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RESEARCH ARTICLE

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Navigating Tensions in Socially Inclusive Design: Design Principles for Assistive Digital Technologies

Katharina Kneissel,[1] Antonie Lockl,[2] Anna Maria Oberländer,[3] Michael Rosemann[4]

[1]FIM Research Center for Information Management / Fraunhofer FIT, Germany, katharina.kneissel@fit.fraunhofer.de
[2]FIM Research Center for Information Management / University of Bayreuth, Germany, antonie.lockl@fim-rc.de
[3]FIM Research Center for Information Management / University of Bayreuth, Germany, anna.oberlaender@fim-rc.de
[4]Centre for Future Enterprise, Queensland University of Technology, Australia, m.rosemann@qut.edu.au

Abstract

Assistive digital technologies (ADTs) hold significant potential to advance the social dimension of digital sustainability by fostering the participation of individuals with accessibility constraints. However, prior research and high abandonment rates indicate that their impact is still limited. To achieve systemic, long-term impact that will sustain social sustainability, socially inclusive design knowledge must address an underlying design tension: While users require constraint-specific individualization, providers aim for impact-oriented generalization. If not addressed, this design tension can lead to ADTs that are either overly individualized, limiting broader applicability, or overly generalized, lacking personal relevance. To address this challenge, we followed a design science research approach, conducting four design cycles informed by 44 interviews with experts, users, and providers, as well as 55 real-world examples. This revealed six competing design requirements, forming three specific design tensions between users and providers. We propose six constraint-agnostic, tension-aware design principles for ADTs that include mechanisms to mitigate design tensions at the artifact level. Our work contributes to socially inclusive design knowledge regarding both design outcomes and the design process and offers important guidance for providers of ADTs.

Keywords: Digital Sustainability, Social Sustainability, Social Inclusion, Socially Inclusive Design, Assistive Digital Technology, Tensions, Design Principles

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1 Introduction

> *We may not be able to cure what cannot be cured, but we can at least use assistive digital technologies to alleviate the negative effects and thus increase liveability.* (CEO and cofounder of a leading MedTech start-up[1])

Digital technologies hold significant potential to foster societal change and a more inclusive society. In this respect, *digital sustainability* emphasizes the use of digital technologies to advance economic, ecological, and social welfare (Kotlarsky et al., 2023). While prior research has focused on the economic and ecological benefits of digital technologies (e.g., Ixmeier et al., 2024; Loock et al., 2013; Melville, 2010), studies exploring their societal potential (e.g., Schoormann & Kutzner, 2020; Tim et al., 2021) are still in their infancy (Kotlarsky et al., 2023).

[1] Referred to below as Expert 24.

As a central impact dimension of social sustainability, social inclusion directly concerns individuals' ability to participate meaningfully and contribute fully to social, cultural, and civic life (Wilson & Secker, 2015). When social inclusion is achieved in a long-term and systemic manner (Brundtland, 1987; Loorbach et al., 2017), it enhances well-being and quality of life at both the individual and collective levels, which are hallmarks of social sustainability (Haugjord & Aanestad, 2024). This interdependence between individual and collective impact is illustrated through the three facets of social inclusion: *Self-determination* means that individuals act autonomously and shape their own lives (Wass et al., 2023); collectively, this reduces reliance on and costs for welfare systems (Chan, 2017). *Belongingness* means that individuals have a sense of acceptance and group membership (Wass et al., 2023); collectively, this strengthens social connectedness and stability (Bardsley et al., 2021). *Social capital* captures the resources an individual contributes to and draws from in exchange within a group (Wass et al., 2023); collectively, this benefits material and immaterial prosperity (Putnam, 1993).

Assistive digital technologies (ADTs) promise to foster social inclusion by increasing the self-determination, belongingness, and social capital (Koddebusch et al., 2024) of individuals with accessibility constraints, such as sensory, motor, or cognitive impairments (Theil et al., 2023). Such constraints affect approximately 1.3 billion people, or around 16% of the global population (World Health Organization, 2025). Examples of ADTs include Microsoft's Seeing AI app, which supports visually impaired users with reading or photo descriptions (Microsoft, 2024) and Apple's LED Flash Alert, which provides visual warnings for hearing-impaired users in potentially dangerous situations (Apple, 2024).

Designing ADTs is challenging because their impact depends not only on access and functionality but especially on the extent to which they address social needs (Faik et al., 2024). *Socially inclusive design* emphasizes the deliberate integration of social inclusion facets into digital technologies (Faik et al., 2024; Tim et al., 2026; Wass et al., 2023). However, given the multifaceted, context-dependent, and often idiosyncratic needs of individuals with accessibility constraints (Kalantari et al., 2025; Oliver, 2013; Theil et al., 2023), such design knowledge tends to be focused on specific constraints (e.g., Jonas et al., 2024), limiting their *systemic* impact. Moreover, reported abandonment rates of up to 80% (Brandt et al., 2020; Howard et al., 2022) indicate insufficient *long-term* impact, attributed to misaligned design choices (e.g., Federici & Borsci, 2016; Pinjatela, 2024).

Therefore, providers require constraint-agnostic design knowledge that guides them towards impactful ADTs for the broadest possible user group while ensuring economic viability. From a user perspective, accessibility constraints need to be met to ensure sustained relevance and use. Consequently, a design tension becomes apparent: Users require *constraint-specific individualization*, whereas providers aim to pursue *impact-oriented generalization*. If left unresolved, this tension can result in ADTs that are either overly individualized or overly generalized, limiting their systemic, long-term impact.

Consider the example of BladderSense,[2] a wearable system that monitors bladder-filling using sensor technology and AI-based data analysis, providing feedback via a companion app and sending timely alerts when critical levels are reached. User requirements for BladderSense vary substantially depending on factors such as age, body stature, and the underlying cause of bladder dysfunction (e.g., postpartum women or men with paraplegia), necessitating individualized technology. Meanwhile, impact and investor objectives urge BladderSense to scale rapidly to address the needs of the approximately 400 million individuals globally who are affected by incontinence (Leslie et al., 2024).

Initial studies have reported on design tensions emerging in the context of ADTs (e.g., Koddebusch et al., 2025). However, the few studies elaborating on how to address them have focused on intervention design rather than on the technologies themselves (e.g., Curto-Millet & Cañibano, 2023). Consequently, there is a need to advance socially inclusive design knowledge at the artifact level, that is, within the design of the ADT itself. Only if providers address these tensions early in the design process can systemic, long-term social inclusion impact be ensured. We therefore ask the following research question: *What are constraint-agnostic and tension-aware design principles for assistive digital technologies that foster social inclusion?*

We took an iterative design science research (DSR) approach consisting of four design cycles (Peffers et al., 2007; Sonnenberg & vom Brocke, 2012): (1) problem awareness and formulation, (2) design requirements, (3) design principles (DPs), and (4) evaluation. We collected primary data through 44 semi-structured interviews with experts, providers, and users of ADTs, complemented by secondary data obtained from analyzing 55 real-world examples. Based on this

[2] One of the three real-world ADTs evaluated in Design Cycle 4.

evidence, we identified the key design challenge, uncovered three design tensions between six design requirements of users and providers, and developed six constraint-agnostic and tension-aware design principles (DPs) that foster social inclusion.

Our study contributes to information systems (IS) research by expanding socially inclusive design knowledge with a constraint-agnostic and tension-aware perspective. To do so, our work focuses on ADTs to foster social inclusion at the individual level, creating enabling conditions for social sustainability at the collective level. Specifically, we advance knowledge of both design outcomes and the design process. Regarding design outcomes, we take a *social by IS* perspective and provide constraint-agnostic DPs applicable across diverse accessibility constraints, enabling transferable capacities for systemic impact. In addition, we target long-term impact by accounting for paradoxical tensions between providers and users of ADTs and embedding their mitigation directly into the DPs rather than treating them as an afterthought. Regarding the design process, our work implies new impetus for evaluating socially inclusive design through a user-centered approach. Together, these contributions also offer practical guidance for providers designing ADTs, supporting them in anticipating and navigating competing demands early in the design process.

2 Research Contextualization

2.1 Social Inclusion as an Impact Dimension of (Digital) Social Sustainability

Digital sustainability is an emerging concept in IS research and is defined as "the development and deployment of digital resources and artifacts toward improving the environment, society, and economic welfare" (Kotlarsky et al., 2023, p. 938). It highlights the potential of digital technologies to contribute to economic, ecological, and social well-being.

Social sustainability is often regarded as ambiguous, and there is no universally accepted definition in the literature (e.g., Isgren & Longo, 2024). Broadly, it can be understood as improvement to the well-being and quality of life of individuals and communities (Haugjord & Aanestad, 2024). In light of this conceptual ambiguity, scholars and practitioners agree on two core aspects of social sustainability: first, its *systemic orientation,* reflected in its focus on both the individual and communities as interdependent entities within social systems (Ebrahim & Rangan, 2014); and second, its inherent *long-term orientation*, underlining how present decisions shape future conditions (Brundtland, 1987).

On closer examination, social sustainability may be described through five interrelated yet distinct impact dimensions (Schoormann & Kutzner, 2020), whereby we understand impact as "lasting changes in the lives of individuals and their societies" (Ebrahim & Rangan, 2014, p.1). The five impact dimensions are social equity, social cohesion, social justice, social diversity, and social inclusion (Schoormann & Kutzner, 2020). In this work, we focus on social inclusion, which refers to enabling all members of a community to fully participate and engage in economic, social, and cultural life (Schoormann & Kutzner, 2020; Wilson & Secker, 2015), thus enhancing both individual and collective well-being (AbuJarour et al., 2018).

Figure 1 depicts the impact relationship between social inclusion and social sustainability across the individual and collective levels (Ebrahim & Rangan, 2014). At the individual level, the facets of social inclusion—that is, self-determination, belongingness, and social capital (Wass et al., 2023)—shape the capacity of an individual to participate meaningfully in society. Notably, impact at the individual level aggregates at the collective level, where it contributes to social sustainability through decreased welfare costs, increased social connectedness, and increased social prosperity.

Social inclusion is increasingly shaped by digital technologies. They can enhance self-determination by enabling access to information and increasing choice but may also restrict it when access and digital skills are unevenly distributed (Dietrich et al., 2026). Similarly, digital technologies can foster belongingness through community-building while also amplifying exclusion or marginalization (Oksanen et al., 2024). Likewise, digital technologies can enhance social capital by facilitating networks and exchange yet also erode it by altering interactions, for example, through increased anonymity or the spread of misinformation (Sabatini & Sarracino, 2014).

Thus, the impact of digital technologies on social sustainability is ambivalent and contingent on their capacity to foster social inclusion. Individual-level social inclusion only aggregates into collective-level social sustainability if it transfers across contexts and persists over time, i.e., if social inclusion is achieved in a systemic and long-term manner. For instance, an individual who experiences inclusion in one situation and at one point in time may still face exclusion in other situations, as diverse contextual demands complicate sustained impact. This creates a fundamental design challenge: Digital technologies must not only enable social inclusion in isolated interactions but, more importantly, they must support it in a systemic and long-term manner.

