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Inclusive Digital Planning – Co-designing a collaborative mapping tool to support the planning of accessible public space for all

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ABSTRACT

Digital planning is loaded with the expectation to make planning more inclusive. However, digital tools currently used in spatial planning processes to facilitate communication and participation of stakeholders often exclude people with disabilities through their design. Consequently, the research question of this study is how to design digital tools to support inclusive participation in the planning and design of public spaces to make them accessible for all. To answer this question, this research aimed to co-design an inclusive collaborative mapping tool with people with disabilities to enhance their participation in the planning and design of accessible public spaces. Developed in collaboration with eight people with various disabilities from the city of Zwolle in the Netherlands, the open-source mapping tool allows the in-situ registration of accessibility issues and supports collaborative decision-making workshops. The co-design process served to identify barriers and obstacles to the accessibility of public spaces in the city as well as user requirements for the inclusive design of the collaborative mapping tool. The tool was tested and evaluated in a collaborative mapping session with people with disabilities and municipal planners from the case study city. Our findings show that the design of inclusive digital planning tools is not limited to software features but also relates to hardware functionalities and the environment in which a tool is used. Taking the lessons learned from the co-design process, we argue that digital, physical, social and procedural accessibility are key to achieving inclusive digital planning.

1. Introduction

Digital planning, defined as “the integration of ICTs into planning processes to support planning engagement, decision-making, daily practices and strategies to achieve desired planning outcomes” (Potts and Webb, 2023, p. 520), is loaded with the expectation to make planning more efficient, effective and inclusive (Lin, Geertman, Pinto, and Witte, 2024). The latter primarily refers to the close participation, engagement, and empowerment of marginalised groups (Lin et al., 2024) and the broader society as a whole (Shin et al., 2024). Both often lack in participatory planning processes (Farias and Widmer, 2017; Radil and Jiao, 2016). However, the understanding of inclusive participation is often very broadly defined and remains vaguely conceptualised in recent studies in the context of digital planning. Batty and Yang (2022) argue that an “inclusive planning process should celebrate diversity and engage with a wider public, so that all groups feel empowered,” and assign a key role to digital technologies in achieving this goal. Pan, Kwak, and Deal (2022) aim to promote inclusive participation in the development of such digital technologies by engaging citizens in co-design processes. Shin et al. (2024, p.2) describe inclusiveness as the “broad participation” of stakeholders in planning to “foster meaningful discussions […] and to influence decision-making”.

To develop a more specific and detailed understanding of the complexity and challenges of inclusive digital planning, in this paper, we explore a contextualised approach to inclusive participation in planning by focusing on the inclusion of people with disabilities in both the design of a digital mapping tool and urban public space, implemented for the city of Zwolle in the Netherlands. inclusive participation of all people, regardless of their physical or cognitive capabilities, is called for in international policies, such as the Sustainable Development Goals (SDGs, United Nations, 2015) and the UN Convention on the Rights of Persons with Disabilities (UN CRPD, United Nations, 2006). Following the social model of disability, we define disability as produced through the relationship between bodies and their social, physical, political, and –

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increasingly - digital environment (Hansen and Philo, 2007; Ross, Buliung, Titchkosky, and Hess, 2023). Hence, addressing processes of inclusion and exclusion in digital planning processes requires the analysis of the diverse relationships between differently abled bodies, the physical, social, and political barriers they face, and the digital technology that might help overcome these barriers.

The current planning and design of urban spaces to support mobility and accessibility at the neighbourhood level do not account for the diverse ways people experience urban space and their diverse requirements (Stafford and Baldwin, 2018). Stafford, Vanik, and Bates (2022) highlight that cities are often designed according to the image of a non-disabled person, resulting in spaces that are physically or socially not accessible to people with disabilities. Moreover, recent studies indicate that people with disabilities are often underrepresented in urban planning processes (Terashima and Clark, 2021). A recent review of 69 scientific papers found that disabilities are hardly considered when assessing the walkability of neighbourhoods (Stafford and Baldwin, 2018). As a result, urban planning frequently perpetuates the marginalisation of disabled individuals (Stafford et al., 2022).

Similar patterns of exclusion can be ascertained concerning the development and application of digital planning tools, for instance, Planning Support Systems (PSS), for the inclusion of citizens in general and people with disabilities in particular. In a review of 116 digital tools for citizen participation, including GIS-based applications, Shin et al. (2024) found many tools providing channels for citizens to voice their concerns, but most of the tools lack proper feedback mechanisms to support mutual interactions between experts and citizens. Flacke, Shrestha, and Aguilar (2020) observed, in a review of 16 Maptable-based PSS for collaborative planning, that most of them are designed for expert stakeholders, while only 4 tools involved citizens. Besides, there is a lack of knowledge on how digital planning tools can account for the usability needs of people with low digital literacy, for example, senior citizens or people with disabilities (Rautenbach, Coetzee, and Çöltekin, 2017; White, Pavlovic, and Poed, 2020). Pan & Deal (2020, p.142) report that the results visualised in PSS applications are "not always intuitive and require a modicum of expertise to grasp". Similarly, smart city tools and internet mapping platforms are often not accessible or cognitively demanding for people with low digital literacy (e.g., senior citizens) when not properly defined, which can affect the quality of participation (Rzeszewski and Kotus, 2019; Wiig, 2016). Pan et al. (2022) describe two reasons for the limited inclusiveness of PSS: their dominant focus on technologies and the supply-side orientation of PSS development. The focus on technology emphasises technocratic and instrumental aspects of participation, treating citizens instead as "testers […] or sources of data" (Cardullo and Kitchin, 2019, p. 10). The supply-side orientation of PSS development results in specific tools that are too generic, complex and inflexible, ignoring the demand derived from specific planning tasks (Vonk, Geertman, and Schot, 2005).

This paper reports the findings of a research project in which we worked towards co-designing an inclusive collaborative mapping tool with people with disabilities, our experts-by-experience, to enhance their participation in the planning and design of accessible public spaces. Reflecting on the co-design experience, we ask: How must collaborative mapping tools be designed to support inclusive participation in the planning and design of public spaces to make them accessible for all? To answer this question, we first describe the context of inclusive public space planning in the Netherlands and summarise the current state of inclusive digital tool development. We describe the barriers and obstacles people with disabilities experience accessing public space and their challenges in working with digital mapping tools. We then translate these findings into user requirements for an inclusive collaborative mapping tool and develop a tool prototype together with the group of people with disabilities. In the final step, we test the tool in a collaborative mapping session with them and municipal planners from the case study area and discuss how it could strengthen inclusive participation in local planning. In the discussion, we summarise the lessons learned regarding design requirements for inclusive digital planning tools and reflect on the challenges and complexities of inclusive digital planning.

