, post-experience surveys were administered to the 12 participants who took part in the Metro experience, at the exit of the Metro station. The survey's purpose was to validate the value of the implemented ideas. Studies 1 and 2 yielded sufficient data to understand PwD's perceptions of value in terms of accessibility and the use of digital and non-digital resources. Specifically:
- Study 1: 12 PwD were interviewed post-Metro experience at the exit of Metro carriage, in regards their perception and opinion of the use of the digital resources experienced during the Metro experience.
 - -Study 2: 12 PwD were interviewed post-Metro experience at the exit of Metro in regards their perception and opinion of the use of the combination of digital and non-digital resources experienced during the Metro experience.

With regard to the ethical considerations arising from our project, it took place at the beginning of the third wave of COVID-19 in Spain in

December 2020 and we were thus keenly aware of the limitations of using ethnographic techniques, as researchers can become a disease vector and infect participants during fieldwork (Fine & Abramson, 2020). Therefore, at the beginning of the project, in December 2020, to avoid physical contact with vulnerable participants, alternative techniques such as online focus groups were considered to address safety issues. These were ultimately worked into the project design and online focus groups, video data on public spaces and online observations were used (Fine & Abramson, 2020; Pandey & Kumar, 2020). However, after vaccinations became widely available at the end of July 2021, we were able to use ethnographic techniques with participants including face-to-face in-depth interviews in the Metro environment. The researchers complied with required health measures, including the use of surgical masks, physical distancing, use of sanitiser and kept participant groups small. Participant observation in public transport settings has been used in recent studies to better understand participants' behaviours and practices. For example, Tomić, Relja, and Popovic (2015) used ethnographic techniques to better identify the everyday practices of drivers, transport staff and passengers. Ramos, Vicente, Passos, Costa, and Reis (2019) used ethnographic techniques to better understand the perception of passengers and their feelings towards public transport. Risser, Iwarsson, and Ståhl (2012) explored how persons with cognitive functional disability managed bus use. Ashton, Barwood, French, Savina, and Worrall (2008) used participant observation for exploring accessible communication resources in public transportation systems.

The project was approved by the (*University name hidden for anonymity*) Ethics Committee. The Ethics Committee number approval is 20210529_ TMB.

All participants signed an informed consent form.

3.2. Participants

To recruit our sample, we established two participant selection criteria: (1) users had to be at least an occasional metro user over the six months leading up to the study, and (2) have experience of using mobile devices. Adhering to these criteria, the participating representatives of Dincat and the IMPD selected 12 participants with disabilities to take part in the project. The same 12 participants took part in Study 1 and Study 2. (See Table 1.)

Table 1
Sample (n = 12).

Variables	Categories	%
Gender	Male	52%
	Female	48%
Frequency of transport use	Daily	7%
	Weekly	43%
	Occasionally	50%
Mode of urban transport	Bus	22%
	Metro	52%
	Other	26%
Age	18–40	72%
	40–55	16%
	Older than 55	12%
Transport-covered need	Employment/Studies	12%
	Leisure/Sport	34%
	Medical/Therapy visits	54%
Monthly household income	Less than 1000 euros	6%
	1000–2999 euros	74%
	More than 3000 euros	20%
Severity of disability	Mild	100%
	Moderate	0%
	Severe	0%
Type of disability	Intellectual	78%
	Physical	12%
	Vision	10%

3.3. Data collection

We drew on [Payne et al. \(2008\)](#) to delimit data analysis and focused on whether provision of digital resources only, or a combination of digital and non-digital resources, in the three encounters – communication, usage and service – had an impact on PwD's perceptions of accessibility of their Metro experience. We also drew on [Heinonen and Strandvik's \(2020\)](#) imposed service innovation classification.

Online focus group was held with participants to discuss the adequacy of the digital resources (in Study 1) and a combination of the digital and non-digital resources (in Study 2) that were introduced in response to the COVID-19 pandemic. As discussed above, these resources were part of the package of measures launched by TMB to ensure COVID-safe journeys. At the time of the focus groups these resources were already partially implemented in the Metro environment and had been tested by most of the selected participants with disabilities in the course of their daily lives. The purpose of the online focus groups was to discuss the participants' public transport experiences in relation to the convenience of use of the digital and non-digital resources.