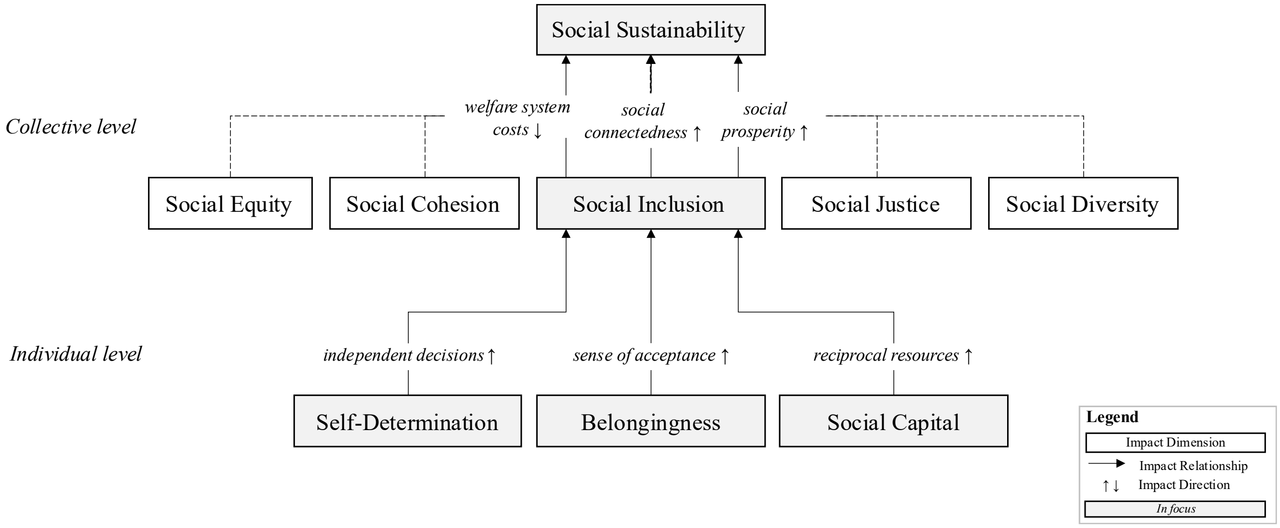

Figure 1. Impact Relationship Between Social Inclusion and Social Sustainability

2.2 Socially Inclusive Design

Addressing this design challenge requires deliberate design choices that account for the specific needs and contexts of individuals with constraints. Yet digital technologies are not commonly designed with these considerations in mind. However, as the design of ADTs directly shapes both adoption and impact (Faik et al., 2024), design decisions play a decisive role in enabling meaningful social inclusion (e.g., Faik et al., 2024; Tim et al., 2026). IS research has therefore focused on design-oriented approaches to fostering social inclusion (e.g., Dilger et al., 2025a; Faik et al., 2024; Wass et al., 2023), which are referred to as *socially inclusive design* and understood as the "intentional design of digital artifacts that prioritize socially relevant needs" (Tim et al., 2026, p.2).

The literature on socially inclusive design comprises knowledge informing the *design process* and knowledge guiding the *design outcome*. The former focuses on how the research process itself can be designed to be socially inclusive, that is, how researchers can meaningfully engage with marginalized groups. For example, Wass et al. (2023) proposed principles for facilitating a socially inclusive design-oriented research process, while Dilger et al. (2025b) provided interview guidelines for engagement with individuals with intellectual and developmental disabilities.

In contrast, the literature informing design outcomes can be divided into *social in IS* and *social by IS* contributions. First, *social in IS* (Schoormann & Kutzner, 2020) refers to social inclusion in the digital world, focusing on bridging the digital divide (e.g., Riggins & Dewan, 2005; Vassilakopoulou & Hustad, 2023). It emphasizes the accessibility and usability of digital technology by all users, regardless of their abilities (Pandey & Zheng, 2023), for example, by providing audio descriptions or high-contrast user interfaces. In this regard, Dilger et al. (2025a) explored the design of inclusive GenAI-based conversational agents for individuals with intellectual and developmental disabilities, while Tim et al. (2026) provided design knowledge for socially inclusive IS artifacts targeting senior citizens.

Second, *social by IS* refers to digitally enabled social inclusion in the physical world, emphasizing enhanced accessibility and social inclusion through digital technologies (Schoormann & Kutzner, 2020), for example, by offering sensory music experiences for the hearing-impaired (Not Impossible LLC, 2024). Research by Díaz Andrade and Doolin (2016) described capabilities enabled by digital technologies for the social inclusion of refugees, while work by Gonzalez and Deng (2023) as well as Petter and Giddens (2023) analyzed social media's impact on social inclusion and exclusion.

2.3 Assistive Digital Technology Design

Social by IS can be enabled through ADTs, defined as software solutions with or without hardware components that support users (i.e., individuals with constraints) in their everyday lives (Koddebusch et al., 2024; Li et al., 2021). Importantly, ADTs differ fundamentally from mass-market technologies. While the latter are designed for nonconstrained users, ADTs aim to address accessibility constraints, which may or may not align with the heterogeneous realities of users' lived experience (Foley & Ferri, 2012).

Accessibility constraints refer to conditions that limit or prevent individuals from accessing services or spaces, thereby reducing their quality of life. Without access to public life, social inclusion is not possible (Farrington & Farrington, 2005). We focus on individual accessibility constraints that arise from physical (e.g., mobility impairment) and psychological factors (e.g., limited cognitive resources), as these directly shape an individual's ability to perceive, reach, and use services and spaces in everyday life (Becker et al., 2023).

Accessibility constraints are multifaceted, context-dependent, and idiosyncratic. Multifaceted constraints are unique and heterogeneous, for example, varying combinations of sensory, cognitive, or psychological limitations (Theil et al., 2023). Context-dependent constraints emerge from the interaction between the individual and their environment, such as a wheelchair user navigating freely until encountering stairs (Oliver, 2013). Idiosyncratic constraints deviate from assumptions about average users. Such deviations, particularly invisible constraints (e.g., autism), are often difficult to recognize, highlighting the mismatch between individual requirements and standard design assumptions (Kalantari et al., 2025).

So far, design-oriented research targeting ADTs has been concerned with addressing specific constraints, offering design knowledge for specific ADTs (e.g., Jonas et al., 2024; Kalantari et al., 2025). Moreover, ADTs are associated with paradoxical tensions that influence the design process and outcomes (Foley & Ferri, 2012). Paradoxes are "contradictory yet interrelated elements that exist simultaneously and persist over time" (Smith & Lewis, 2011, p. 382). In our context, ADTs may, for instance, paradoxically enhance social connectedness while increasing users' exposure to stigma or prejudice (Gao et al., 2024). If paradoxical design tensions are not addressed properly, ADTs may underperform (Wessel et al., 2025).

Existing studies point toward possible ways of managing such design tensions. For instance, Wessel et al. (2025) identified competing demands as design trade-offs within their proposed DPs yet largely left their management to providers. By contrast, Breiter et al. (2025) conceptualized competing demands as dialectical tensions framed in terms of thesis and antithesis and proposed DPs as a form of synthesis. Curto-Millet and Cañibano (2023) introduced a framework comprising four strategic approaches to manage paradoxical tensions in social inclusion interventions: positive discrimination, integrative oscillation, equitability, and iterative inclusivity. While these studies offer valuable insights, they either do not explicitly recognize the paradoxical nature of design tensions or resolve them at the artifact level.

2.4 Challenges of Designing Assistive Digital Technologies for Social Inclusion

Looking at the design of ADTs through a social sustainability lens reveals interrelated challenges that limit their long-term, systemic impact. Providers primarily rely on constraint-specific design knowledge. While such knowledge provides valuable insights into the multifaceted, context-dependent, and often idiosyncratic needs of individuals with accessibility constraints, it offers limited potential for broader applicability. Hence, constraint-agnostic design knowledge is required that enables providers to design ADTs for the broadest possible user group while ensuring economic viability. Yet this gives rise to a design tension: Users with accessibility constraints require *constraint-specific individualization* that addresses their unique needs, which stands in tension with the *impact-oriented generalization* that providers pursue.

Currently, this tension is not addressed systematically in the design process. Instead, it is resolved by users in everyday practice or handled by providers in ad hoc fashion without structured guidance (Steen, 2011; Wessel et al., 2025). The result is a prevalence of short-term, localized interventions that may alleviate immediate accessibility constraints but fail to create long-term or systemic impact, which is reflected in high abandonment rates (Brandt et al., 2020; Howard et al., 2022). Consequently, sustained social inclusion is often not achieved.

3 Research Approach

To develop constraint-agnostic, tension-aware DPs, we employed a DSR approach (Peffers et al., 2007; Sonnenberg & vom Brocke, 2012). Formulated as prescriptive statements (Gregor et al., 2020), DPs are meta-artifacts (Iivari, 2003) that provide ex ante knowledge for the design of IS artifacts (Iivari, 2003; Möller et al., 2020). Our DSR process comprised four distinct, iterative design cycles (Figure 2). In Design Cycle 1, we developed an understanding of the social sustainability problem and identified the design tension between providers and users as the key design challenge. Design Cycle 2 focused on identifying specific design tensions between the requirements of providers and users. Design Cycle 3 centered on developing six empirically grounded constraint-agnostic, tension-aware DPs. Design Cycle 4 evaluated the real-world impact of the DPs.

We drew on empirical data from 24 expert interviews. The interviews were semi-structured and included users with accessibility constraints, professionals working closely with users, and providers of ADTs. Some experts were selected from our professional networks, with others identified through snowball sampling (Bhattacherjee, 2012). The expert interviews were exploratory, serving two main purposes: (1) to deepen our understanding of the problem space, including the design tensions, by discussing the lived experience of dealing with accessibility constraints, the potential and limits of ADTs, and their impact on social inclusion, and (2) to examine current and potential solutions and related design aspects of ADTs that could mitigate tensions and foster social inclusion. With the experts' consent, all interviews were recorded, transcribed, and then analyzed. The interviewees' varied perspectives enabled a rich triangulation of insights. We concluded data collection after 24 interviews because the themes, requirements, and design aspects became increasingly repetitive, indicating theoretical saturation. An overview of the interview participants is provided in Table A1 in Appendix A.

3.1 Design Cycle 1: Problem Awareness and Formulation

In Design Cycle 1, we aimed to develop an in-depth understanding of the key design challenge of the social sustainability problem. To systematically uncover the problem space, we analyzed the first part of the 24 expert interviews, using the qualitative coding methodology proposed by Gioia et al. (2013). Through iterative coding, discussions, and workshops within the author team that were informed by further relevant literature (see Section 2), the key design challenge in the development of ADTs emerged—that is, the design tension between providers and users. The final data structure of Design Cycle 1 is presented in Appendix Table D1.

3.2 Design Cycle 2: Design Tensions Between Competing Design Requirements

Design Cycle 2 explored the design challenge in greater depth, leading to identification of the competing design requirements of providers and users and the emergence of the three specific design tensions. In this Design Cycle, we reanalyzed the first part of the 24 expert interviews with a focus on the design requirements of providers and users. We systematically examined all interview passages that articulated met and unmet expectations of users, priorities of providers, problematic features, and potential negative impacts of ADTs. We used an open coding procedure, identifying 36 first-order concepts, which we iteratively synthesized into nine second-order themes (Gioia et al., 2013). The identified design tensions formed three aggregate dimensions that encapsulate the competing design requirements of providers and users of ADTs. The final data structure of our design requirements and design tensions is presented in Appendix Table E1.

3.3 Design Cycle 3: Constraint-Agnostic and Tension-Aware Design Principles

Design Cycle 3 focused on developing and iteratively refining constraint-agnostic, tension-aware DPs that address the identified design tensions. Here, we drew on the second part of the 24 expert interviews, with a focus on the solution space, as well as on 55 real-world examples of ADTs that served as illustrative cases. The development of the DPs involved iterations between empirical insights and conceptual abstraction, ensuring that the resulting DPs remained empirically grounded and practically relevant.

We systematically examined all interview passages that articulated functionalities, features, or mechanisms addressing the identified design tensions. Through open coding, we extracted 162 first-order concepts, which we subsequently synthesized into 18 second-order themes (Gioia et al., 2013). In a final step, these themes were consolidated into six constraint-agnostic, tension-aware DPs following the template proposed by Gregor et al. (2020).

	Design Cycle 1 Problem Awareness and Formulation	**Design Cycle 2** Competing Design Requirements	**Design Cycle 3** Design Principles	**Design Cycle 4** Evaluation
Goal	Understand the social sustainability problem and the related design challenge	Identify design requirements and design tensions between providers and users	Develop constraint-agnostic, tension-aware design principles that mitigate identified design tensions	Evaluate (in terms of social inclusion impact) and refine design principles
Data Collection	24 expert interviews (1st part with a focus on the overarching problem)	24 expert interviews (1st part with a focus on the specific problems)	24 expert interviews (2nd part with a focus on the solution) 55 real-world examples	17 user interviews and 3 provider interviews (across three real-world cases)
Outcome	Overarching design tension between providers and users	Six competing design requirements forming three specific design tensions	Six empirically grounded, constraint-agnostic, tension-aware design principles	Empirically validated and refined design principles

Figure 2. Iterative Research Approach

To refine our DPs across ADTs, we analyzed 55 real-world examples identified using Crunchbase, a platform for company insights (Crunchbase Inc., 2026). We systematically reviewed and analyzed publicly available information. Subsequently, we compared our DPs with the functionalities of the real-world examples to examine where certain DPs appeared, how exactly these DPs were instantiated (e.g., in terms of technology features), and which relevant functionalities were not yet captured by our DPs, thereby informing their further development. This process allowed us to refine our DPs and to ensure their constraint-agnostic nature. A detailed description of the selection process is provided in Appendix B, along with an overview of all real-world examples and their corresponding contributions to the DPs in Appendix Table B1. The final data structure for the tension-aware DPs is presented in Appendix Table F1.