2. Related work

2.1. Disabilities and inclusive access to public space in the Netherlands

In the Netherlands, an estimated 2 million people are living with a disability (Rijksoverheid, n.d.-a). This includes people with visual, mobility, auditory, and cognitive disabilities and corresponds to more than 11 % of the population, making it the largest minority group in the country. In acknowledgement of a need for an increased focus on the participation of people with disabilities in society and accelerating public policy reforms, the Netherlands ratified the UN CRPD in 2016. It requires municipalities to take appropriate measures to guarantee that people with disabilities have the autonomy to choose where and how they want to live, have access to the care and services they require, live as independently as possible, and have access to information, public facilities, and social services, equal to all other residents. Since its ratification, these requirements have been translated into various guidelines ('handrijkingen') and manuals (e.g., CROW Richtlijn Toegankelijkheid (accessibility) (van de Vrugt, Schouwenaar, and Pietersen, 2014)) aimed at stimulating municipal governments to formulate and implement local inclusion agendas. They were also included in the new National Environment and Planning Act (Omgevingswet, Rijksoverheid, n.d.-b), which postulates in article 4.21 that "the accessibility to new, as yet unconstructed, buildings and the immediate surroundings are guaranteed for people with disabilities".

Several Dutch cities have translated these principles into guidelines for inclusive public spaces. For example, the mid-sized city of Harderwijk has created a comprehensive guidebook for inclusion in public spaces, categorising it into three levels: basic, basic extra, and green (Ruimte Voor Loopen, 2024). This classification distinguishes the standard requirements for all public spaces (basics), additional necessities around crucial societal and medical destinations (such as shopping streets and hospitals), and considerations for the inclusivity and accessibility of public green spaces. Accessibility is evaluated across various categories, including sidewalks, route guidance, elevation differences, rest areas, crossings, parking spaces, bus stops, playgrounds, and street furniture (Gemeente Harderwijk and Goudappel, 2022). Similarly, Zwolle, the case of this research, has published design guidelines for inclusive public spaces (see Section 3).

2.2. Requirements of digital planning tools for people with disabilities

We are by no means the first to raise the issues of inclusion and communication in urban planning through technology. Ever since the 'communicative turn' in planning (Healey, 1992; Yiftachel and Huxley, 2000), there have been repeated calls for more democratic forms of planning, which encourage plurality of opinions and incorporate debate, conflict and collaboration as part of the planning of collective space. Pushing against top-down, functionalist, and technocratic planning regimes, communicative and democratic planning emphasises the importance of centring the knowledge and experiences of minorities in planning urban space (Healey, 1992). In this context, research and design have focused on how geo-information tools can address participatory processes in planning and governance, such as the inclusion of local knowledge, respect of contributions by participants, and accountability (Falco and Kleinhans, 2018; McCall, 2021; Pfeffer, Martinez, O'Sullivan, and Scott, 2015). As a result, over the past two decades, an impressive number of tools have been developed that focus on supporting the communication and participation of stakeholders in planning processes (Lin and Benneker, 2022).

Recent scholarship has emphasised the importance of meaningful, collaborative, and representative stakeholder participation in urban design as crucial for the planning and development of inclusive cities that contribute to citizens' well-being (Dane et al., 2024; Geertman and Witte, 2024). Batty and Yang (2022) stress the importance of how digital planning tools are deployed for achieving inclusivity planning. They shall support people-centric planning processes (Pfeffer, Flacke, Nourian, and Kuffer, 2025) which enhance the engagement and collaboration of all stakeholders (Batty and Yang, 2022). In line with that, Pan et al. (2022) argue that PSS can empower citizens when they are involved in a co-design process, which also helps achieve a better match between planning and context. Various recent studies have documented the feasibility of co-design processes with diverse user groups for designing suitable digital tools (Aguilar, Calisto, Flacke, Akbar, and Pfeffer, 2021; Prestby, Robinson, McLaughlin, Dudas, and Grozinger, 2023; Rittenbruch et al., 2021).

Meaningful participation and inclusion are created through the design of (assistive) tools (Danemayer et al., 2023) and the process and environment in which they are embedded. Brömmelstroet (2017) describes how the usability, clarity, and credibility of planning support tools contribute to their communicative value in planning practice. In line with this, Danemayer et al. (2023) list how usability, capabilities, environment, and lifestyle all determine the potential value and adoption of assistive technologies (AT) for people with disabilities.

It is essential to keep in mind, as Egard and Hansson (2021) note, that the increased use of digital technologies mediates the participation of people with disabilities in positive and negative ways. On the one hand, digital technologies, such as ATs, allow for a more seamless integration of diverse user needs. They make it possible to integrate multiple functionalities, such as speech operation, zooming, and transcriptions, into one technology, such as a mobile phone. Additionally, digital technologies and internet-based platforms have contributed to diversifying the forms of communication and collaboration within and between disability communities. Through multimedia communication (written text, voice messaging, and video calls) and asynchronous and multilocational interaction, technologies can help remove the architectural and communicatory barriers that traditional participation and collaboration produce (Thompson, 2019). On the other hand, digital tools designed for a particular group of people with disabilities might contribute to widening the digital divide as they will not work for others within the heterogeneous group of people with significant individual differences (Johansson, 2019).

Examples of digital geospatial tools that have been developed for inclusive use are scarce. Arenas, Castellanos García, and Garzón Carrillo (2021) developed a collaborative mapping tool implemented on a mobile device that allowed people with sensorial and physical disabilities to map accessible locations in Ibagué, Colombia (Arenas et al., 2021). Krüger, Krümpelmann, Pelka, and Schulz (2023) developed the Wheelmap (Sozialhelden, n.d.) using a citizen science approach to collect information from wheelchair users on the accessibility of hotels and restaurants.

Remarkable in these examples of inclusive mapping is that they are developed for specific user groups and contexts. Yet, this potentially limits their use for other groups and contexts. To guide the design of tools that are usable for all people regardless of their abilities, the universal design principles were developed in 1997 (Centre for Excellence in Universal Design (CEUD), n.d.). The seven principles aim to ensure that all people can use tools to the greatest extent possible (Persson, Åhman, Yngling, and Gulliksen, 2015). Given the stark heterogeneity within groups of people with disabilities and the variety of contexts, Abascal, Barbosa, Nicolle, and Zaphiris (2016) conclude that the key aspect of universal design is to develop flexible approaches that can be adjusted for individual needs and contexts (Principle 2).

Insights into the individual needs of people with various disabilities can be derived from existing norms and research studies. The Web Content Accessibility Guidelines (Web Content Accessibility Guidelines (WCAG), 2024) specify international standards for making web content accessible for a wide range of users with disabilities, including blindness and low vision, deafness and hearing loss, limited movement, speech disabilities, photosensitivity, and combinations of these. While some of the most common accessibility features are already included in current computer operating systems, specific solutions are often needed if a person's abilities deviate from this norm (Braun, Wölfel, Renner, and Menschik, 2020).

3. Methodology

The study employed an inter- and transdisciplinary team-science approach and various data collection, analysis and tool development methods to co-design an inclusive collaborative mapping tool. In the following section, we report on the research team composition and case study, the design of the research, and the methods used.

3.1. Research team and case study

The research was conducted in the regional capital city of Zwolle, the Netherlands, consisting of about 129.000 inhabitants (www.zwolle.nl). The choice of the case was determined by the ambitions of the city, the access to an active community engaged with questions of accessibility, and the support from the municipality. The city of Zwolle has a clear ambition of inclusive participation and accessibility (Gemeente Zwolle, 2024a), reflected in the design guidelines for public spaces (Gemeente Zwolle, 2024b), the appointment of a manager who is responsible for active mobility in the city and by providing support to the active community organisation 'Accessible Zwolle' (Toegankelijk Zwolle, n.d.-a). Accessible Zwolle aims to create an accessible and inclusive society by advocating for people with disabilities through an expert-by-experience approach. Experts-by-experience systematically collect evidence on accessibility issues in public spaces from a cross-disability perspective (Toegankelijk Zwolle, n.d.-b), organise events, share their experiences with others, or advise the city on inclusive accessibility.