All online focus groups, observation techniques during the Metro experience and the post-Metro experience interviews were audio recorded and transcribed.

3.3.1. Phase 1: Online focus groups

All relevant ideas about adaptations needed in the new technologies and new designs identified in the focus groups in studies 1 and 2 were

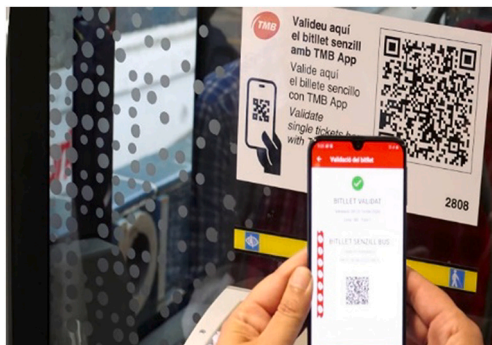


Fig. 2. Digital ticket validation using a mobile device.

considered. See [Figs. 2–7](#) for illustrative examples.

3.3.1.1. Study 1: online focus groups –: identifying digital resources for improving accessibility. Two online focus groups were carried out involving the stakeholders (six staff members, two representatives of associations for PwD and 12 PwD) and the researcher. The aim in Phase 1 was to discuss new ideas on whether the digital resources developed by TMB in response to the pandemic added accessibility value to PwD's Metro experience. We sought to explore the participants' perceptions of whether these digital resources were creating value for PwD. As one of the participant selection criteria was being a Metro user in the six months leading up to the study, our sample had previous experience with the new digital resources. This criterion was important for our research to ensure that PwD had some familiarity with digital technologies.

The participants discussed digital resources for PwD that they found to be effective in improving the Metro travel experience. These included digital resources that had been partially developed by TMB pre-pandemic, such as websites and apps (TMB-Mobilitat app) for buying tickets online, using mobile devices to receive and validate tickets (self-service), viewing online timetables, monitoring services in real time, and displaying service and carriage occupancy levels. For example, the TMB app allows for trip planning, real time information on services ect.

3.3.1.2. Study 2 online focus groups: identifying a combination of digital and non-digital resources for improving accessibility. The online focus groups discussed a combination of suitable digital and non-digital resources for improving the Metro travel experience. Some of the relevant ideas were related to the three critical encounters, including timely communicative support resources for passengers using text chats or messaging applications such as WhatsApp and Twitter, reinforcing staff assistance, occupancy tracking and display screens, new signage for accessibility ect... These ideas came from the idea generation process and represented imposed service innovations ([Heinonen & Strandvik, 2020](#)) rolled out by TMB to quickly respond to the COVID-19 pandemic. The adequacy of the design of the Metro rolling stock to meet universal design expectations and signage was also a relevant topic for discussion.

3.3.2. Phase 2: Adjustments and audit

In Phase 2, the use of the digital resources and their adequacy to access needs were discussed with participants in the focus groups ([Figs. 2 to 7](#)). These are examples of the digital resources from the urban

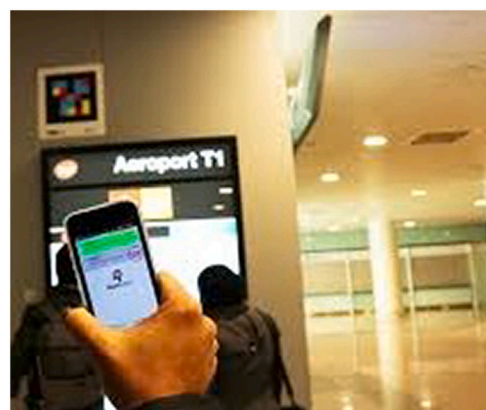


Fig. 3. Digital NaviLens to guide people with visual impairments on their metro journey. NaviLens is a system that uses signals placed throughout the Metro that can be detected by blind people with their phone. ... The system consists of a web application with which labels are designed and managed and a mobile app is used to read them. TMB has implemented NaviLens throughout the urban transportation system.



Fig. 4. Screens displaying occupancy-related information.