3.4 Design Cycle 4: Evaluation Across Three Real-World Cases

In Design Cycle 4, we evaluated and refined our DPs. To do so, we investigated the instantiation of the DPs, the mitigation of design tensions, and the resulting social inclusion impact through three established real-world ADTs in 17 user interviews and three provider interviews.

However, the impact of ADTs is not immediately measurable because it emerges over time through sustained use, hindering the evaluation of the DPs through newly created artifacts. Therefore, we decided to select established real-world ADTs for user-centered evaluation. This emphasis on end users was deliberate, as users are best positioned to judge whether DPs address their constraints and have an impact on social inclusion. We selected three real-world ADT examples from an initial pool of 14 cases, which were filtered on three criteria: feasible user access, relevance for access and participation in public life, and providers' willingness to collaborate and facilitate user contact.

The user evaluation had three phases. First, providers served as intermediaries for gaining access to users. Initial conversations with the providers focused on explaining the purpose, structure, and relevance of the evaluation, presenting the design tensions and DPs, and outlining the evaluation process.

Second, we conducted semi-structured interviews with 17 users of the three ADTs. The sample included users with paraplegia, multiple sclerosis, ulcerative colitis, and bladder weakness, reflecting a broad spectrum of accessibility constraints (see Appendix Table C1). The interviews explored how users integrated the ADTs into their daily routines, how their specific accessibility needs were met, and how their use of ADTs affected their perceptions of social inclusion. As users cannot be expected to explicitly recognize or articulate abstract DPs, they were not asked to identify or directly reflect on them. Instead, data collection focused on how users interacted with features embodying the DPs, such as the role of information, which types of information they found valuable, how they used information, and which aspects of it they perceived to be missing or disturbing. This allowed us to infer which DPs were instantiated and experienced in real-world use. From this, we examined the relevance and impact of the DPs in relation to users' experiences of self-determination, belongingness, and social capital.

As many conversations touched on highly personal and emotionally sensitive topics, a respectful and empathetic interview atmosphere was essential. Some interviews required adaptive communication strategies and flexible pacing due to fatigue or communication barriers resulting from medical interventions. With the users' consent, all interviews were recorded, transcribed, and then analyzed using selective coding focused on the perceived social inclusion impact of the DPs, while the tensions were kept in mind as a continuous analytical point of reference. The empirical findings from this phase were central to revising and finalizing the constraint-agnostic, tension-aware DPs, leading to the consolidation, removal, and addition of DPs.

Third, we engaged in further discussions with each of the technology providers (see Appendix Table C2) to share the findings from the second phase. This enabled the providers to gain deeper insight into users' lived experience, as well as opportunities for improvement in line with the DPs. We also included an in-depth discussion of each DP's understandability, relevance, and applicability from the provider perspective (Iivari et al., 2021). This dialogue ensured that our research would be not only conceptual but also translatable in practice. The final data structure for the evaluation is presented in Appendix Table G1.

4 Results

4.1 Problem Awareness and Formulation

Our research on the socially inclusive design of ADTs was sparked by early conversations about the 2032 Olympic and Paralympic Games in Brisbane, Australia. We engaged in discussions, for instance with a board member of the Games, on inclusive games—a topic of great public interest. Participating in events like the Olympics fosters social inclusion at the individual level (AbuJarour et al., 2018), paving the way for social sustainability at the collective level. These discussions consistently highlighted the potential of digital technologies to foster social inclusion and the importance of their design in fully realizing this potential.

Inspired by these early conversations, we explored this design challenge in greater depth. Our empirical insights revealed conflicting objectives of providers and users of ADTs, even though they share the purpose of fostering social inclusion. The analysis highlighted a pattern according to which users demand *constraint-specific individualization* while providers are guided by *impact-oriented generalization*.

From a user perspective, the experts highlighted the necessity of addressing accessibility requirements shaped by users' individual needs and contextual dependencies. While all digital technologies must account for individual user differences, these requirements become far more multifaceted, context-dependent, and idiosyncratic in the context of accessibility constraints. As Expert 3 noted, "What people with a mobility impairment require versus what people with a vision impairment require is different. That probably won't be the same digital solution." By contrast, from a provider perspective, Expert 3 stressed that ADTs "should be universally designed, so it doesn't matter who you are and what constraints you have." The resulting design tension between these two objectives becomes explicit in Expert 5's question, "How do we universally design ... so that people's [individual] needs are met?" Expert 7 further articulated this design tension:

> *The challenge is ... having a universal solution which fits a lot of different people. Like, we have agreed to speak English, which is a common and universal language to connect, but, at the same time, we know that there are people [who] don't speak English.*

While individualization is critical for delivering meaningful, context-sensitive assistance for users, generalization is essential for economic viability and systemic impact—yet it risks reinforcing exclusionary norms (Fogli et al., 2020). This challenge is complicated by ethical considerations, as design choices can subtly undermine users' autonomy, shaping whether technological support is experienced as empowering or intrusive (Álvarez-Aguado et al., 2026).

Previous work has emphasized the paradoxical nature of these tensions (e.g., Fogli et al., 2020; Gao et al., 2024), which are characterized by interrelatedness, complementarity, and simultaneity (Gaim et al., 2018). The *interrelatedness* of providers' and users' objectives becomes evident as they shape each other (e.g., Leonardi, 2011; Orlikowski, 2007). For instance, providers need to adapt their designs in response to how users engage with ADT. Conversely, users may adapt their behaviors or expectations in response to the affordances and constraints introduced by the technology. *Complementarity* emerges from the distinct yet mutually reinforcing contributions offered by each objective (Gaim & Wåhlin, 2016) toward the shared purpose of social inclusion: Providers aim for broad accessibility and scalability, fostering inclusivity at the collective level, while users prioritize personal relevance, ensuring social inclusion at the individual level. *Simultaneity* is reflected in both objectives operating in parallel and being navigated concurrently (Smith & Lewis, 2011). Therefore, one objective cannot be prioritized over the other; rather, their coexistence requires ongoing negotiation and mutual adjustment (Gaim et al., 2018).

To situate this design tension within its context, we drew on prior work (e.g., Becker et al., 2023; Farrington & Farrington, 2005; Koddebusch et al., 2024) and integrated our empirical insights to visualize the relationships between the core constructs of our research (see Figure 3). Rather than depicting a process or variance model, Figure 3 shows the interplay between the *design space* and the *use space*, with ADTs at their intersection.

Each space represents particular viewpoints and priorities (Steen, 2011). The providers' *design space* reflects the creation of ADTs, including their features and intended use scenarios (Botero et al., 2010; Steen, 2011). By contrast, the *use space* captures interactions with ADTs, influenced by users' needs, constraints, and practices (Botero et al., 2010). When users experience accessibility constraints, they are prompted to adopt ADTs, aiming to reduce the hindering effects of constraints on access, a crucial prerequisite for social inclusion (Farrington & Farrington, 2005). In turn, social inclusion sustains social sustainability when achieved in a systemic and long-term manner (see Section 2.1). Within the *design space* lies the design tension to be addressed: *constraint-specific individualization* (i.e., relevance for accessibility constraints and long-term impact) versus *impact-oriented generalization* (i.e., broad applicability and systemic impact).

4.2 Design Tensions Between Competing Design Requirements

Building on the overarching design tension, we surface the underlying design requirements that shape the specific design tensions between providers and users. Table 1 presents and contrasts the design tensions (DTs).

Digitization vs. dignity: When designing ADTs, providers leverage digitization to respond to human needs. As Expert 11 noted, "Digital is making big strides for both the vision-impaired and the hearing-impaired. And digital will make huge impacts for people with cognitive disabilities." At the same time, maintaining meaningful and dignified human interaction is crucial for social inclusion, particularly for individuals with accessibility constraints. Expert 3 stated, "It [the ADT] wasn't dignifying at all. It was embarrassing to have a loudspeaker blaring while you're just trying to figure out where you are."

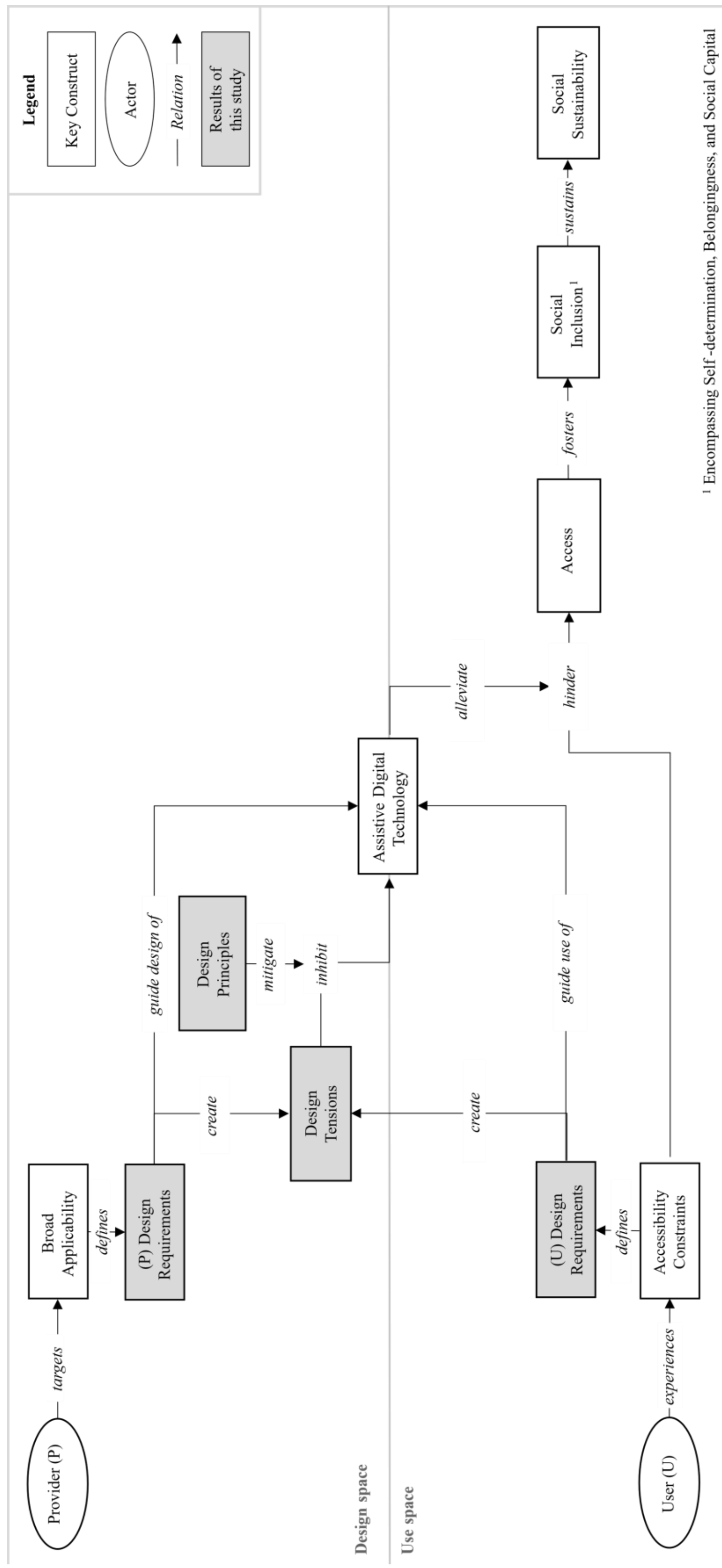

Figure 3. Key Constructs and Relationships

Table 1. Overview of Design Requirements Forming Design Tensions

	Design requirements	
	Providers	**Users**
DT1	**Digitization:** Providers must offer technologies that convert analog information into accessible digital formats, for efficiency, scalability, and convenience.	**Dignity:** Users require interactions that affirm their worth and recognize them as respected individuals, emphasizing empathy, understanding, and meaningful social connection.
DT2	**Assistance:** Providers must offer technologies that ensure guidance and resources that efficiently and effectively help users navigate tasks and situations.	**Autonomy**: Users require the possibility of making self-determined decisions and completing tasks independently, without being restricted or bypassed.
DT3	**Flexibility:** Providers must offer technologies that are adaptable to environmental changes and disruptions and responsive to evolving technological conditions.	**Reliability**: Users require technology that works consistently and without failure across changing contexts, as their independence and well-being depend on it.