The research team conducting this study consists of four groups: 1) the scientific researchers with a background in urban planning, geography, technology development and disability studies; 2) a group of people with disabilities who are experts-by-experience in the city of Zwolle; 3) a national umbrella organisation for the needs and issues of people with disabilities in the Netherlands, and 4) a company specialised in developing geospatial software applications and tools. The coordinating team, including the scientific researchers, a representative from the Dutch umbrella organisation and a representative from Accessible Zwolle, took care of the practical coordination of the co-design/collaborative sessions, documenting the process, translating the insights from the collaborative sessions into design requirements, and reporting on the project through academic outputs.

The group of co-researchers consisted of eight people with diverse mobility and sensory impairments (wheelchair users and sight or hearing impairment) living in Zwolle and its surroundings. In addition, depending on the group composition, a sign language interpreter was present at the co-design sessions. The responsibility of the co-researchers was to identify the main issues of mobility within and access to public space, share their insights, critically test the tool prototype, and provide feedback on the documentation and reporting of the project. Several experts-by-experience had been involved in previous activities of TZ assessing the accessibility of public facilities for people with disabilities. The task division was partly informed by the different needs within the project, the diverging abilities, and time availability. The experts-by-experience all participated voluntarily.

3.2. Co-design process

Our exploratory co-design research effectively combined spatial and qualitative data and methods, specifically photovoice-supported geo-narratives, participatory workshops, and collaborative maptable tool development.

The overall methodology of the study was divided into four phases (Fig. 1).

A key element of the first phase was the first co-design workshop, which aimed to acquaint the teams of researchers and co-researchers with each other, establish roles, and define the methodological approach. The co-researchers provided input regarding how to define the accessible city, the indicators for assessing accessibility, and how to structure the co-design process. Everybody also made explicit what competence and resources they could bring to the research process. The maptable was introduced and used to discuss spatial aspects of the case study area.

The second phase consisted of three co-design workshops to elicit user requirements for the inclusive mapping tool. Workshop 2 served to determine the tool's main aim and plan the fieldwork tour to capture aspects of inclusive accessibility from the co-researchers' point of view. The tour (workshop 3) was done in the city centre of Zwolle applying photovoice (Annang et al., 2016) and geo-narratives (Kwan and Ding, 2008), resulting in a collection of geocoded photos with descriptions illustrating good and poor examples of accessible planning and design in the city centre of Zwolle. In workshop 4, the photos and geo-narratives from the fieldwork tour were discussed, analysed and categorised as mapping features for the tool. The maptable tool was used to explore the geocoded photographs and collect feedback on how to integrate photographs into the maptable tool. During all three workshops, the academic researchers made written notes, which were thematically organised into user requirements for the tool, informing phase three.

The third phase included three sprints of six weeks to iteratively develop the tool by the software developers based on the user requirements and test the tool iteratively together with the co-researchers. The basis of the tool development was a collaborative mapping and decision-making platform for maptables developed in earlier projects (Aguilar et al., 2021; Aguilar, Flacke, Simon, and Pfeffer, 2023). In two test workshops, namely after the second and at the end of the third development sprint, the co-researchers tested the prototype and provided feedback to the scientific team. Feedback was carefully documented in written notes and discussed with the developers, finding a balance between desirability and feasibility within the project context. In follow-up meetings with the co-researchers, the scientific researchers shared what feedback was implemented, how, and why certain choices were made in the development.

In the final application workshop, the collaborative mapping tool was presented to the municipal officials of Zwolle. In this workshop, spatial data and information on problems and barriers regarding the accessibility of public spaces in Zwolle collected by the co-researchers and visualised in the mapping tool were discussed with officials from the municipal GIS, urban planning, and inclusion departments. The discussion aimed to understand why certain design choices are made in the city and identify possible interventions to improve accessibility. The workshop was jointly organised and moderated by the research team and the municipality. At the end of the workshop, the usefulness and usability issues (Russo, Lanzilotti, Costabile, and Pettit, 2018) of the tool were discussed.

4. Results

Informed by the social model of disabilities (Hansen and Philo, 2007), we investigate what and how people with disabilities can contribute to the planning and design of inclusively accessible public spaces in cities based on their experiences of the urban environment, and how their experiences can be mapped and made available for joint decision making to better address these issues and engage them in related planning processes. In the following, we first report on how an accessible city was defined in our research and what barriers and obstacles were found in the city for diverse disabilities. Then, we discuss what user requirements for the mapping tool prototype resulted from it and how they were implemented in the inclusive collaborative mapping tool. In the last section, we summarise the test workshop with the municipality and the discussion of the usefulness of the tool.

4.1. Barriers and obstacles to inclusive access to public spaces

The starting point of the co-design process was to achieve a common understanding among the researchers and co-researchers of what an accessible city (toegankelijke stad) means to them. Firstly, it was argued that the accessible city refers to the proactive creation of choice and opportunity for all urban residents irrespective of their (dis)abilities. The term proactive is essential in this definition as it points towards the municipality's responsibility to take the lead in creating an accessible city. Secondly, the team added that the accessible city means that both physical and social spaces are made accessible. Hence, it is important to remove both physical and social barriers limiting people with diverse disabilities to participate in urban life in ways they see fit.

Making public space accessible for all presumes that the public space is accessible by diverse modes of transport. In line with that, the CROW guidelines for inclusive accessibility to public spaces (van de Vrugt et al., 2014) distinguish four categories of accessibility relevant to people with physical or cognitive impairments: Walking routes, bus stops, travel and route information, and parking places. During the photovoice fieldwork trip in the inner city of Zwolle, the co-researchers documented several accessibility issues for people with different types of disabilities in the

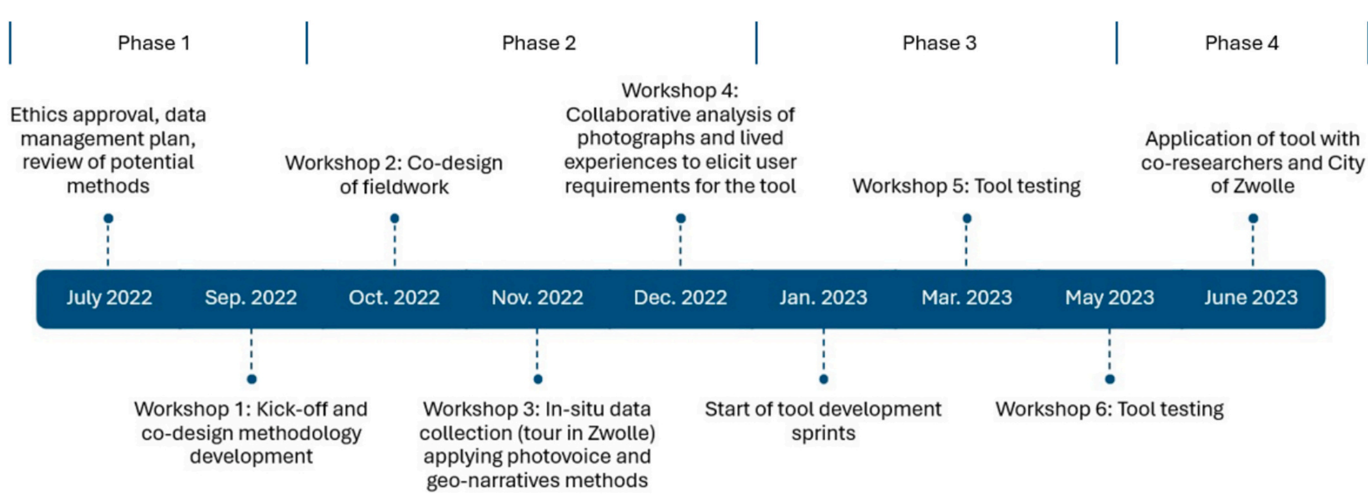

Fig. 1. Timeline of the co-design process.

public space. Table 1 relates the issues identified in the field by the stakeholders to the CROW categories with bus stops, travel and route information issues summarised under public transport.