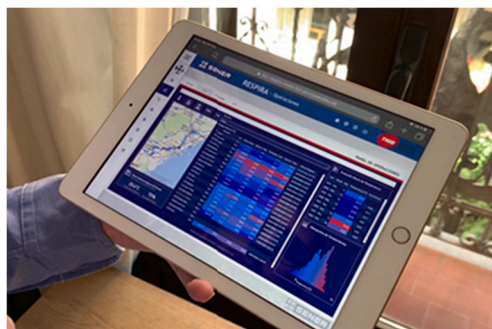


Fig. 5. Occupancy tracking system.

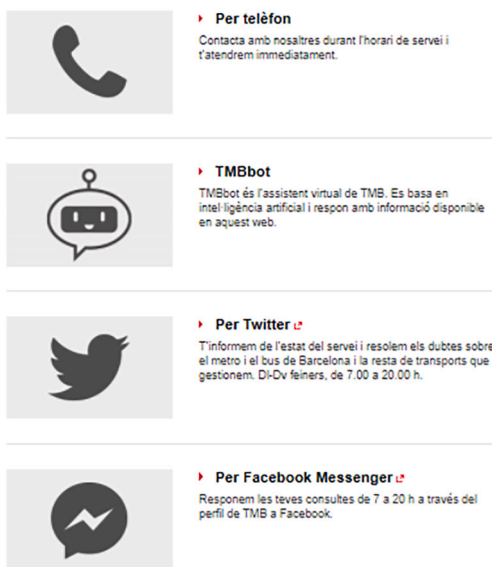


Fig. 6. New digital communication tools—namely the TMBbot assistive support system, Facebook Messenger and Twitter—to reinforce communication encounters with passengers during COVID-19, offering them guidance, resources and support to handle self-services.

public transport measures against COVID-19 programme launched by TMB. The ideas for adjustments to meet the participants’ access needs that were considered positive by the stakeholders were discussed, developed and audited in Phase 2 and then tested and validated by participants in Phase 3 during a Metro visit, and in Phase 4 using post-visit experience surveys with participants.

- Study 1 focused exclusively on digital measures
- Study 2 focused on the combination of digital and non-digital measures



Fig. 7. Online and offline signage informing passengers about how to behave during their journey.

3.3.3. Phase 3: During the visit to the new Metro experience

Researchers shadowed participants in a single Metro experience and observed them during the 45 min visit to the Metro experience. The aim was to register the participant’s reactions, behaviour, opinions and knowledge about the new implemented digital and non-digital elements in the carriage to test for positive or negative impacts on their travel experience (Ellway & Dean, 2016).

3.3.4. Phase 4: post-metro experience participant surveys

After the Metro visit, the 12 participants with disability were individually interviewed with 30 min surveys by 3 researchers (one lead researcher and two assistant researchers) at the exit of the Metro carriage. The aim was to explore participants’ perceptions of their experience with the digital and non-digital interactions and encounters with the physical environment and Metro staff. The survey questions were based on a literature review of digitalisation and accessibility in response to the COVID-19 pandemic, service-imposed innovation and the value co-creation experience in public transport.

After the data collection in phases 1, 2, 3 and 4 was complete for both studies, the researcher reported having enough information to answer our research questions (Strauss & Corbin, 1998).

- Questions from study 1 focused exclusively on digital measures
- Questions from study 2 focused on the combination of digital and non-digital measures

3.4. Data analysis

The researcher reviewed the observations, 40 photos, transcripts from focus groups and surveys and notes taken in the focus groups several times and carried out a thematic analysis (Bazeley, 2007) using ATLAS-ti software (Saldaña, 2015) creating a relational map. Then, after linking the data with concepts from our literature review (Cresswell, 2007) a selective coding process was identified. Links between the three digital and non-digital encounters were identified. We turned to a recent study by Heinonen and Strandvik (2020) to guide our analysis. Three main categories were identified because of the co-creation process. These three categories drawn on Payne et al. (2008) represent the digital and non-digital innovations arising as a result of TMB’s rapid response to the pandemic, which were critical factors for resorting accessibility for PwD during the pandemic. These were:

- 1) Digital and non-digital critical communication encounters: the perceived quality of information provided about online ticket purchase, timetables, etc.
- 2) Digital and non-digital critical usage encounters: the perceived level of quality of delivery innovations such as online ticket purchase, timetables and digital ticket validation systems via mobile devices.