This gives rise to a design tension: The more that human experiences are digitized for efficiency, scalability, and convenience, the greater the risk of undermining the very dignity that ADT seeks to support. Expert 8 highlighted this tension:

> *A lot of people still value talking to someone instead of just going online. That's a really big thing for them; it makes them feel valued and seen. That personal connection really helps to ease their mind about their concerns. But, for us, of course, that's more effort.*

As social inclusion depends on individuals feeling recognized, respected, and valued (Wass et al., 2023), ADTs that inadvertently produce interactions that feel undignified risk undermining, rather than fostering, social inclusion.

Assistance vs. autonomy: When designing ADTs, providers aim to empower users. Expert 9 explained that "with our online services, we want to help educate individuals prior to arriving at the venue around what the venue offers regarding accessibility." At the same time, users need ADTs that allow them to make decisions and perform tasks independently without becoming dependent on continuous guidance or intervention. As noted by Expert 24: "An individual should ... be able to put the device on themselves, be able to use the app themselves, without having to rely on anyone else so that personal freedom and self-determination are maximally increased."

Another design tension emerged: ADTs designed to assist users might unintentionally undermine their autonomy. Expert 21 elaborated: "At the airport, when there comes a ramp, the guides try to push the girls [in wheelchairs] up. But the girls don't need that, and they don't want that. It's a question of value." As social inclusion is not only about access but also about participation, ADTs that foster dependency or diminish users' sense of control impede rather than enhance social inclusion.

Flexibility vs. reliability: Providers of assistive technologies must accommodate users by offering technologies that are adaptable to environmental changes and disruptions and responsive to evolving technological conditions. As Expert 3 explained: "We need to be able to update information remotely. Because it is constantly changing." At the same time, for users, reliability is essential: failures or unpredictable behavior can directly compromise safety, independence, and participation. Consequently, users often hold higher expectations for reliability than providers. Expert 23 illustrated this vividly: "Imagine you're sitting in the cinema and the translation program doesn't work. Then you just get really annoyed ... and you can't really understand anything and feel excluded."

This establishes another design tension: ADTs must be reliable while remaining flexible to respond to environmental variability. Expert 5 emphasized this tension: "[Information has] to be accurate and reliable and that can be one of the most difficult things when things are changing quickly." As the social inclusion impact of ADTs depends on reliable functionality, failures or unpredictable behavior may lead to users becoming isolated, frustrated, or excluded from everyday activities.

4.3 Constraint-Agnostic and Tension-Aware Design Principles

For ADTs to achieve an equilibrium between competing design requirements that fosters social inclusion (Smith & Lewis, 2011), the underlying design tensions must be mitigated. Therefore, we propose six constraint-agnostic, tension-aware DPs. Figure 4 shows the DPs and their relation to the competing design requirements.

We present each DP, structured according to the three design tensions, following the guidance by Gregor et al. (2020). The DPs are applied by providers (i.e., *implementers*) in the design space, resulting in ADTs that are used by individuals with accessibility constraints (i.e., *users*) in the use space. We summarize each DP by addressing the dimensions of *aim* (to be achieved for the user), *context* (conditions that shape the aim), *enactor* (subsidiary artifact that enables the mechanism), *mechanism* (how the aim can be achieved), *boundary conditions* (limitations) and *rationale* (justification for how the mechanism achieves the aim) (Gregor et al., 2020). We then provide more detailed explanations and examples of the mechanisms, illustrating how the DPs contribute to mitigating the respective design tensions.

The tension between digitization and dignity is mitigated through DP1 (*seamless integration*) and DP2 (*bilateral interaction*). See Table 2 and Figure 5.

Seamless integration: DP1 ensures that ADTs expand users' capabilities while minimizing additional physical or cognitive effort or inconvenience so that users are empowered to manage constraints in a self-determined way and to develop a sense of belonging. Seamless integration mitigates the tension between *digitization* and *dignity* by ensuring that ADTs enhance rather than disrupt human experiences.

This can be achieved in two ways: (1) by providing easy interoperability with existing digital infrastructure, which enables the ADT to interact with the users' other devices and services fluidly, reducing friction, minimizing user effort, and preventing overwhelming or redundant digital experiences, and (2) by ensuring that natural embedding of hardware in and around the body and/or the physical environment allows technology to subtly extend users' routines and spaces rather than being intrusive. These two mechanisms create an unobtrusive permeation between the ADT and users' physical and digital boundaries that meets requirements for *dignity* while leveraging the possibilities of *digitization*, as illustrated in Figure 5 by the single-headed arrows.

For example, Beltmap is an orientation aid that combines a mobile app with a wearable device that provides navigational guidance through vibration for visually impaired users. The belt can be worn discreetly under a jacket, with users perceiving it to be nonintrusive. Through discreet wearability and subtle haptic cues, Beltmap achieves seamless integration into users' daily lives (Beltmap, 2020).

Bilateral interaction: DP2 ensures that ADTs foster meaningful and dignified communication and collaboration, shared learning, and knowledge cocreation, empowering users to cultivate a sense of belonging and access social capital. Bilateral interaction mitigates the tension between *digitization* and *dignity* by ensuring that technology supports authentic, reciprocal engagement rather than replacing human connection.

This can be achieved in two ways: (1) by enabling proactive and reactive communication, allowing users to seek guidance, clarify information, and receive feedback, and (2) by enabling community-driven exchange with peers for shared experiences and collaborative problem-solving. The double-headed arrows in Figure 5 demonstrate how the requirements for dignity and the possibilities of digitization interact, enabling support that is effective, convenient, and scalable, as well as dignified.

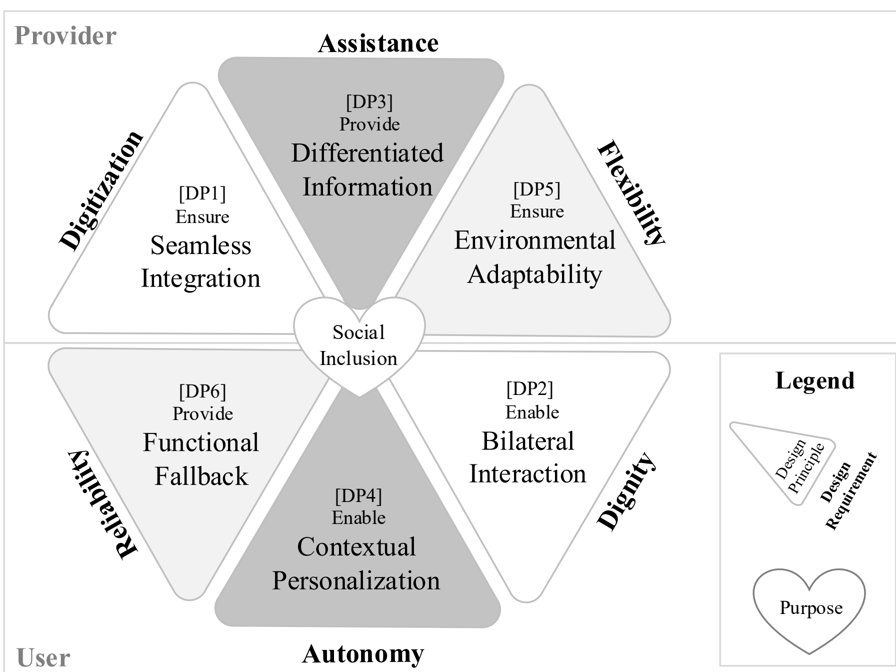

Figure 4. Six Tension-Aware DPs for ADTs

Table 2. DPs for Mitigating the Tension Between Digitization and Dignity

	Ensuring seamless integration (DP1)	Enabling bilateral interaction (DP2)
Aim	ADTs should expand the users' capabilities while minimizing additional physical or cognitive effort or inconvenience so that users are empowered to manage their constraints in a dignified, self-determined way and can develop a sense of belonging.	ADTs should foster meaningful and dignified communication, shared learning, and knowledge cocreation so that users are empowered to build social capital and develop a sense of belonging.
Context	Given that technologies that are intrusive, stigmatizing, or difficult to integrate into everyday routines can create additional barriers for individuals with accessibility constraints, undermining adoption and long-term use, …	Given that for individuals with accessibility constraints, limited opportunities for interaction, feedback, and mutual support can lead to social isolation and information asymmetries, …
Enactor	… employ connectivity, sensing and sensemaking technologies, and standardized interfaces …	… employ communication interfaces, community platforms, collaborative tools and interaction design …
Mechanism	… to ensure that the ADT integrates seamlessly, i.e., unobtrusively and conveniently, with users with accessibility constraints and their environment. This can be achieved by: • providing easy interoperability with existing digital infrastructure. • providing natural embedding in and around the body and/or the physical environment.	… to enable bilateral interaction and knowledge exchange with humans through the ADT. This can be achieved by: • enabling proactive and reactive communication with professionals and nonprofessionals. • enabling community-driven exchange with peers affected by similar constraints.
Boundary condition	Efforts to achieve seamless integration must not impair or restrict core functions to ensure their reliability and uninterrupted operation.	Professionals must be appropriately educated and, as well as peers, be empathetic to provide informed, compassionate, and respectful assistance.
Rationale	The seamless, i.e., unobtrusive and convenient, integration of ADT and users with constraints allows the technology to expand the users' capabilities, without requiring additional physical or cognitive effort or inconvenience, where the technology adapts to the user rather than the reverse. This seamless integration fosters: • *self-determination* because the technology is hardly perceptible to the user but expands the user's abilities. • *a sense of belonging* because the technology cannot be easily perceived by others, thus preventing stigmatization and facilitating participation in public life.	Bilateral interactions and knowledge exchanges foster meaningful collaboration, shared learning, and knowledge cocreation by allowing users to correct misinterpretations in real time, reducing frustration and safety risks. By integrating professional and peer knowledge on constraint-relevant information through community exchange, users share experiences, insights, and individual solutions. This bilateral interaction fosters: • *social capital* because reactive communication allows users to access human resources, builds trust and motivation, and empowers users to engage more confidently and authentically in social settings. • *a sense of belonging* because users gain mutual understanding through technology, reinforcing a sense of being genuinely "heard."
Illustrative quotations	"It would be great to have a location-based service that you could activate. When you enter a venue hosting an event, the available accessibility features would automatically switch on. You wouldn't need to book an audio description separately ... , it would just work. That would be a real improvement." (Expert 2) "For people with disabilities or older people, or people who have low literacy or cognitive impairments, if that technology is not intuitive and easy, then they're going to be marginalized and excluded." (Expert 13)	"The idea of having a two-way communication with someone inside the petrol station is priceless. Because otherwise the only way for you to communicate is by horns beeping and shouting out of the window, which is just embarrassing." (User 8)* "If I have any new findings, why shouldn't I be able to share them with others so that they can profit from that as well?" (User 15)*
Note: * This DP was incorporated during the evaluation phase. User quotations are presented here to reflect insights gathered during Design Cycle 4.		

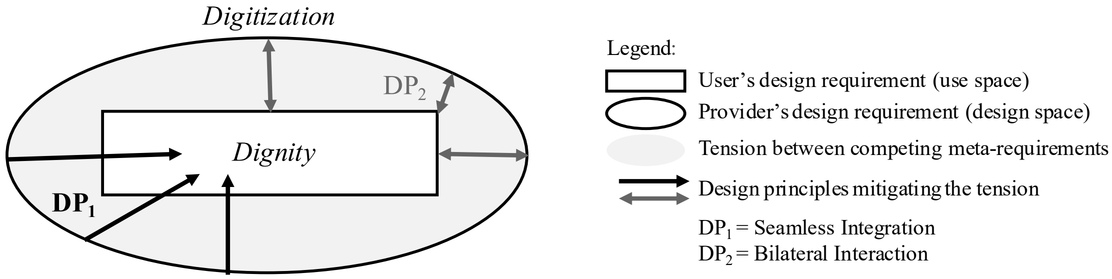

Figure 5. Visualization of the Mechanisms for DP1 and DP2

For example, SmartSteps is a mobile app for users with intellectual disabilities offering decision support through step-by-step flowcharts and decision trees. SmartSteps embeds multiple communication pathways that enable both professional guidance and peer support. Features such as speak-aloud buttons empower users to actively articulate their needs and intentions, while integrated options to contact emergency services, caregivers, or trusted peers enable timely and responsive human intervention. By enabling users to receive assistance and initiate communication, the app fosters shared understanding, trust, and a sense of belonging (SmartSteps LLC, 2024).