Concerning walking routes, the traffic design in the city was described as being sometimes illogical, counter-intuitive, or unsafe for people with disabilities. For example, when ramps are not aligned to each other at a crossing or traffic lights or their audio-tickers are turned off after 8 pm, which makes it more difficult and dangerous for people with disabilities to cross the street. Other critical issues for all people with diverse disabilities were the surface (pavement) of walking routes, the design of ramps, and various obstacles in the streets. The pavement ideally needs to have a smooth and consistent surface for people using a guidance stick. Otherwise, each bump means they get a shock to their shoulder. For people using a wheelchair or a walker, uneven pavement can be uncomfortable or hinder their movement (Fig. 1d). The most critical issues regarding the design of ramps are their angle and placement in relation to the motorised traffic, or if they lack at all

(Fig. 1c) on the streets and whether signs related to the ramp are well-positioned. Typical obstacles and barriers in public space that hinder movement on walking routes (Fig. 1a) are either fixed and permanent (lanterns, signposts, benches) or mobile and temporal (bikes, scooters, scaffolding, chairs and tables on terraces, construction work). For people with visual impairments, guidelines on the ground must be consistent, integrated with natural guidelines (e.g., walls/vegetation), and accessible. In Zwolle, many guidelines are not appropriately integrated with natural guidelines, are blocked by obstacles (Fig. 1b), or are simply missing.

Problems concerning public transport are mainly if busses have a (mobile) ramp for people using a wheelchair and if the bus driver is willing to help them enter the bus. Concerning travel and route information, often accessible information on how to get from one location to another by bus, if temporary obstacles are on the route, and if alternative routes are required, are often lacking. Another barrier for people with auditive impairment is if no alternative to sound/spoken text is available to inform about travel and route information. Issues related to parking are mainly if priority parking lots adhere to the guidelines and are placed well in the parking place.

Table 1
Inclusive accessibility issues in public spaces: identified barriers and obstacles.

Main accessibility categories	Issues identified by co-researchers	Description	Problematic for whom
Walking routes	Traffic design	Can be illogical/ counterintuitive or unsafe	All people with disabilities
	Ramps	Placement and shape of ramps	All people with disabilities
	Pavement	Smooth surface, consistent	Wheelchair users
	Guidelines	Consistent, integrated with natural guidelines, and accessible/visible	People with visual impairment
	Obstacles	Fixed and permanent or mobile and temporal	Wheelchair users, People with visual impairment
	Lighting	When turned off at night for energy-saving reasons	All people with disabilities
	Sounds	Sound of traffic lights switched off after 8 pm	People with visual or auditive impairment
Public transport	Bus stops	Ramps for entrance, driver helping	Wheelchair users
	Barriers to access	Alternative to sound/ spoken text for people with auditive impairments.	People with auditive impairments
Parking paces	Parking	Issues of placement and shape	Wheelchair users

Throughout all co-design sessions, the co-researchers emphasised the importance of a cross-disability perspective (Drainoni et al., 2006) when mapping barriers and obstacles to inclusive accessibility. A barrier perceived by a particular group of people with disabilities (see Table 1) might mean the opposite for another group. For example, single-level pavements may increase accessibility for wheelchair users while making it more difficult for people with visual impairments to navigate the tactile pavement.

4.2. User requirements for the inclusive collaborative mapping tool

The reflection on the definition of the accessible city, the fieldwork tour, and the discussion of the tour results, as well as the encounters with the maptable served to identify user requirements for the inclusive, collaborative mapping tool. They included both requirements regarding the hardware, i.e. the maptable, the space and environment in which it is used, and requirements related to the software features of the mapping tool.

Essential requirements regarding the hardware and the environment in which the maptable is used were to make the maptable accessible for wheelchair users. Its touchscreen needs to be tiltable and should not exceed a diagonal screen size of approximately 49 in. to allow users to touch all corners of the screen. The screen needs to be adjustable in height to enable its use while standing and sitting around it. Regarding the environment, in particular, the lighting of the room is important as direct light on the screen might lead to reflections that limit its visibility, particularly for people with visual impairments.

The elicited software requirements for the maptable tool can be distinguished into generic inclusive tool requirements independent of the content and context of the tool application and requirements specific to the topic of accessibility to public space. Content-independent requirements are described in Table 2.

Many of the generic software requirements listed in Table 2 are nowadays standard for inclusive digital apps and tools and are defined in available norms and standards (W3C, 2016). However, we have not come across PSS tools that explicitly refer to these requirements in the literature. Nevertheless, PSS tool developers might already implicitly consider many of these requirements based on their own workshop experiences. After all, the generic user requirements are of general relevance concerning the usability of PSS tools and may ease the work with a maptable for stakeholders in different contexts and use cases independent of the levels of (dis)abilities of the users. Specific features included in the tool for mapping accessibility to public space are listed in Table 3.

The identified context-specific user requirements of the inclusive mapping tool (Table 3) resulted from the above-identified barriers and obstacles in public space hindering or hampering inclusive accessibility

Table 2
Content-independent user requirements of the inclusive mapping tool.

Generic user requirements	Description
Contrast text to background (interface and map layers)	Contrast ratio of at least 4.5:1 (minimum) needed for people with visual impairments; optimum is 7:1
Text font	Text fonts sans serifs, easier to read for people with visual impairments
Text size	Large text size is needed for people with visual impairments; never encode information with absolute text sizes, use relative sizes instead
Text spacing	Text with sufficient spacing between letters as well as between words is required for people with visual impairments,
Full-screen view of tool	Full-screen view is needed to avoid distraction for people with visual impairments
Street search	Street search to support the identification of locations and navigation for people with limited map literacy
Photos/images	ALT attributes for images, better provide utility descriptions than literal descriptions

Table 3
Context-specific user requirements of the inclusive mapping tool.

Context-specific software requirements	Description
Mapping accessibility issues: physical barriers, good examples	Mapping points features into different categories (see Table 1), both positive and negative examples
Photo capturing	Include geocoded photos of spatial locations taken by users when reporting barriers
Visualising geocoded photos of barriers	Clicking on photos visualised as thumbnails in a layer displays these photos in a separate window
Capture spoken words as text for single photos	Select a photo from the layer above and record text into an attribute or audio signal
Aerial photos of different seasons (winter/summer)	Showing vegetation with and without leaves to support the identification of routes and locations

(see Table 1). They are further motivated by the context in which the co-researchers envision the collaborative mapping tool to be used (see below). Following a comprehensive mapping of barriers and obstacles as well as positive solutions, the tool is designed to be used for joint discussions with local planners and decision-makers at the maptable. It is meant to direct their attention to the problems hotspots, but also to learn from good examples of how inclusive accessibility issues have been addressed. For both, a photo might say more than 1000 words. Hence, explaining the content of an image in ALT text is required as standard in inclusive tools. Additionally, capturing these explanatory words by word-to-text recognition also enables people with motoric disabilities, which prevent them from using keyboards, to contribute these features.