3) Digital and non-digital service innovation encounters: the quality of professional consultation innovations such as new communication resources and resources and support for passenger online self-service and the quality of new staff support systems and training programmes to reinforce assistance provided by staff to PwD.

Table 2 below shows the coding process for Study 1 and 2.

4. Findings

This study aimed to test the digital and non-digital measures implemented by a transport operator for PwD. In line with Tirachini and Cats (2020) and Payne et al. (2008), this study sought first to identify the digital and non-digital measures emerging as a consequence of the rapid response of TMB to the COVID-19 pandemic using a value co-creation process, and to address the many challenges faced by PwD in their digital and non-digital public transport experiences.

We sought to answer the following research questions:

RQ1. : What were the main service encounter innovations that emerged in response to the COVID-19 pandemic to address public transport accessibility for PwD?

RQ2. : What service encounter innovations bring the best value to PwD’s public transport experience, including the digital experience or the combination of the digital and non-digital experience?

4.1. Innovations as a response to the COVID-19 pandemic

In regards to RQ1, We drew on Heinonen and Strandvik’s (2020) taxonomy of imposed service innovations to identify digital and non-digital service innovations that would not have emerged under normal circumstances and related to improving accessibility. These included:

1. Adapted delivery innovations using universal design and staff training: TMB has offered online ticket purchase and timetables since pre-COVID-19 pandemic. This is in line with Budd & Ison, 2020; Cochran, 2020 and Weiner & Armenta, 2020. Tickets can be validated digitally at the entrance of Metro stations using a mobile device, thus limiting contact and increasing PwD’s perception that their journey is safer (Cochran, 2020; Weiner & Armenta, 2020). Innovations in this category are related to service delivery and use. Innovations can create value for PwD if universal design and staff training provide PwD with support, if needed, in their use of digital resources (see Table 2).

“The ticket booking and validation self-service using my mobile at the metro entrance works great and I avoid touching the ticket machines, but you need to have access to mobile data since Wi-Fi does not work very well in the underground,” (participant with mild vision impairment).

“When passengers approach the validation systems, there are TMB staff to provide support if required. The staff has been properly trained in disability, making sure PwD and the elderly receive support accessing digital systems when they need to.” (Director of accessibility, TMB).

2. New, inclusive design of physical distancing innovations adapted to PwD’s access needs (Gkiotsalitis & Cats, 2021; Tirachini & Cats, 2020): TMB provides timely information and resources using online and physical signage to inform passengers about how to behave during their journey to ensure physical distancing. Such behaviours include refraining from talking and maintaining as much physical distance as possible. Signage and other information systems need a new design to ensure PwD are given priority seating and access to

Table 2
The coding process.

Open coding	Axial coding	Main themes (selective coding)
<p>“The ticket booking and validation self-service using my mobile at the metro entrance works great and I avoid touching the ticket machines, but you need to have access to mobile data since Wi-Fi does not work very well in the underground,” (participant with mild vision impairment)</p>	<p>Adapted delivery innovations using Universal design and staff training to give support to PwD in their use of digital solutions (usage encounter)</p>	<p>Importance of Universal design applied to the digital delivery of innovations for accessibility (critical digital usage encounter).</p>
<p>“The current signage with pictograms for the reserved areas is clear to me but it is not respected by others, and I always have to ask others to preserve my right of use of the reserved area for PwD. There are a lot of prams and bicycles in the reserved area, it is really tiring,” (participant with physical disability).</p>	<p>Adapted a new inclusive design of physical distancing innovations to PwD’s access needs with new signage and improvements in colour design (communication encounter).</p>	<p>Importance of a new design for the reserved seating area to improve respect for priority seating and access to public transportation safely.</p>
<p>“TMB now displays the occupancy of metro trains, which is useful for staying safe on our journey, but this is only available in very few metro stations, which is very inconvenient for us,” (participant with physical impairment).</p> <p>“The displays of occupancy in metro trains are not available in sound, which is very inconvenient for us,” (participant with mild visual impairment).</p> <p>“I used to call TMB when a lift or something was not working, but now they make you use these social media tools where, although I am a bit used to them, I don’t know if the person I am asking will understand my needs as it is very impersonal,” (participant with poor vision).</p> <p>“If I have an issue, I prefer to ask the staff on the platforms or use the SOS information point at stations rather than sending a message via Twitter or Facebook. I don’t feel this works for me,” (participant with physical disability).</p> <p>“TMB has not only developed adverts announcing that the metro is a safe place for all, but they are also</p>	<p>Technology and digital innovations adapted to PwD’s access needs using Universal design standards (usage encounter)</p> <p>Digital interaction with staff (service encounter)</p> <p>Social connection innovations in accessibility (communication encounter)</p>	<p>Importance of Universal design applied to initiatives which include occupancy tracking systems and display screens providing occupancy-related information.</p> <p>Importance of staff training in giving support to PwD using digital interaction with staff and other passengers, using communication tools to support passenger self-service via Twitter, artificial intelligence-based support system TMBbot, Facebook Messenger and WhatsApp.</p> <p>These social innovations raise individual and collective awareness of the responsibility to ensure safe public transportation journeys.</p>