The tension between assistance and autonomy is mitigated through DP3 (*differentiated information*) and DP4 (*contextual personalization*). See Table 3 and Figure 6.

Differentiated information: DP3 ensures that ADTs enable users to make informed and independent decisions, empowering them to act in a self-determined way, enhance their sense of belonging, and build social capital. Differentiated information mitigates the tension between assistance and autonomy by supporting users to understand their surroundings and options, evaluate accessibility and contextual factors, and choose actions that best align with their intentions and needs.

This can be achieved in two ways: (1) by providing access to all available, context-specific information (e.g., environmental, spatial) in a structured, neutral form, allowing users to understand and evaluate their surroundings and options, and (2) by delivering information in multisensory formats (e.g., visual, auditory, tactile), supporting easy interpretation and accessibility for users with diverse sensory and cognitive needs. Together, these mechanisms, illustrated by the single-headed arrows in Figure 6, create a transparent knowledge base for making confident, informed decisions. Users are empowered to explore their surroundings and uncover available assistance while retaining autonomy over their choice of options.

For example, Cérge is an accessibility app that offers visual stories, virtual tours, and sensory and audio guides for venues, helping users prepare thoroughly before their visit. By providing detailed information, the app allows users to make self-determined decisions about a venue's accessibility (Cérge, 2026).

Contextual personalization: DP4 ensures that ADTs adapt to each user's individual context, enabling greater self-determination. Contextual personalization mitigates the tension between assistance and autonomy by enabling the technology to continuously adapt to each user's preferences and needs, aligning with user intentions without compromising autonomy.

This can be achieved in two ways: (1) by allowing manual adjustments, giving users the ability to make decisions about functionality, preferences, and system settings, and (2) by enabling automatic adjustments, where data-driven insights are translated into adaptive improvements in system performance (e.g., context-aware recommendations) while preserving user oversight and control. Together, these mechanisms ensure that the technology responds to individual and context-dependent user needs. As a result, the requirements for assistance and autonomy are integrated. Figure 6 illustrates this integration by showing the technology's adaptive nature (design space) and the options for personalized support (use space) through single-headed arrows that indicate how adjustments flow from design to use and remain aligned with user needs.

For example, Spectrums.ai offers a platform to support neurodivergent individuals in navigating their daily lives. The platform automatically adjusts to each user's unique neurodivergent profile by providing personalized tools such as symptom trackers, behavior insights, and mood monitoring. The platform analyzes user data in real time to offer tailored care. In addition, users are enabled to manually adjust settings such as font size, colors, and notifications, to align with their sensory and cognitive preferences. This ensures that each user receives support adapted to their individual needs, empowering them to manage their neurodivergence independently (Spectrums A.I., 2024).

The tension between flexibility and reliability is mitigated through DP5 (*environmental adaptability*) and DP6 (*functional fallback*). See Table 4 and Figure 7.

Table 3. DPs for Mitigating the Tension Between Assistance and Autonomy

	Providing differentiated information (DP3)	**Enabling contextual personalization (DP4)**
Aim	ADTs should enable users to make informed and independent decisions so that users are empowered to act in a self-determined way, build social capital, and ultimately enhance their sense of belonging.	ADTs should adapt to each user's individual preferences, abilities, and needs so that users are empowered to act with greater self-determination.
Context	Given that individuals with accessibility constraints often have heightened information needs yet frequently receive information that is incomplete, overly standardized, or inaccessible, thereby limiting informed decision-making, …	Given that individuals with accessibility constraints experience multifaceted and context-dependent needs that mass-market technologies often fail to adequately address, …
Enactor	… employ sensing and sense-making technologies to collect, process, and transform all available raw data …	… employ modularity, adaptive and configurable features, and artificial agency …
Mechanism	… to provide differentiated (i.e., multifaceted and context-dependent) information tailored to users with accessibility constraints through the ADT. This can be achieved by: • providing access to all available, context-specific information (e.g., environmental, spatial) in a structured and neutral form. • providing information in multisensory formats (e.g., sensory, visual, auditory).	… to enable context- and constraint-specific personalization of the ADT to the user with accessibility constraints. This can be achieved by: • allowing for manual adjustments regarding functionality and settings, with the user maintaining agency. • enabling automatic adjustments by translating data-driven insights into adaptive improvements in system behavior (e.g., intelligent defaults) and performance.
Boundary condition	The information provided must be complete and accurate to ensure information reliability.	User data must be processed in compliance with data security standards to ensure responsible handling.
Rationale	Differentiated relevant information allows for informed and independent decision-making by enabling users to understand their surroundings and options, evaluate accessibility and contextual factors, and choose actions that best align with their intentions, abilities, and needs. This differentiated information fosters: • *self-determination* because individuals can prepare for and engage in experiences according to their own abilities and assess accessibility on their own terms. • *social capital* because access to relevant information creates a common ground that promotes communication, coordination, and mutual respect, thereby strengthening community bonds even in the absence of direct interaction. • *a sense of belonging* because information in multisensory formats ensures equal accessibility for users with diverse sensory or cognitive needs, fostering the feeling of being valued.	Contextual personalization of ADTs enables the adaption to each user's individual preferences, abilities, and needs by tailoring functionality and content to the wide diversity of accessibility constraints, thereby enhancing usability and individual relevance. This contextual personalization fosters: • *self-determination* because by adapting to the user's context, such as recent activities, constraints, or behavior, ADTs can support users while ensuring they retain full control and freedom to decide which adaptations are applied and when.
Illustrative quotations	"Is it accessible or not? Well, what does that mean? For example, if you're a person on the ASD spectrum, what does accessible mean to you compared to someone who uses a wheelchair? We need to proactively provide people information so they can make better decisions on their own ... about what's accessible to them or not." (Expert 3) "We need a good flow of information in advance to make the whole experience somehow plannable because a lack of information can already be the first barrier, and I don't even have to be disabled." (Expert 16)	"[The ADT solution] could just learn from your behavior what your constraints are." (Expert 2) "I'd love that you'd be able to filter it by the constraints or needs that you specifically have." (Expert 3)
Note: ASD = autism spectrum disorder.		

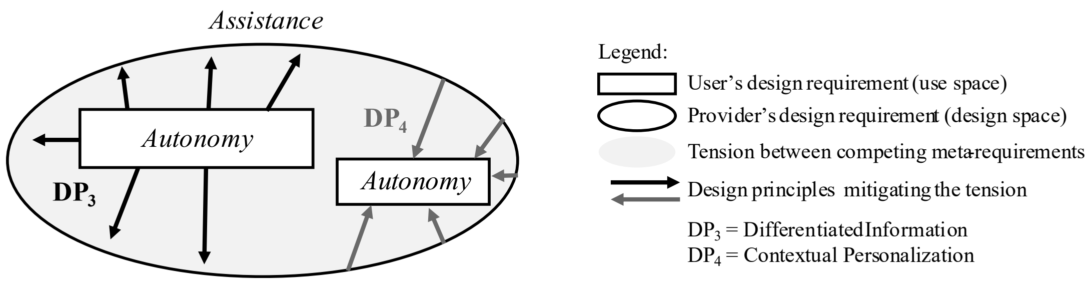

Figure 6. Visualization of the Mechanisms for DP3 and DP4

Table 4. DPs for Mitigating the Tension Between Flexibility and Reliability

	Ensuring environmental adaptability (DP5)	**Providing functional fallback (DP6)**
Aim	ADTs should function reliably in dynamic and changing environmental conditions so that users are empowered to exercise greater self-determination despite external variability.	ADTs should provide reliable and robust functionality so that users are empowered to act independently and in a self-determined way without fear of system failure.
Context	Given that individuals with accessibility constraints rely on ADTs in dynamic, contextually varying environments, with environmental conditions potentially interfering with perception, interaction, and system responsiveness, …	Given that individuals with accessibility constraints often depend on ADTs for essential tasks, where technical failures can disrupt daily routines, undermine autonomy, and even compromise safety, …
Enactor	… employ context-aware sensing, adaptive control technologies, and AI…	… employ fault-tolerant and independent system architectures, redundant system technologies, and user-facing communication interfaces …
Mechanism	… to ensure the ADT effectively adapts to environmental variability and disruptions. This can be achieved by: • enabling predictive error prevention through proactive detection and mitigation of environmentally induced disruptions (e.g., loud noises). • ensuring high error tolerance by enabling robust recovery and sustained functionality despite environmental variability, uncertainty, or degradation of contextual inputs.	… to provide functional fallback options and notifications for the ADT in the event of technical failure. This can be achieved by: • allowing for gradual downgrading to progressively reduce nonessential functions while preserving critical functionality. • integrating operational independence and redundancies, such as local processing and offline capabilities or alternative system components.
Boundary condition	Inherent limitations of the technology in use (e.g., hardware and software) and environmental conditions must be considered to ensure realistic expectations.	Fallback options must be proportional to the criticality of the functionality, distinguishing between critical applications (e.g., medical) vs. noncritical utilities to ensure safety levels according to the potential impact of failure.
Rationale	Adaptation to environmental variability and disruptions enables the ADT to function reliably in dynamic and changing conditions by ensuring proactive error prevention and error tolerance. This environmental adaptability fosters: • *self-determination* because users can act independently and confidently, even when moving, facing uncertainty, or making minor mistakes.	Functional fallback options ensure the reliable and robust functionality of ADT by providing flexibility to adapt to changing technological conditions, such as partial service outages, degraded inputs, or missing components. This functional fallback fosters: • *self-determination* because consistent and dependable functionality enhances usability and supports user autonomy.
Illustrative quotations	"The messages on the beacons could not be updated remotely, and if something changed in the built environment, such as a new shop opening, the message was incorrect and misleading and could only be updated with great effort." (Expert 3) "Errors happen, like we all know. So, when there is an error, we need to have an alternative and ... make sure we can flexibly accommodate needs." (Expert 9)	"If you're relying on technology to provide accessibility and inclusion, what's the fallback plan? My daughter wears hearing aids; that's technology she relies on for inclusion. Does it fail? Yes, it does. So, we need a backup plan." (Expert 5) "If I'm going to rely on a [digital] device, then it has to be 99.9% functional." (Expert 19)

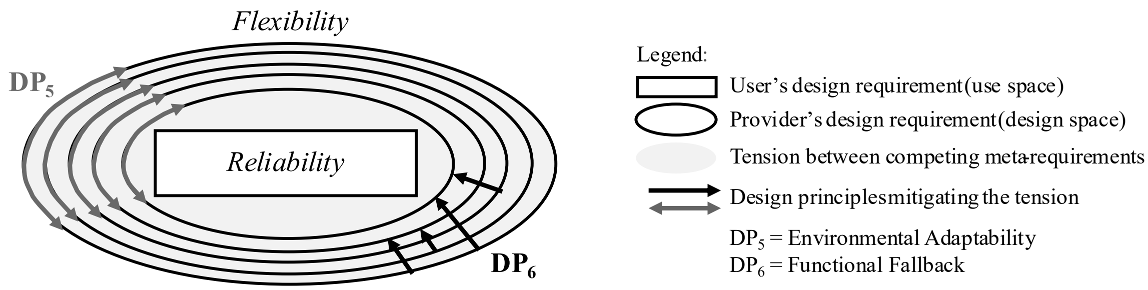

Figure 7. Visualization of the Mechanisms for DP5 and DP6

Environmental adaptability: DP5 ensures that ADTs are capable of adapting to the user's dynamic environmental conditions to enable greater self-determination. Environmental adaptability mitigates the tension between flexibility and reliability by the technology remaining stable while adapting to changing conditions.

This can be achieved in two ways: (1) by ensuring predictive error prevention through real-time monitoring and the anticipation of environmentally induced disruptions, allowing the technology to preemptively adjust its behavior, and (2) by ensuring high error tolerance despite environmental variability or degradation of contextual inputs. Together, these mechanisms enable the technology to maintain consistent support in unpredictable user environments. The ADT operates within a defined layer of flexibility, maintaining resilience and adaptability without compromising stability, illustrated by the double-headed arrows spanning the flexibility layers of the design space in Figure 7.