4.3. The collaborative mapping tool

The inclusive collaborative mapping tool developed in the context of the research is based on the open-source mapping platform Open Geospatial Interactive Tool (OGITO, Aguilar et al., 2021, 2023), which is made explicitly for maptables and published on GitHub (GitHub, 2024a) https://github.com/rosaguilar/ogito. This web-based mapping platform was collaboratively designed to be intuitive and user-friendly and to facilitate stakeholder engagement and discussions, particularly serving the needs of non-expert stakeholders. The usability and usefulness of the OGITO tool have been tested in a case study on rural land use planning in Indonesia with laypersons (villagers) (Aguilar et al., 2021) and a European case study on noise action planning with planning practitioners (Aguilar et al., 2023).

Based on discussions with the co-researchers, the OGITO-inclusive collaborative mapping tool (GitHub, 2024b) https://github.com/52North/OGITO has been adapted to support two modes of working related to different steps of decision-making towards urban accessibility. First, to capture and report inclusive accessibility issues and point out best-practice solutions for accessible public space in the streets, the tool had been adapted to function properly on a mobile device, such as a tablet computer. Second, using the reported data in collaborative decision-making workshops with other stakeholders, it has been adapted to visualise and present data using a maptable. For both working modes, the software design requirements elicited above were included as much as possible.

The key feature of the tool for reporting purposes allows the users to capture and document barriers of accessibility to public space in the categories identified above (see Section 4.1) either while being in the streets and using the tool on a mobile device, or at home on a website with photos that have been taken beforehand or by others. The co-researchers suggested allowing to map both accessibility barriers and obstacles as well as best-practice solutions or positive structural interventions, as the latter provides an opportunity to learn from what works in practice. The feature is implemented as a dialogue that first asks the user to map a spatial location of an issue on a map or aerial photo of the area and then to add details of the problem or solutions to the database (see Fig. 3). The following information is to be added to each location in a pop-up menu:

- Type of problem/solutions (categories from Table 1) (1)
- Verbal description of the problem (2)
- Date of reporting (3)
- Indication of whether a problem or a good solution has been mapped (4)
- In case of a problem: perceived urgency of the problem to be fixed (3-point scale)
- Option to upload a photo supporting the observation (see Fig. 3) (5)
- Short explanation of what is shown on the photo (to be used as ALT text in the tool) (6)
- Address where the photo was taken (7).

To support collaborative decision-making with other stakeholders, all reported problems and solutions described above are collected in the database and visualised on the maptable. Further layers of spatial information, such as a topographic map and an aerial photo, bus lines and stops are added to the Table of Contents for spatial orientation in the map as suggested by the co-researchers and can be independently turned off or on. To retrieve detailed information on single issues mapped, a new window pops up when clicking the location visualising the photo taken and the additional details stored in the database (see Fig. 4).

A street search feature has been added to the tool, supporting the inspection of specific areas. When selecting a particular street, the map extension shown on the screen automatically zooms to the given location. To enhance the inclusive use of the collaborative mapping tool, the following features were added, partly making use of standard accessibility features of Microsoft Windows 11 operating systems (OS), such as the magnifier and read-aloud application (see Fig. 5).

- Full-screen visualisation of the tool interface (1)
- High contrast of tool interface
- Magnifier to enlarge selection screen elements (2)
- Read aloud button for single text boxes (3)
- ALT image text for photos.

4.4. Testing and evaluation of the tool

Before the final application workshop in June 2023, the co-researchers mapped accessibility issues in the inner city of Zwolle using the developed tool prototype. Overall, 47 problems of inclusive accessibility and four good solutions were mapped in this testing of the tool (see Fig. 6). Almost half of the locations were mapped as temporal or permanent physical obstacles within the inner city of Zwolle, among them objects such as scooters, parasols and tables of cafes and restaurants, garbage cans, and flowerpots on the sidewalk. Problems with the surface or pavement of the sidewalk were mainly related to misplaced or missing ramps. Regarding guidelines, the most significant problems were recorded related to the transition from natural guidelines (walls, green features, curbs, etc.), to installed guidelines. These transitions were often counter-intuitive, blocked, or hard to distinguish from other lines on the surface (lacking contrast). The four positive examples mapped include a guideline crossing a café terrace that was kept free from obstacles, flowerpots in the streets that were not blocking access, and a sidewalk where all objects in the street were concentrated on one side to keep the other side free.

The co-researchers and five staff members from Zwolle municipality, including the inclusive accessibility manager, attended the final workshop. The workshop aimed to present the findings of the co-design process and the collaborative mapping tool to the municipality for reflection and to discuss the tool's potential future applicability.

The reactions to the testing of the tool by the municipal staff members were predominantly positive. One staff member called it an eyeopener that helps raise awareness and create an understanding of issues of inclusive accessibility. It was explicitly mentioned how important the photos are for pinpointing the exact problem in a specific location. For some situations, it was even suggested that a short video would have helped to better understand the issue at hand (e.g. how a bench hinders the access of a wheelchair user). Some problems within the urban design were justified by the municipal staff members based on the purpose they have according to guidelines, e.g. a pole blocking a walk line was meant to stop cars. Other issues were acknowledged as a lack of enforcement of existing rules and regulations. One of the municipal staff members remarked that including suggestions for improvement may help inform future planning.

Concerning the potential use of the tools in existing participatory planning processes and the municipality's workflow, both potential links to existing systems and overlaps and redundancies with existing software applications used by the municipality were discussed. Reported holes and gaps in the pavement could, for example, be included in an app that the municipality maintains for the road workers in charge of fixing them. It was further suggested that the collected knowledge of what works well may serve the municipality as a template when designing new solutions for other locations. The staff members of the municipality further appreciated the conceptual design of the tool and the collaborative process. It was argued that the conceptualisation informing the inclusive design of the maptable tool could be integrated into an existing web platform maintained by the municipality in which citizens can report general issues or complaints encountered in public space (Gemeente Zwolle, 2024c).

5. Discussion: The complexities and challenges of inclusive digital planning

In the following, we reflect on the experiences from the co-design process and obtained results regarding collaborative mapping tools and discuss the challenges and complexities towards inclusive participation to make space accessible for all. We start in Section 5.1 with the lessons learned for the design of inclusive digital planning tools. Section 5.2 presents a framework of inclusive digital planning based on the research results. In Section 5.3, we discuss the limitations of the presented research.

5.1. Lessons learned regarding the design of inclusive digital planning tools

Reflecting on the definition of an accessible city and conducting photovoice walking tours, coupled with the exploration of hardware and software requirements for a collaborative mapping tool, has been instrumental in identifying user requirements for inclusive digital planning tools. From the requirements presented in Section 4, it becomes evident that the design of inclusive digital planning tools is not only limited to the software but also relates to hardware functionalities and the environment in which a tool is used.