(continued on next page)

Table 2 (continued)

Open coding	Axial coding	Main themes (selective coding)
<p>promoting socially valuable slogans such as: "You are the force that moves us, we hope it can work out for us," (participant with mild vision impairment). "Reserved seats for the disabled are always occupied by other people and this is an issue for us. Now TMB are announcing over the public address systems that PwD are a priority and seats should be reserved for us," (participant with physical impairment).</p>		

public transportation.

"We have started to inform other passengers about the right of PwD and the elderly to priority seating using public address systems, but we need to work on an improved signage design because we receive a considerable number of complaints from PwD about other passengers not respecting their reserved seat area, etc." (assistant director of accessibility, TMB).

"With COVID-19 we need other passengers to refrain from using the reserved seating area for PwD. I encounter bicycles, prams etc., so sometimes I have to wait for the next train to be emptier." (participant with physical disability).

Technology and digital innovations adapted to PwD's access needs: TMB introduced new, real-time technology systems, including train and carriage occupancy tracking and display screens to help PwD make decisions about the metro train they should take to ensure a safer ride. NaviLens technologies for people with visual impairments have been extended and reinforced to avoid failures in their use for enhancing accessibility in all stations to provide passengers with real-time assistance using mobile devices. NaviLens is a new technology that lets people with visual impairment scan a QR code with the use of a mobile camera and get the necessary information contextualized through audio elements. (Fig. 2)

"The screens displaying occupancy-related information are OK since they help me identify which times the metro trains are emptier, and I can make decisions on which train to take since I don't feel safe if the train is crowded with the current COVID-19 pandemic situation." (participant with physical disability).

"For the time being, I can't use the screens displaying occupancy-related information on Line 5 since they are not available in sound, so it is useless for me." (Participant with visual impairment).

Digital interaction with staff: TMB created new real-time communication channel. Some leverage passengers' service experiences to help other passengers with self-service; some put passengers in touch with staff via twitter, Facebook messenger and WhatsApp; and there is an artificial intelligence-based support resource available called TMBbot. To ensure value in use for PwD, TMB has trained their staff to give appropriate support to address PwD concerns and needs when using communications channels in real-time

"We receive some daily messages in real-time through Twitter, WhatsApp and Facebook Messenger from passengers complaining about issues they experience during their Metro visit, including the behaviour of other passengers. PwD and the elderly are a priority for us, thus we are providing our community managers and staff dealing with communications channels with training in disability to better cater for their real-time access needs and provide them with a prompt and proper response." (Director of accessibility at TMB).

"When I have a problem with the elevator at my metro station, I send a message via WhatsApp to TMB and they answer my message very quickly and give me a response. It works well for me." (participant with physical disability).

Social connection innovations in accessibility: TMB has addressed PwD's individual relationships and communication with other users (disabled and non-disabled). Online and offline information and public address systems on platforms are used to convey the message that PwD and the elderly must be given priority seating and treatment. These practices have a clear social value

"Despite having run awareness initiatives for people to respect reserved seating areas for PwD, we receive a surprising number of complaints from PwD about the behaviour of other passengers not willing to give PwD reserved seats and with hostile attitudes towards them. We need to work more intensively with associations representing PwD to address this important social issue." (TMB staff).

"My son has autism, and he has the right to a seat in a reserved seating area for disabled. Unfortunately, the other day an older woman very rudely asked my son give up the seat." (TMB staff participant).