For example, NaviLens is a technology that uses special codes that can be scanned from long distances, at wide angles, in motion, and under varying lighting conditions, without the user needing to relocate or focus on them. This ensures high error tolerance, making NaviLense code highly reliable in dynamic environments such as busy train stations or crowded public spaces, where traditional QR codes often fail. NaviLens thus enables visually impaired users to navigate independently and safely (NaviLens, 2024).

Functional fallback: DP6 guides how ADTs provide reliable, stable functionality that enables users to act independently without fear of system failure, thereby reinforcing self-determination. Functional fallback mitigates the tension between flexibility and reliability by allowing the technology to dynamically operate within layers of flexibility while retaining a stable core that preserves critical functionality in the event of errors or disruptions and also fostering trust by notifying users of unexpected system behavior.

This can be achieved in two ways: (1) by allowing for gradual downgrading, reducing nonessential functions while preserving critical operations and core functionality during partial failures or performance degradation, and (2) by integrating operational independence and technical redundancies such as offline capabilities or alternative system pathways to ensure continuity of essential functions and overall system resilience. Together, these mechanisms enhance the technology's reliability and support for consistent user experience even under adverse conditions. This is illustrated in Figure 7 by the single-headed arrows moving from the outer layers of flexibility toward the inner core of reliability, where the technology can "fall back" towards the "stable core," ensuring continuity and functionality.

For example, Waymap is a navigation platform that operates independently of Wi-Fi, GPS, Bluetooth, or mobile signals. After users download the map of a venue or route, Waymap uses the smartphone's built-in motion sensors to track movement and orientation, ensuring that navigation works reliably even in underground, indoor, or signal-dead zones. Waymap thus ensures that users are never left without guidance, supporting self-determination (Waymap Ltd., 2021).

4.4 Evaluation Across Three Real-World Cases

We now present the evaluation of our six constraint-agnostic, tension-aware DPs, focusing on how they advance social inclusion at the individual level. Our evaluation approach emphasizes the lived experience of users, as the impact of ADTs typically emerges over time through sustained use. We structure our evaluation around three cases, namely, FuelAssist, EasyRest, and BladderSense.[3] We illustrate how the DPs are instantiated in practice and evaluate their social inclusion impact, that is, their perceived influence on

[3] For data-protection reasons, the names of the ADTs have been anonymized, and pseudonyms are used throughout this article.

users for self-determination, belongingness, and social capital. Although each case involves multiple design tensions and DPs, for clarity, we focus on one emphasized design tension and its corresponding DPs for each case.

Case 1: FuelAssist is an app that supports drivers with physical limitations in refueling their vehicles by enabling them to locate nearby gas stations, notify staff in advance of their arrival, and receive on-site assistance. In this case, the tension between *digitization* and *dignity* is particularly relevant, as digital technologies can increase efficiency and facilitate communication in everyday activities, such as refueling, but could potentially amplify exposure or stigmatization if human support is poorly mediated or if the technology introduces additional effort for users already facing barriers in performing everyday tasks. As the app provider explained:

> *When we built the app, we built it to remove the human, because people usually don't like to ask for help. ... But what we see now is that sometimes there needs to be more human interaction, because information gets lost or is not correctly understood by the petrol station staff.*

Across interviews, users consistently described FuelAssist as seamlessly integrated (DP1) into their daily routines. Seamlessness is primarily associated with simplicity and effortless interoperability of the app with the user's smartphone. User 8 emphasized how the app blends into everyday life: "So, in terms of integration into daily life, it's seamless. You don't even need to think much; that seamless [integration] gives you a lot of freedom that you can just act and participate in like the daily life." Seamless integration is linked to two facets of social inclusion: a stronger sense of belonging and enhanced self-determination. Regarding sense of belonging, users stated that FuelAssist reduces the visibility of their physical constraints, preempting potentially uncomfortable social situations. By requesting assistance in advance, users avoid on-the-spot negotiations or refusals that could highlight difference or dependency. User 8 articulated this as follows:

> *What makes it so seamless is the idea that you can ask beforehand. There's not going to be this awkward interaction of, oh no, we've got a disabled person, what are we going to do? ... And if the station replies, we're unable to assist, no big deal. That's great. I'll just try another one. ... It's just kind of just preempting any kind of social awkwardness, which makes me feel uncomfortable.*

Further, FuelAssist enables users to act independently without relying on companions or ad hoc help from strangers. As User 8 explained:

> *I just use the app and go get fuel. It's that simple. And if there was an additional step, then it wouldn't be making it any easier than having somebody in your car with you. ... That seamless [integration] gives me a lot of freedom that I can just participate in the daily life on my own.*

In addition, users consistently described bilateral interaction (DP2) as a defining DP of FuelAssist, experienced through two-way communication with gas station staff. This reciprocity transforms assistance from ad hoc demands into negotiated interactions in which both parties retain dignity. User 7 described this as follows:

> *So, I know that when I get there, I tap the app to let them know that I've arrived. And then they come out to me, and that's fantastic, because I don't have to get out of the car, because I can't really. So, you know, for me, it's perfect.*

While FuelAssist already provides bilateral interaction features, the provider flagged future developments:

> *Moving forward, we aim to integrate functionality that allows users not only to chat with petrol station staff but also to call them directly. This will be particularly useful in situations where a user is already at the petrol station, but no staff member is there yet.*

Bilateral interaction is linked to two facets of social inclusion: belongingness and social capital. It enhances users' sense of belonging by enabling communication that preserves dignity and minimizes the public visibility of constraints. By allowing users to communicate discreetly and asynchronously, FuelAssist reduces the need for public signaling, which users often associate with embarrassment or social exposure. As User 8 explained: "The idea of having a two-way communication with someone inside the petrol station is priceless. Because otherwise the only way for you to communicate is by horns beeping and shouting out of the window, which is just embarrassing." Further, bilateral interaction enhances users' social capital by fostering more considerate relationships with service staff. User 8 contrasted this approach with earlier one-directional solutions:

> *The original buzzer idea wasn't really fair on the companies because it was, like, [the] disabled person wants help now, you must drop everything and help them, and that's not really fair for how a business operates, whereas I think with [this solution], it's much more polite and cognizant of the fact that people in these businesses are busy.*

Case 2: EasyRest is an app that supports individuals with accessibility constraints in locating nearby public restrooms by providing information on their availability, location, and accessibility features. The tension between *assistance* and *autonomy* is particularly relevant here, as users depend on external information to manage bodily needs. While such assistance can reduce stress and increase independence, overly intrusive, imprecise, or generic solutions could undermine spontaneity and autonomy.

Across interviews, users consistently emphasized that differentiated information (DP3) is a core design feature of EasyRest. Knowing in advance where accessible toilets are located via context-specific information substantially reduces uncertainty and anxiety. As User 12 explained: "The app helps me a lot, because I can just see where the barrier-free toilets are." This emphasis on anticipation and preparation was echoed by the provider of EasyRest, who highlighted that access to detailed information fundamentally changes the user's experience:

> *That's one of the most important things for people with [constraints], preparing for traveling. ... If you know beforehand, for instance, the path is like this or that, then the individual is not totally nervous, and this makes life better.*

Differentiated information is a cornerstone for all facets of social inclusion, namely, self-determination, belongingness, and social capital. Regarding self-determination, EasyRest enables users to make informed decisions on their own terms. Importantly, differentiation of information acknowledges that accessibility is not a one-size-fits-all concept. User 17 vividly described how differentiated information transforms both confidence and agency:

> *It was a dream, really. Even when we stopped at rest areas, I always knew exactly and in advance what kind of rest area it was. It's almost fun when you just try it out and realize, yes, it works. There's such a feeling of happiness, such security and self-determination, I can't even describe it.*

Further, differentiated information fosters a sense of belonging by allowing users to participate more freely in social activities. Knowing where accessible toilets are located reduces the need for constant vigilance, enhancing social activities. User 15 explained this as follows:

> *Especially when you're out and about in a park, sometimes there's a disabled toilet at the entrance, but then none further on. And when you know that you need to use the toilet every 45 minutes to an hour, you must plan your route accordingly to make sure it works, and the app is actually a very good solution for that.*

Ultimately, differentiated information contributes to users' social capital by increasing psychological safety, particularly in unfamiliar environments. Users described relying on EasyRest when traveling or navigating to new places, where uncertainty can quickly escalate into panic. As User 12 explained:

> *For one thing, the better the app, the safer I feel, because I rely on the information I get, especially when I'm on holiday or when I'm in areas where I don't know my way around. I have bowel movement problems, which sometimes leads to a certain panic when you don't know where the toilet is; ... with the app I feel much, much safer.*

At the same time, users also identified potential improvements. Several expressed a desire for even more precise and detailed information (e.g., opening hours, greater location accuracy), reflecting that meaningful assistance depends not on generic classifications but on nuanced, experience-based information. User 12 noted that "a little more information, a little more accuracy would help to even further improve the app. Although disabled toilets are theoretically standardized, in practice they often look quite different."

In addition, users emphasized the importance of contextual personalization (DP4), which in EasyRest is realized through manually adjustable filters and selectable toilet categories that allow tailoring of the app's information to individual needs and situational contexts. EasyRest enables users to specify which types of facilities are relevant to them at any time. As User 15 explained, "There is a setting option where I can display toilet types when I click on the button. There are public toilets, public plus wheelchair accessible toilets, and Euro Key toilets." Further, User 17 reflected on the importance of adapting complexity to individual preferences:

> *I think it's great that the more an app can do, the better. But I also know a lot of people who find it overwhelming and panic. It just makes things more difficult for them. That's why I think it's important to keep all options open.*

EasyRest supports self-determination by acknowledging variability rather than forcing users into rigid categories. Users define what "accessible" means to them in each context. This adaptable personalization is particularly important because many accessibility constraints, especially for chronic or fluctuating conditions, are not static. User 14 described how changing health states directly affect their needs:

> *I'm trying out different biologics, and there are phases when everything really feels normal again—and then suddenly there's another flare-up. The app needs to take that into account and learn from it, because when you finally have a period of relief, unfortunately, it often doesn't last very long.*

Case 3: BladderSense is a wearable system that supports users with bladder dysfunction by sending alerts, monitoring bladder-filling levels using integrated sensor technology and AI-based data analysis, and providing feedback via a companion app. The tension between *reliability* and *flexibility* is particularly relevant here: While users depend on accurate, continuous monitoring for medically relevant decision-making, rigid systems that require immobility or constant adjustment can severely limit participation in everyday activities.

Across interviews, users and providers emphasized that environmental adaptability (DP5) is essential for real-world use—i.e., the ability of BladderSense to function reliably despite movement, shifting positions, and environmental variability. BladderSense is explicitly designed with a high error tolerance to accommodate everyday activities. As the provider explained:

> *We cannot force a patient to not move all day. Yes, then the measurement would be as good as possible, but the patient is not flexible. ... We want to enable flexibility in everyday life, whereby the user can also drive around, move around ... So, we must deal with an error rate.*

This design choice directly supports self-determination by allowing users to integrate the device into their daily routines without having to adapt their behavior. Users stress that reliable performance during movement enables independent participation. As User 5 explained, "I would like to be able to use [BladderSense] everywhere, from morning until I go to sleep ... It should keep working when I'm at physiotherapy, where there's a lot of movement." Crucially, users described how flexibility becomes meaningful only when paired with reliability. What causes stress is not occasional inaccuracy but the need for constant vigilance. User 5 added: "What would stress me out is knowing it must not move at all because then I'd constantly be checking every five minutes to see if it's still where it should be."

Given the medical relevance of bladder-monitoring, users also emphasized the importance of functional fallback (DP6). When ADTs support critical bodily functions, failure is not merely inconvenient but potentially harmful. As User 2 stated: "As it's ... a medical device, it simply must function at all times." Operational independence and redundancies such as offline functionality, as well as clear notifications when data is unreliable or when there are system failures, are therefore not optional add-ons but central to adoption. Importantly, users emphasize that reliability does not mean perfection but predictability and transparency. As User 5 explained: "It's totally fine if something doesn't work occasionally. ... But if it becomes a permanent problem, I will probably use it less, because I don't want to deal with it every time." Ultimately, functional fallback goes beyond technical safeguards; it offers psychological reassurance, thus supporting self-determination. User 3 described this as follows:

> *It's a huge mental relief for me to be able to just go out for a beer with friends ... and to have the system to reliably warn me when my bladder needs emptying. I don't have to think about it all the time and can enjoy my life in a more self-determined and relaxed way.*

Several users proposed improvements underlining the importance of functional fallback mechanisms. User 4 suggested early warnings when sensor data no longer aligns with expected patterns: "If the device suddenly no longer delivers reliable data ... then there must be an alarm. A notification that tells you in advance: 'The position is not correct right now, please check.'"