First, regarding the software design of digital planning tools, our research shows the importance of considering inclusiveness in terms of interface design and data visualisation. The interface design should ensure that all information and features of the tool are accessible for all users, independent of their limitations. State-of-the-art computer operating systems (OS) already include various accessibility features, such as a screen magnifier or a read-out-loud button that can be easily integrated into the tool. Depending on the context and user group, additional accessibility features might be required to accommodate people with limited fine motor skills or who are visually impaired. This would require, for example, voice command and text-to-speech or text-to-braille applications. As many people with disabilities regularly use ATs like voice recording on their smartphones, it is important that digital planning tools function in line with the most common assistive applications.

The research further revealed that additional layers of spatial data could also enhance the tool's accessibility for people with low spatial literacy (Rautenbach et al., 2017). Adding layers of bus lines and stops with names increased the legibility of the map for users who typically use bus transport within the city. The feature to search for street names was another layer of information that helped users navigate the map. Finally, adding ALT text to figures and photos on the map makes it more inclusive for people with visual impairments.

Secondly, inclusiveness should also be considered in the hardware requirements of the tool and the environment in which it is placed. Interactive touchscreen devices, as they are used in maptable PSS applications, have proven to be particularly helpful for people with intellectual disabilities as they ease engagement in communication more than writing or speaking (Skogly Kversøy, Kellems, Kuyini Alhassan, Bussey, and Daae Kversøy, 2020). In our research, however, the maptable needed to be titled and vertically adjustable to ensure people on foot and using a wheelchair could equally access the tool. Also, the maptable size matters, as people with reduced mobility should be able to reach all corners without walking around it. Connecting additional hardware, such as a joystick, can increase the accessibility of the maptable as it allows people with limited motor skills can operate the system without using the touchscreen.

Finally, the environment in which the table is operated plays a role in its usability for people with disabilities. Goodspeed and Pelzer (2020) define the environment in which a digital planning tool is used as a sociotechnical setting supporting a dialogue between stakeholders, which is crucial for the outcomes of the process (Salter, Campbell, Journeay, and Sheppard, 2009). Our research showed that appropriate lighting is required to make the content easily legible from all angles, and sufficient space around the device is important to ensure everybody, including wheelchair users, can navigate around it, but in other contexts, further aspects might be relevant. General guidance on how to design the environment for the inclusive digital planning tools can be derived from universal design guidelines (Law, Soo Yi, Choi, and Jacko, 2007).

It is essential to note that the tool we developed in this research explicitly results from the user requirements elicited during the co-design process with people with mobility disabilities. Other features and accessibility requirements might be needed for other participants. As digital planning tools must respond to such specific context factors (Geertman and Stillwell, 2020) to achieve high usability and usefulness, developing a single tool for each use case would not be possible. Instead, in line with Principle 2 of the universal design principles, we argue that inclusive digital planning tools should be designed with high flexibility to address a wide range of individual preferences and abilities.

5.2. A framework of inclusive digital planning

A key finding from this research is that it takes more than a suitable inclusive planning tool to make digital planning inclusive for people with diverse disabilities. Taking the lessons learned from the entire research and co-design process, we argue that the key to inclusive digital planning is digital, physical, social and procedural accessibility. The UN CRPD defines the concept of accessibility comprehensively. Article 9 of the convention reads: "To enable persons with disabilities to live independently and participate fully in all aspects of life, States Parties shall take appropriate measures to ensure to persons with disabilities access, on an equal basis with others, to the physical environment, to transportation, to information and communications, including information and communications technologies and systems, and other facilities and services open or provided to the public, both in urban and in rural areas" (United Nations, 2006). Based on this definition, we claim that inclusive digital planning must address both planning processes and the resulting space it shapes and must consider the four dimensions of accessibility as depicted in Fig. 7.

Digital accessibility refers to the digital planning tools that are used to support the participation of stakeholders in the planning process. They need to be accessible to everyone regardless of their abilities or disabilities and in line with universal design requirements (see above). Ideally, their development is driven by a specific demand and involves stakeholders from the beginning, e.g. through a co-design process (Pan et al., 2022). They need to match with the various political, institutional and cultural context factors (Geertman and Stillwell, 2020) but also adapt to the digital skills, abilities and motivations of the participants (Kolotouchkina, Ripoll González, and Belabas, 2024).

With procedural accessibility, a term we borrow from the environmental justice debate (Todd and Zografos, 2005; Walker, 2009), we refer to the requirement that planning processes need to be open, transparent and accessible for people with disabilities to ensure inclusive plan development. As this research showed clearly, people with disabilities are experts-by-experience in their cities and can act as ambassadors to contribute their knowledge to the planning process. This requires invited spaces (Gaventa, 2006) where the contribution can take place. Such processes further require particular facilitation (Goodspeed and Pelzer, 2020), such as, in our case, a sign language interpreter. Further requirements might entail that the meeting location is accessible to people with mobility disabilities but also that relevant planning documents are made available in a version with plain language (Meltzer, Barnes, and Wehbe, 2025) for people with intellectual disabilities. If needed, people with disabilities might require training in order to contribute to planning processes (Kolotouchkina et al., 2024).

Physical accessibility refers to the ability and freedom to move in space. A lack of physical accessibility can lead to total exclusion from public life (Szaszák and Kecskés, 2020). In principle, physical accessibility is always a result of planning decisions but is often affected by potential trade-offs. Planners need to weigh various needs and values for the city in their design. In planning practice, solutions are often implemented from an engineering point of view that outweighs the needs and requirements of people with disabilities (see Section 4.4). In Zwolle, for example, this means weighing the aesthetic and cultural heritage value of its historical inner city against the need to redesign cobblestone-paved squares to improve physical accessibility (Fig. 2c). Communication within planning processes between people with disabilities and city planners might help to design more inclusive solutions or to better understand specific decisions and trade-offs.

Finally, social accessibility refers to the inclusive participation in public life of people with disabilities. Particularly, it relates to the feeling of a sense of belonging in space. Our research in Zwolle has shown how, in practice, accessibility aspects were often neglected in public space. For example, our co-researchers pointed out how the tables