4.2. Value of the measures implemented in response to the COVID-19 pandemic for accessibility and encounters

In regards to RQ2, From our data, we have gained insight into how, by implementing the appropriate adjustments for accessibility to the digital resources arising from the urban public transport measures against Covid-19 programme in the three encounters (communication, usage, and service), the satisfaction on accessibility of PwD scores higher in importance when universal design is applied and when staff are trained to provide support (in the use of such digital resources by PwD.

"The first time I was told I had to validate my ticket, I didn't know how it worked, but with the support of TMB staff, and the system which includes NaviLens, it was quite easy and quick for me and it made me feel safe as I didn't need to touch anything." (Participant with visual impairment).

Table 3 shows the digital and non-digital resources which PwD perceived as enhancing accessibility from their Metro visit.

Below we discuss our findings with regard to the specific encounters: communication, usage and service. (See Figs. 8,9,10 and 11)

4.2.1. Communication

The communication encounter is critical for ensuring accurate information provision and, thus, for gaining PwD's trust in the transportation system as a safe way to travel (Cochran, 2020). Adequate information provided digitally (e.g. online information on timetables, COVID-19 measures and recommendations for safe travel) and non-digital (e.g. signage on COVID-19 measures and passenger behaviour rules) facilitated PwD decision-making regarding whether and how to use the Metro. However, Study 2 clearly showed that the value outcome is greater when information provision is designed in advance to meet the communication needs of PwD.

Table 3
Inclusive resources for accessibility implemented as a reaction to COVID-19 pandemic.

Inclusive resources	Critical encounter type/Type of imposed service innovation	Value outcome for PwD
New design with sensor technology and service assistance button in place exclusively for PwD use in trains	Communication/adapted technology and digital innovations to the PwD's access needs	Positive
Ongoing training for Metro staff involved in the Metro experience to support PwD in their use of digital products and services	Service/Digital interaction with staff	Positive
New design including improved signage features for reserved seats for PwD, with more physical distance and more colourful, with different signage for prams and bicycles (Figs. 9 and 11)	Usage	Positive
Red colour in reserved seats and enhancing signage (Fig. 10)	Usage	Positive



Fig. 10. Improved reserved areas for PwD. Implementation of sensor technology to avoid accidents when entering the trains.



Fig. 8. Improved signage and areas for PwD where the areas for bicycles and prams have been clearly separated from the reserved seating for PwD.



Fig. 9. Red used to improve reserved. Seating area for PwD. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)



Fig. 11. Service assistance button in place for exclusive PwD use.

but I couldn't wait for the service and took an alternative means of transport." (participant with a physical disability).

"TMB has improved its provision of online information about COVID-19 measures and timetables. Now it's easier to plan your journey. I have also noticed that they have reinforced staff support on the platforms, which makes you feel safer in the metro." (participant with a mild intellectual disability).

"I worry about the metro being overcrowded, and TMB informs passengers about how to behave to minimise COVID-19 infections, but some passengers, despite the information, keep talking and fail to follow COVID-19 health rules. So, TMB has to reinforce metro staff to warn passengers to follow the rules." (participant with a mild intellectual disability).

4.2.2. Usage and service

The perceptions of PwD gathered in both studies clearly show that usage encounters with digital resources can improve the Metro experience for PwD, allowing them to more smoothly find their way to and within the Metro system with more personalized and flexible elements (Vickerman, 2020). However, non-digital service encounters also prove key in providing comprehensive assistance to PwD in their use of digital resources. The value of PwD's Metro experience can be enhanced when transport operator staff understand accessibility requirements and assist users when they employ digital resources in usage encounters (Donetto, Pierr, Tsianakas, & Robert, 2015).

It is important to make current products and services fully accessible. The use of digital resources such as NaviLens and occupancy tracking systems are proven to give different groups of PwD more autonomy (Tirachini & Cats, 2020; Vickerman, 2020). However, PwD's perceptions are more positive when staff can be reached to ask for assistance

"The other day in Diagonal metro station the lift was temporarily out of order. Now TMB offers a quick communication tool using Twitter, so I sent a message to report the incident. TMB quickly replied to my message,

when such digital resources fail (Donetto et al., 2015; Tirachini & Cats, 2020).