5 Discussion

5.1 Theoretical Implications

Digital sustainability promises the advancement of economic, ecological, and social welfare through digital technologies (Kotlarsky et al., 2023). ADTs have the potential to foster social inclusion as a central impact dimension of social sustainability. When social inclusion is achieved in a *long-term* and *systemic* manner (Brundtland, 1987; Loorbach et al., 2017), it enhances well-being and quality of life at both individual and collective levels, supporting social sustainability (Haugjord & Aanestad, 2024). Hence, we understand designing ADTs not only as a direct social inclusion problem but also as an indirect social sustainability problem. We thus set out to extend socially inclusive design knowledge (e.g., Dilger et al., 2025a; Faik et al., 2024; Wass et al., 2023) towards a more systemic and long-term impact of ADTs, specifically contributing knowledge about the design outcomes and design process.

With respect to socially inclusive design outcomes, we provide constraint-agnostic, tension-aware DPs for ADTs, which we understand as a nascent theory for design and action (Gregor, 2006; Gregor & Hevner, 2013). As such, first, we complement existing design knowledge with an explicit *social by IS* perspective (Schoorman & Kutzner, 2020). While important design work has focused on fostering digital participation (i.e., *social in IS*) (e.g., Riggins & Dewan, 2005; Vassilakopoulou & Hustad, 2023), our empirical findings show that the integration of socially relevant needs is equally important in ADTs, enabling social inclusion in the physical world beyond digital boundaries. This shift in perspective is meaningful, as social sustainability ultimately materializes through individuals' lived experience in the physical world, where everyday interactions shape collective impact (e.g., Bäckman, 2024; Eshleman, 2026).

Second, we extend socially inclusive design knowledge with a constraint-agnostic perspective. Existing research in socially inclusive design and related fields predominantly focuses on specific constraint types such as bladder dysfunction (Jonas et al., 2024) or age-related limitations (Zhang et al., 2025). While these contributions provide valuable context-sensitive insights, they are difficult to generalize from. In contrast, our constraint-agnostic DPs are applicable across diverse constraint types. Importantly, the aim is not to develop ADTs that simultaneously accommodate all possible constraints. Rather, we identify constraint-agnostic DPs that remain relevant across diverse contexts and user needs to enable the development of multiple context-sensitive ADTs providing transferable capacities for systemic impact.

Third, we extend socially inclusive design knowledge with a tension-aware perspective. Specifically, we uncover design tensions resulting from competing design requirements between providers and users of ADTs and provide mechanisms to mitigate them. Prior research has pointed to the role of tensions in socially inclusive design—for example, targeting the paradoxical relationship between social inclusion and exclusion as a result of IS-based interventions (Curto-Millet & Cañibano, 2023). However, these studies have paid limited attention to how such tensions materialize at the artifact level (i.e., a specific technology) and how they can be mitigated there. Studies from other IS streams, such as those by Breiter et al. (2025) and Wessel et al. (2025), conceptualize design tensions either as dialectical or as trade-offs, leaving the management of competing demands without further guidance to the provider or the users in everyday practice. Drawing on previous social inclusion literature (e.g., Foley & Ferri, 2012) and our empirical insights, we offer a complementary perspective, identifying design tensions as paradoxical in nature and deeply embedded in the design process. Hence, they should not be treated as an afterthought but rather directly accounted for in the development of DPs. Consequently, identifying and addressing these paradoxical tensions early, alongside understanding the mechanisms through which they can be mitigated, is critical to ensuring the sustained use and long-term impact of ADTs.

With respect to the socially inclusive design process, our work also implies new impetus for evaluation. While existing research has established principles to facilitate a socially inclusive design-oriented research process (Wass et al., 2023) and addressed specific aspects such as interview guidelines for individuals with disabilities (Dilger et al., 2025b), our work adds to the evaluation of socially inclusive design. To evaluate our constraint-agnostic, tension-aware DPs on the three facets of social inclusion—namely, self-determination, belongingness, and social capital (Wass et al., 2023)—we conducted a user-centered evaluation, with participants who all had lived experience with accessibility constraints. Based on the qualitative, deeply personal feedback of 17 users of real-world ADTs, we gained insights into how socially inclusive design can mitigate tensions. Given that a systemic, long-term impact on social inclusion needs significant time to unfold and is hard to predict, we did not develop a digital artifact for evaluation. Instead, we followed an evaluation approach leveraging established, real-world ADTs to analyze the DPs' practical instantiations and potential impacts. This approach incorporates social inclusion concerns into the evaluation of design-oriented research, advancing methodological guidance (e.g., Wass et al., 2023; Zhang et al., 2025).

Our evaluation cannot assess the impact of our DPs on social sustainability, although we clearly aim for advancing digital (social) sustainability. Our work focuses on the DPs of ADTs to foster social inclusion at the individual level. We understand social inclusion, however, as a boundary dimension for achieving social sustainability at the collective level. Only when individuals are enabled to participate meaningfully in social, cultural, and civic life will broader societal impacts on factors such as social connectedness, social prosperity, and well-being emerge. While our DPs aim for long-term, systemic impact, their primary locus of intervention remains at the individual level, as design knowledge materializes through concrete artifacts and user interactions. By reconciling individualization with generalization, a pathway opens for scaling individual-level impact toward collective-level impact. In this sense, constraint-agnostic, tension-aware design knowledge does not directly produce social sustainability; rather, it establishes the enabling conditions from which sustained, collective impact can evolve. This positions socially inclusive design as a critical yet inherently bounded mechanism: It can shape the conditions for social sustainability but cannot fully determine its emergence.

5.2 Practical Implications

Our work provides two valuable recommendations for practice. First, by providing prescriptive DPs, we offer guidance to providers for designing ADTs that foster social inclusion. Our DPs represent actionable insights derived from empirical evidence, developed and evaluated in close collaboration with experts and users. Our evaluation demonstrates that these DPs are valuable, reusable, and adaptable. While not every DP must be applied with equal weight in every ADT, providers should reflect on their relevance based on the context, target group, and intended use of the ADT. For providers with established ADTs, the DPs can be used to critically assess and improve these technologies by identifying gaps and opportunities for fostering social inclusion.

Second, our findings uncover tensions inherent to the design process of ADTs, thereby supporting providers in anticipating and mindfully navigating competing demands early. Rather than treating tensions as obstacles to be resolved only once they emerge in later development stages, recognizing them upfront enables more deliberate and informed design decisions, reducing the risk of user abandonment and increasing the likelihood of long-term impact. Importantly, our findings indicate that design tensions should not merely be mitigated but actively managed as a productive source of innovation. This is exemplified by BladderSense, which integrates individualization with pressures to scale across a large and diverse user population. Actively engaging with this tension enables the development of ADTs that advance social inclusion and create long-term, systemic impact.

6 Conclusion

As with any research, our work is subject to limitations that offer valuable opportunities for further research. First, our findings are grounded in four iterative design cycles, informed by a robust empirical database comprising 44 interviews and 55 real-world examples. While these insights enabled us to combine unique perspectives and experiences and to triangulate a holistic understanding, they are subjective in various ways (e.g., in the interpretation of questions and answers). Although we aimed to explore diverse perspectives, our dataset does not capture the full range of possible viewpoints, for instance, those of users with differing levels of digital literacy or investors with distinct requirements. Therefore, we encourage future research to integrate additional empirical evidence to validate our DPs and provide deeper insights into how they mitigate design tensions. Second, drawing on our empirical database, we identify and illustrate paradoxical design tensions and present six tension-aware DPs. Future research could refine and evaluate these DPs by applying them in the early stages of ADT design and assessing their long-term relevance and use across different contexts. Ultimately, an important avenue for future research is to investigate how ADTs contribute to the impact of social sustainability at the societal level. Beyond conceptually explaining such contributions, future studies should aim to operationalize and empirically measure their societal impact through rigorous impact assessment approaches.

In conclusion, digital technologies increasingly act as catalysts for societal change, advancing inclusive societies. While ADTs have the power to positively impact social inclusion, it should, nevertheless, be emphasized that they cannot resolve underlying constraints but can only be used to increase liveability and well-being for individuals. Our work provides a foundation for future research on digital (social) sustainability and socially inclusive design, working toward social inclusion for all. In doing so, we not only aim at advancing the social frontier of digital sustainability research but also at mobilizing the IS community to further investigate, critique, and purposefully shape the societal impact of digital technologies.

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Appendix A: Expert Interviews (Design Cycles 1, 2, 3)

Table A1 provides an overview of the experts interviewed for Design Cycles 1, 2, and 3, including their role, organization and domain of expertise.

Table A1. Overview of the Expert Interview Sample

#	Role	Organization	Domain of Expertise
1	Manager venues and cemeteries	City council	Cultural events
2	Creative program coordinator	City council	Cultural events
3	Access and inclusion team lead	City council	Cultural events
4	Capability and learning manager	City council	Inclusive workforce development
5	Learning and development consultant	City council	Inclusive workforce development
6	Manager information services	City council	Digital accessibility
7	Access and inclusion project manager	City council	Public services and infrastructure
8	Events and venue coordinator	City council	Cultural events
9	Events and venue manager	City council	Cultural events
10	Senior advisor access and advocacy	Foundation	Individuals with spinal cord damage or other physical disabilities
11	Chief advisor government	Foundation	Individuals with spinal cord damage or other physical disabilities
12	Disability officer	City council	Public services and infrastructure
13	Executive manager accessible transport	City council	Accessible transportation
14	Chief research & innovation officer	Consultancy	Digital accessibility
15	Artistic director & co-founder	Event agency	Cultural events
16	State coach for paralympic sport	Sports federation	Paralympic sport
17	Managing director & publisher	Media agency	Paralympic sport
18	Project manager, consultant, & nursing scientist	Foundation	Individuals with paraplegia
19	Former national coach in paralympic sport	Sports federation	Paralympic sport
20	Assistant to national team in paralympic sport	Sports federation	Paralympic sport
21	Paralympic athlete	Sports federation	Paralympic sport
22	Head of mobility and inclusion, former national coach in paralympic sport	Hospital	Paralympic sport
23	Municipal disability officer	City council	Public services and infrastructure
24	Co-founder & CEO	MedTech start-up	Individuals with incontinence

Appendix B: Real-World Examples (Design Cycle 3)

We collected the sample through a keyword-based search conducted on Crunchbase (Crunchbase Inc., 2026). As constraint is a term frequently used in research but not, in our understanding, used in practice, we included related terms, such as *disability* (also: *disabilities, disabled*) and *impairment* (also *impairments, impaired*) in our search string. Additionally, we included common types of constraints, such as physical constraints *(wheelchair, blind, low vision, deaf, sign language, hard of hearing)* and cognitive constraints (*neurodiverse* [also: *neurodiversity, neurodivergent*], *autism, asd, adhd, anxiety*). For the industry filter, we selected *Software, Mobile, Information Technology, Data and Analytics,* and *Internet Services*.

We conducted the search on Crunchbase in May 2024, leading to 2872 initial results. We screened each real-world example against our previously defined inclusion criteria, namely: (1) digital (i.e., the real-world example is digital as derived from the example's description), (2) socially inclusive (i.e., the real-world example directly aims at fostering social inclusion as an outcome), and (3) in-person context (i.e., the real-world example is intended to be applied by individuals as a tool to participate in in-person experiences). Accordingly, we excluded, for example, digital communities for individuals with disabilities or e-learning offers to build social capabilities. We also removed examples with insufficient website information. This resulted in a sample of 55 real-world examples. Table B1 lists all 55 real-world examples, including their name, a short description, and the design principle which they inform (based on the publicly available information).