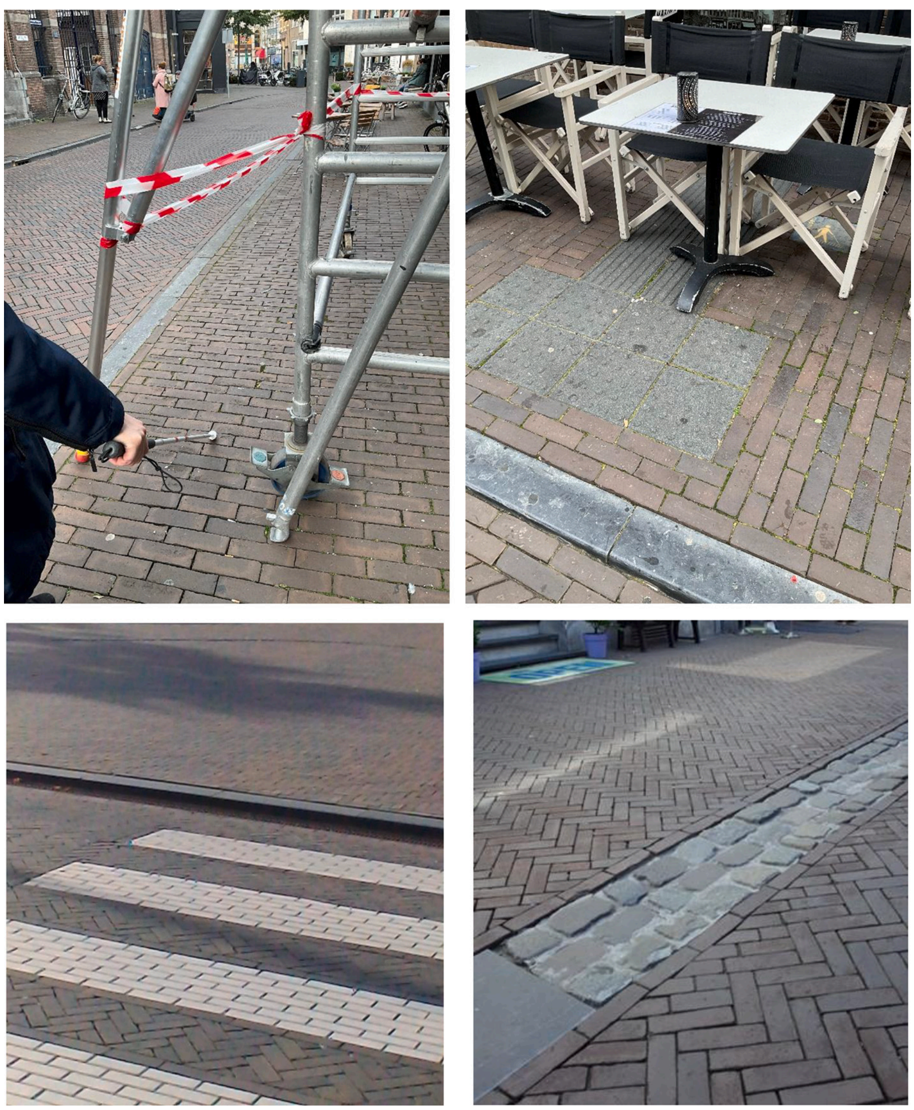

Fig. 2. (a–d (clockwise, starting upper left)) Images of accessibility issues taken during fieldwork in Zwolle. a: obstacle, scaffolding on the footpath; b: guidelines and meeting point for people with disabilities blocked by tables; c: ramp missing at a zebra-crossing; d: cobblestone pavement (photos: authors and co-researchers).

Fig. 3. Interface of mapping tool, procedure to map barriers (numbers in yellow circles refer to numbers above in the bullet point list). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

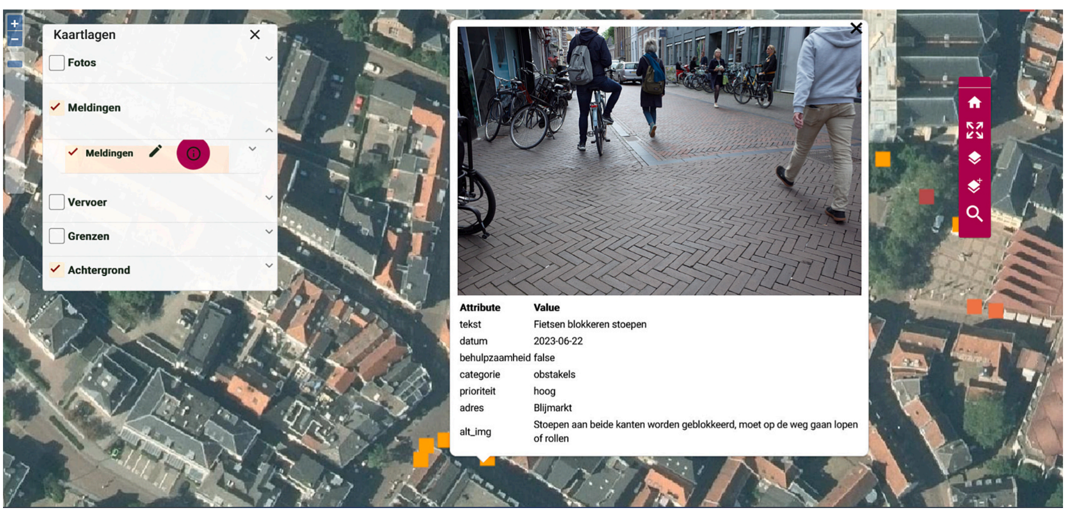

Fig. 4. Interface of the mapping tool showing mapped locations, image of one location and explanatory text visualised.

of a street café in locations that are supposed to be kept free for people with disabilities, means not only that this space is physically not accessible for people in a wheelchair or using a cane; it also signals that people with disabilities are not considered or welcomed in society (Fig. 2b). The same applies to the guidelines in the ground for people with visual impairment, which are often blocked by street furniture (Fig. 2b). Stafford et al. (2022, p. 116) describe such situations of socially inaccessible locations as losing "my sense of belonging within the community".

As explained in the text above, these four accessibility dimensions are not independent but affect each other mutually. Procedural accessibility to planning processes is a prerequisite to contributing to digital planning. Vice versa, high digital accessibility of planning tools supports making meaningful contributions to planning processes. Likewise, as Szaszák and Kecskés (2020) point out, physical accessibility is a prerequisite to social interaction and safe participation in public life, and meaningful participation in planning processes may stimulate social learning and an active contribution to society (Natarajan, 2017). Hence, as indicated by the framework, to achieve inclusive digital planning and accessible space for all, we need to consider all four dimensions equally within the digital planning process.

5.3. Limitations of the study

Given the scope of the study, we were not able to address the diversity of people with disabilities and all their diverse skills and abilities comprehensively. We only implemented a collaborative mapping tool that enables and supports the interaction of people with mild auditive and visual impairments and adopted the hardware for people using a wheelchair. More features and extensive user testing would be needed to make the tool truly inclusive (Hennig, Zobl, and Wasserburger, 2017). For instance, we have been unable to accommodate people with limited fine motor skills or who are blind. Moreover, a fully inclusive mapping tool would also require the involvement of people with cognitive disabilities (Brüggemann et al., 2023).

Involving other groups of people with disabilities would further include studying the opportunities and challenges of integrating proprietary hardware solutions and assistive technologies into the collaborative mapping processes and the digital tool setup. Integrating a joystick to operate the maptable, for instance, for people with limited fine motor skills or voice command and text-to-speech or text-to-braille applications are options we have not explored yet. In general, the smooth integration of Ats into the digital tool environment is a field for