“TMB has improved its NaviLens technology performance and now I trust this technology, but you need to have enough mobile data to make use of it since Wi-Fi doesn't work properly in some stations in the underground. Wi-Fi should be available in the underground.” (participant with visual impairment).

“TMB has rolled out occupancy tracking systems on platforms, which is helpful in that it lets you know which carriage is emptier so you can have a safer journey, but this is missing on some platforms. I think it should be implemented in all the stations for more security. Despite this, you can always ask for assistance on Metro platforms to ensure safer entry into the carriages.” (participant with mild intellectual disability).

“Now you can easily validate your ticket using a mobile device, although you need to have a mobile and access to mobile data in case the Wi-Fi doesn't hold up at that moment on the platforms.” (participant with visual impairment).

“Now there are intercoms at platforms, so if you have a ticket validation issue you can contact TMB staff to get assistance at any time.” (participant with mild intellectual disability).

The improved design of the reserved seating areas for PwD, with clearer and enhanced signage and the introduction of separate signage for prams and bicycles, was proven to be positive for the PwD Metro experience. With more colourful and enhanced signage, PwD felt the reserved seating area would be more respected by others. Additional support with the implementation of assistance buttons for PwD within the Metro experience has proven positive.

5. Discussion and conclusions

5.1. Theoretical implications

Our study aimed to answer the call for further research on resources for restoring accessibility in public transport amidst the ongoing COVID-19 pandemic and any future pandemics (Armitage & Nellums, 2020; Cochran, 2020) to ensure equal access to public transport (Wang et al., 2022). It also used the co-design process framework to empirically test the value of the imposed service innovations as discussed by Heinonen and Strandvik (2020) with reference made to changed implemented by the transport operator TMB in Barcelona, Spain. There has been growing interest in the use of digital resources, new technologies and devices for transportation accessibility (Machala & Havří, 2019; Safronov et al., 2018; Valderrama-Pineda, 2016), yet this field needs further empirical research. Our goal was to add to the extant literature via this case study.

It is clear that transportation systems should include PwD in all stages of the planning process through co-creation (Armitage & Nellums, 2020; Cerdan Chiscano, 2020; Cochran, 2020) for a more inclusive transportation design. Therefore, our study offers new empirical insight into how the co-creation and co-design process with PwD, as a response to COVID-19, can be managed by engaging in value co-creation (Payne et al., 2008; Vargo & Lusch, 2008). We have explored what combination of digital and non-digital resources provided by transport operators create the best value for PwD (Kleinaltenkamp et al., 2012; Vargo & Lusch, 2008). This is relevant since digitalisation may pose a challenge for this demographic (Sjödin et al., 2020). Our results concur with Sabella and Bezyak (2019) in that transport operators can better manage improvements in the user's Metro experience by taking a more targeted approach. In line with De Vos (2020), Farinloye et al. (2019) and Wang et al. (2022) our study contributes to better understand how PwD engage with digital and non-digital resources in a public transport setting. By listening to PwD's voices, a new design for Metro trains has been developed using the value co-creation process to improve the public transport experience. A new signage system with more colourful,

clearly delineated in areas/seating reserved for PwD and the elderly and enhanced features, separated from other passengers with access needs like bicycles and prams has been explored and proved to be positive for all PwD.

Beyond considering users' opinions, the process requires a re-design of encounters based on a better understanding of PwD's use of digital resources through a mutual collaboration and learning process. If we are to ever overcome or provide transformative solutions for accessibility barriers within the transportation system, a mutual understanding of PwD's issues and practices with respect to digital resources is needed.

The data analysis resulting from the open coding process provided rich insights about PwD's perceptions regarding the value of the digital and non-digital resources provided by TMB in its encounters with passengers. This process yielded interesting insights on the performance of critical innovations used in encounters to enhance accessibility.

Table 3 shows an emerging result: according to the surveys, the participants in Study 2 were more positive about their Metro experience than the participants in Study 1. Thus, there are two critical factors that should be borne in mind when seeking to create value experiences for PwD.

First, digital resources provided by a transport operator must be designed to meet the accessibility needs of PwD to ensure their optimal use in the Metro experience. For instance, a passenger with mild vision impairment reported that Line 5 lacked the new display screens that provide occupancy-related information in audio format for the blind. Accessible and universal design is key when it comes to implementing innovations. In this respect, adopting a co-creation process helps transport operators to ensure accessibility by giving a voice to PwD and engaging in a mutual process whereby new innovations are designed or adjusted.

Secondly, our results coincide with Goggin (2018) in that, although digitalisation can make it easier for PwD to navigate Metro rides, it poses some challenges, particularly when Wi-Fi is not available in the underground or people with intellectual disabilities are unable to easily use self-service devices. For instance, one participant with an intellectual disability reported that Wi-Fi does not work properly on some platforms and that having transport staff available assisted them.

Our results coincide with Holstein et al. (2021) and show that PwD perceive better value in their Metro experience when the resources provided by transport operators are both digital and non-digital, as opposed to a fully digitalised service. For example, some participants reported that they perceived a safer metro journey when TMB staff were making sure that other passengers were following all health and safety measures, including that passengers were wearing masks.

We have also provided a greater understanding of the service encounters and the role of transport staff in assisting PwD, and these are key determinants (Donetto et al., 2015) of PwD's perception of value in their Metro experience when digital resources fail. We agree with Holstein et al. (2021), in that a better understanding of the positive combination of digital and non-digital resources can help transport operators design positive public transport experiences for PwD.

5.2. Practical implications for public transport operators

Our results follow Cochran (2020) who suggested a more inclusive pandemic response is needed to address the challenges coming from the impact of COVID-19 on PwD in public transport settings. The findings of this study can help transport operators to adjust their transport innovations and thus redesign their encounters and relationships with PwD amidst COVID-19 for a more sustainable and accessible public transport experience (Farinloye et al., 2019). We have empirically explored Machala and Havří's (2019) claim that digitalisation can positively impact on user experience, and we can conclude, in line with Holstein et al. (2021) that a combination of digital and non-digital resources provided by transport operators increases PwD's perception of safety and accessibility.

Likewise, our results may guide transport operators in determining what digital and non-digital resources provide the greatest value for PwD. First, they can help providers in developing new products or facilities, such as the new display screens that offer service and carriage occupancy information (Tirachini & Cats, 2020; Vickerman, 2020). In this regard, adjustments based on universal design that meet the communication needs of blind people and support for users with disabilities should be considered to create the best value for them in their Metro experience. Second, our results confirm that staff are a relevant resource for assisting PwD when digitalisation fails.

In summary, the COVID-19 pandemic has brought with it unique challenges that in turn provide opportunities for transport operators to reinforce their relationship with PwD by bringing inclusive transportation design and PwD's level of satisfaction into alignment. The results of this study offer transport operators actionable guidance for designing more accessible transportation services and environments amidst COVID-19. In this respect, our research aimed to provide transport operators with a guide for managing the value co-creation process. In line with Cochran (2020) we have found that it is essential for operators to provide trained staff to offer real-time assistance (Tirachini & Cats, 2020) to PwD when digitalisation fails and to apply universal design before digital innovations are implemented. When this is done correctly, PwD will perceive an increase in accessibility. In our research, we have identified several ways in which innovations emerged in encounters between transport operators and users as a result of COVID-19, and we have pinpointed which innovations generate the best value for PwD in terms of accessibility. Ultimately, we provide useful insight on how the process should be managed so that the co-creation outcome generates value and learning for both sides.

6. Limitations and future directions

As with all studies undertaken during COVID-19, the impact on people with disability's willingness to be involved in research cannot be underestimated. While we would have liked to have had larger numbers of PwD involved in the study, our first and foremost responsibility was to have a safe study that provided the optimum conditions for the safety of participants. Given that social context is always important within social science research, it would be good to replicate the study in other parts of Spain, Europe and other continents. We are exploring options to do this with a country in the southern hemisphere. It would also be good to replicate with other public transport modes. Lastly, similar to Tsafarakis et al. (2019) another technique that could be used in participant observations studies is the Conjoint Analysis for obtaining further insights into public transport users little observed so far to complement qualitative data raised in this study.

Author statement

Dr. Monica Cerdan Chiscano & Prof. Simon Darcy contributed both equally to the literature review, the design and implementation of the research, to the analysis of the results and to the writing of the manuscript.

Data availability

Data will be made available on request.

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