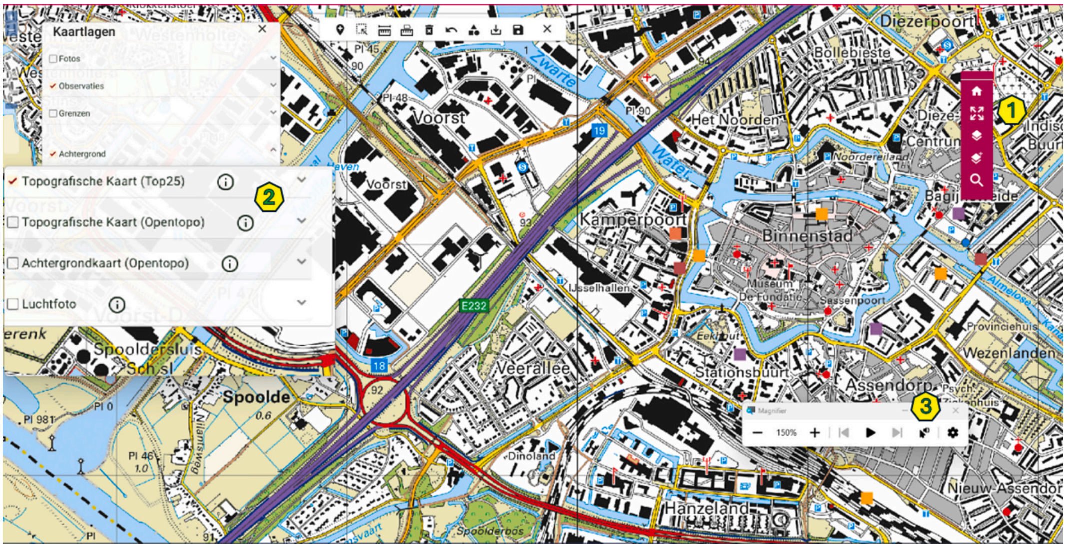

Fig. 5. Interface of mapping tool with features for improved visibility and readability.

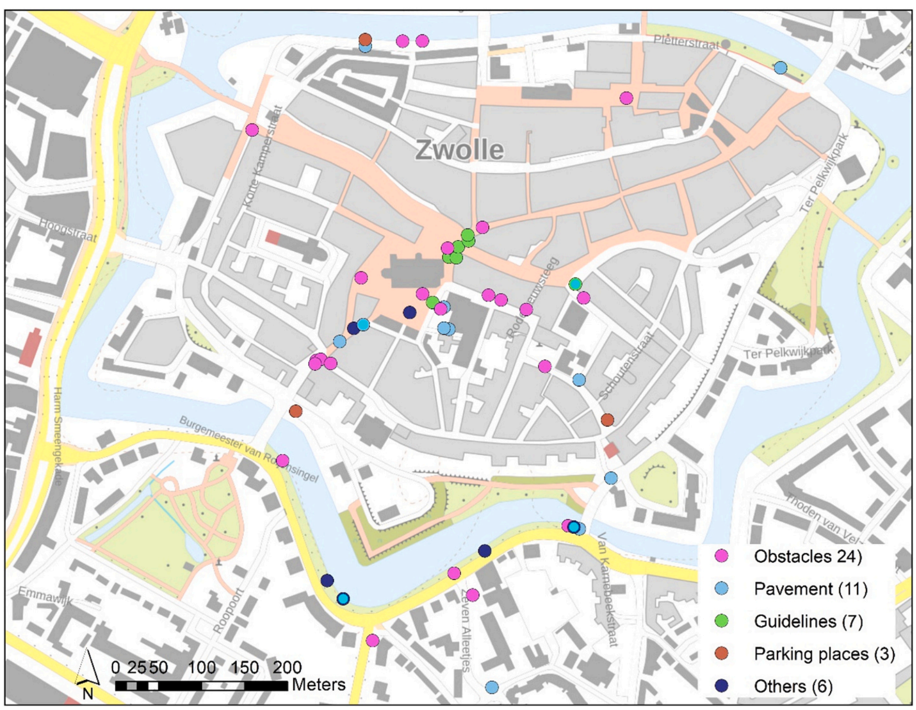

Fig. 6. Accessibility issues mapped by the co-researchers during the tool testing phase (cartography: authors).

future research.

Finally, a comprehensive evaluation of the usability and usefulness of the collaborative mapping tool would be needed. The rather qualitative evaluation conducted together with the municipality of Zwolle (see Section 4.4) indicated a high relevance of the tool prototype for the planning practice of the city. A more detailed quantitative evaluation of the tool, ideally embedded in the application of the tool in an actual planning process, would deepen these insights and result in further points of improvement.

6. Conclusions

The research aimed to gain insights into how collaborative mapping tools must be designed to support inclusive participation in the planning and design of public spaces to make them accessible for all. It revealed several challenges towards making public space in cities fully accessible for all people. The accessibility to urban public spaces – as demonstrated for the city of Zwolle – can be improved in many ways. Such solutions are always context-specific and must be formulated based on comprehensive participatory approaches that include all actors. The research further identified several challenges in making digital planning deliver its promise to be inclusive. Inclusive digital planning demands suitable digital planning tools that fulfil the requirements of the universal design principles of software and hardware and the environment they are used in. Beyond that, key to inclusive digital planning is digital, physical, social and procedural accessibility. All dimensions need to be considered within digital planning processes. While the lessons learnt from the study result from the work with people with disabilities and the found

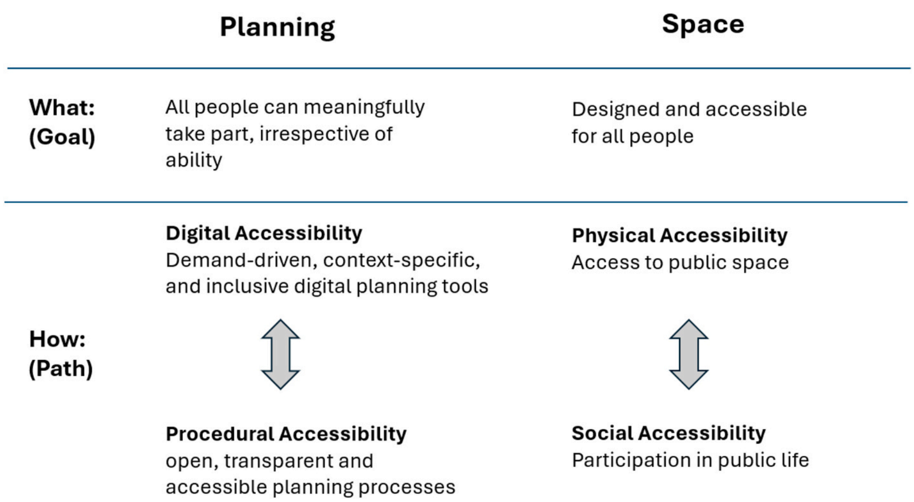

Fig. 7. Framework of inclusive digital planning.

solutions directly address their needs, we argue that the latter, in many cases, may also serve average-abled people. Our contribution advances existing knowledge on the design of inclusive planning tools that are useful, usable and fit for the context, but also provides a methodology on how to work with experts-by-experience in practice.

This study generates various ideas for follow-up research activities. One is to explore the broader applicability of both the co-design process and the framework of inclusive digital planning in different contexts, case studies and locations, ideally applied to real-world planning projects. Such activities would almost naturally involve further user groups with other (dis)-abilities to elicit their user requirements for inclusive mapping tools, for instance, people with cognitive disabilities. Finally, it would be important to explore user requirements and digital planning tools with other groups often marginalised in urban planning processes to broaden the empirical basis for inclusive digital planning.

CRediT authorship contribution statement

Johannes Flacke: Writing – review & editing, Writing – original draft, Visualization, Supervision, Software, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **Fenna Imara Hoefsloot:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Conceptualization. **Karin Pfeffer:** Writing – review & editing, Visualization, Methodology, Investigation, Funding acquisition, Conceptualization.

Ethical approval

The study received ethical approval from the ethics committee of the University of Humanistic Studies on 15 September 2022.

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