Table B1. Overview of the Real-World Examples

#	Name	Description	Design principles					
			1	2	3	4	5	6
1	Adapt the Game	Accessible event ticketing for disabled fans	X		X	X		
2	Airpoly	AI object and color recognition for visual interpretation			X			
3	ARIA	Smart glasses converting visuals into audio.	X		X			
4	ARx Vision	Talking camera, converting visuals into audio.	X		X			(X)
5	AYES	Crossing guidance via visual, audio & tactile signals			X			X
6	Beltmap	Vibration-based mobility guidance belt	X		X			
7	BielGlasses	Smart glasses enhancing residual vision			X	X		
8	Biped.ai	Wearable obstacle detection with audio guidance	X		X			
9	BrightSign	Glove translating sign language to speech/text		X	X	(X)		
10	Cerge	Personalized disability support for services	X	X	X			
11	Click and Go Wayfinding	Spoken navigation and mapping guidance			X			
12	Cognitopia	Communication and daily support tools		X	X	X		
13	CuteCircuit	Haptic/immersive music experiences	X		X			
14	Deaf AI	Real-time speech to sign language conversion	X	X	X			
15	Different Breed	Inclusive online ticketing	X		X	X		
16	Envision	Audio-based visual interpretation	X	X	X			

17	eSight	Vision enhancement wearable glasses	X		X	X		
18	Eyedaptic	Assistive glasses for low vision			X			
19	Ezymob	Mobility planning for disabled users		X	X	X		
20	Field of vision	Touch-based game experience for blind users			X			
21	Foresight AR	Environmental audio description for navigation			X			
22	Frasil	Communication and access support tools		X		X		
23	GoSense	Sound-based perception enhancement	X		X			
24	iAccess life	Crowd-sourced venue accessibility ratings			X			
25	iDentifi	AI object recognition with audio output			X	(X)		
26	Kalogon	Ergonomic pressure-relief cushions	X			X	X	
27	Lazarillo	Navigation for visually impaired users			X			
28	Limber Technologies	Safety monitoring for fall reduction				X		
29	Limix	Sign language to voice translation	X	X	X	(x)		
30	Lumen	Sensory guidance via audio feedback			X			
31	Mycrocoast	Live narration of sport events	X		X			
32	NaviLense	Specialized codes for information access for blind users			X		X	
33	PoiLabs	Audio-guided indoor positioning			X			
34	RightHear	Audio-enabled environment signage	X		X			
35	Route4U	Accessible route planning			X			
36	SeamlessCARE	Emotion detection for non-verbal communication		X	X	X		
37	Smart Access	Safe route planning for accessibility needs			X			
38	Sociability	Finding and rating accessible places		X	X	X		
39	Speaksee Venue Accessibility	Real-time captions for hearing impairment	X	X	X		X	
40	Spectrums AI	Behavioral and learning support systems		X		X		
41	StepHear	Orientation via spoken guidance		X	X			
42	Strap Technologies	Haptic navigation wearable for blind users			X			
43	Theater Ears	Multilingual movie audio access			X			

44	Tiimo	Neurodivergent-friendly daily planner				X		
45	TuneMap	Community-driven navigation data		X	X			
46	Visiontif	Real-time scene description device	X		X			
47	Visualify	Converts audio alerts into visuals			X			
48	Waymap	GPS-free indoor/outdoor guidance	X		X	X		X
49	We Hear You	Sign to speech/text and back translation			X			
50	WheelRoute	Urban infrastructure accessibility mapping			X			
51	WeWalk	AI-powered mobility cane	X	X	X		(X)	
52	Wheelmap	Map of wheelchair accessible locations		X	X			
53	Xander	Speech-to-text wearable captions	X		X		X	X
54	Embr Labs	Personal temperature regulation device	X			X		
55	Smart Steps	Guidance for education, work, and daily challenges				X		

Note: DPs [1] Seamless Integration, [2] Bilateral Interaction, [3] Differentiated Information, [4] Contextual Personalization, [5] Environmental Adaptability, [6] Functional Fallback.

Appendix C. Overview of the Evaluation Interviews (Design Cycle 4)

Table C1 presents an overview of the user interviews (n = 17), including participants' individual accessibility constraints. Table C2 presents an overview of the provider interviews (n = 3), with each interview assigned to one of the three ADTs.

Table C1. User Interviews

#	ADT	Individual accessibility constraint
1	BladderSense	Paraplegic
2		Overactive bladder
3		Paraplegic
4		Paraplegic
5		Paraplegic
6		Paraplegic
7	FuelAssist	Paralyzed leg
8		Paraplegic
9		Paraplegic
10		Paraplegic
11	EasyRest	Short bowel syndrome
12		Ulcerative colitis
13		Stoma
14		Ulcerative colitis
15		Multiple sclerosis
16		Stoma
17		Intestinal inflammation

Table C2. Provider Interviews

#	Assistive digital technology	Role	Professional experience
1	BladderSense	CEO & co-founder	> 5 years
2	FuelAssist	Founder	> 20 years
3	EasyRest	CTO & software developer	> 5 years

Appendix D. Data Structure Problem Awareness and Formulation (Design Cycle 1)

We analyzed all 44 semi structured interviews, including 24 expert interviews, 17 user interviews, and three provider interviews, following Gioia et al. (2013) to ensure qualitative rigor in inductive research. In Appendices D-G, we present an overview of our static data structure, which emerged through iterative development within each design cycle. For reasons of length, we did not elaborate on every iteration within the design cycles. All iterations have been documented comprehensively, and we are happy to provide insights into the development of the design narratives upon request.

Table D1 depicts the data structure of Design Cycle 1 (problem awareness and formulation), showing six illustrative first-order concepts (out of 24), three second-order themes and one aggregate dimension.

Table D1. Data Structure Problem Awareness and Formulation

<table>
<tr><th>Illustrative first-order concepts</th><th>Second-order themes</th><th>Aggregate dimensions</th></tr>
<tr><td>Embedding solutions in universal design as a standard, that would make things a lot more accessible and scalable. (Expert 5)</td><td rowspan="2">Impact-oriented generalization (provider)</td><td rowspan="6">Tension between impact-oriented generalization and constraint-specific individualization</td></tr>
<tr><td>It [assistive digital technology] should be universally designed – so it doesn’t matter who you are and what constraints or abilities you have. ... . (Expert 3)</td></tr>
<tr><td>What people with a mobility impairment require versus what people with a vision impairment require are different. They probably won't be the same digital solution. (Expert 3)</td><td rowspan="2">Constraint-specific individualization (user)</td></tr>
<tr><td>We would definitely need to be flexible in the solution –as to what would concern each individual. (Expert 9)</td></tr>
<tr><td>How do we universally design ... so that people’s [individual] needs are met? (Expert 5)</td><td rowspan="2">Competing demands</td></tr>
<tr><td>There are many different restrictions, which is why it is not easy to make it inclusive for everyone. You must somehow cover the basic need and then it must be individualized. (Expert 16)</td></tr>
</table>

Appendix E: Data Structure Competing Design Requirements (Design Cycle 2)

Table E1 depicts the data structure of Design Cycle 2 (competing design requirements), showing nine illustrative first-order concepts (out of 36), nine second-order themes and three aggregate dimensions.

Table E1. Data Structure of Competing Design Requirements

<table>
<tr><th>Illustrative first-order concepts</th><th>Second-order themes</th><th>Aggregate dimensions</th></tr>
<tr><td>Digital is making big strides for both the vision impaired and the hearing impaired. And digital will make huge impacts for people with cognitive disabilities. (Expert 11)</td><td>Digitization</td><td rowspan="3">Tension between digitization and dignity</td></tr>
<tr><td>It triggers the speaker and then everyone in a five-meter radius looks at you because it says, you are on the, it's got this big authoritative voice that says, you are on the corner of this and that street. To your left is Hungry Jacks and to your whatever, and it's like, oh man, it is not discreet or dignifying. (Expert 3)</td><td>Dignity</td></tr>
<tr><td>I find that a lot of people still value talking to someone, instead of just going online. That's a really big thing for them, it makes them feel valued and seen. That personal connection really helps to ease their mind about their concerns. But for us, of course, that's more effort. (Expert 8)</td><td>Competing demands</td></tr>
<tr><td>What we need is a human being somewhere who can intervene and assist. (Expert 12)</td><td>Assistance</td><td rowspan="3">Tension between assistance and autonomy</td></tr>
<tr><td>I think it's harder to self-advocate at big scale events, right? If you're a participant who's coming to my course and you're one of 16 people, you can come up to me, you can have a conversation, you can ask for what you need. But if you're at a stadium with thousands of other people and you find you don't have access, there's no mechanism to self-advocate and change that in that moment. (Expert 5)</td><td>Autonomy</td></tr>
<tr><td>At the airport, when there comes a ramp, the guides try to push the girls [in wheelchairs] up. But the girls don't need that, and they don't want that. It's a question of value. But for the guides who don't have to deal with this daily, they just want to help. (Expert 21)</td><td>Competing demands</td></tr>
<tr><td>A flexible, accessible area is really important for us. One that accommodates wheelchair users, elderly, or just someone who doesn't like having people touch them. Just be flexible and open-minded about it all. (Expert 8)</td><td>Flexibility</td><td rowspan="3">Tension between flexibility and reliability</td></tr>
<tr><td>We recently had the … Games here, but I have never attempted to visit them because [accessible] transports to unreliable. (Expert 13)</td><td>Reliability</td></tr>
<tr><td>[Information] have to be accurate and reliable and that can be one of the most difficult things when things are changing quickly. (Expert 5)</td><td>Competing demands</td></tr>
</table>

Appendix F: Data Structure Design Principles (Design Cycle 3)

Table F1 presents the data structure of Design Cycle 3 (design principles), depicting 20 illustrative first-order concepts (out of 162), 18 second-order themes and five aggregate dimensions (= design principles). The design principle *enable bilateral interaction* was introduced during the evaluation stage (Design Cycle 4) and is therefore not included in this data structure. For this design principle, supporting empirical evidence is provided in Table G1.

Table F1. Data Structure of Design Principles (Design Cycle 3)

Illustrative first-order concepts	Second-order themes	Aggregate dimensions
It [the digital solution] was not discreet in any way. So, it would be … embarrassing to have a big loudspeaker blaring at you when you are trying to figure out where you are. (Expert 3)	Dignified design	Ensuring seamless integration
I would prefer and expect that I can use an online booking platform just like anyone else to book the same tickets and not to have to wait two or three days for someone to call me back and say sorry you missed out on the tickets. I have experienced that firsthand. (Expert 10)	Dignified design	Ensuring seamless integration
Google Maps is worldwide available already. So why create something new? We should just be adding to what already exists and people feel comfortable with. (Expert 3)	Technical integration	Ensuring seamless integration
Novel digital solutions should be integrated with existing platforms. (Expert 14)	Technical integration	Ensuring seamless integration
[…]		Ensuring seamless integration
I would love it if people could easily find information about accommodation, activities and tourism attractions without having to make a phone call and clarify, for example, what does the accessible room include? It comes down to sharing information. (Expert 3)	Information availability	Providing differentiated information
We need a good flow of information to make the whole experience somehow plannable, because a lack of information can already be the first barrier, and I don't even have to be disabled. (Expert 16)	Information availability	Providing differentiated information
Is it accessible or not? Well, what does that mean? For example, if you're a person on the ASD spectrum, what does accessible mean to you compared to someone who uses a wheelchair? We need to provide people information so they can make decisions … about what's accessible to them or not. (Expert 3)	Information differentiation	Providing differentiated information
Accessibility is requested. For sure, but for whom? Which accessibility? There is little differentiation in statements and information. For example, we are wheelchair accessible but have nothing for the deaf or hard of hearing. (Expert 18)	Information differentiation	Providing differentiated information
[…]		Providing differentiated information
We don't have to assume, and we just have to … collect the data about what people need. (Expert 2)	User-data collection	Enabling contextual personalization
Every spectator with a disability is a source of information about what works, what doesn't work, what their preferences are according to their unique disability – and that's hugely powerful data. (Expert 7)	User-data collection	Enabling contextual personalization
If someone is blind, there is a system where they could just link in to have a narration if the event. (Expert 5)	(Granular) modularity	Enabling contextual personalization
Making different modules compatible with each other. And everyone can choose what they need. (Expert 7)	(Granular) modularity	Enabling contextual personalization
[…]		Enabling contextual personalization

The messages on the beacons could not be updated remotely, and if something changed in the built environment, such as a new shop opening, the message was incorrect and misleading and could only be updated with great effort. (Expert 3)	Error tolerance	Ensuring environmental adaptability
Errors happen, like we all know. So, when there is an error, we need to have an alternative and … make sure we can flexibily accommodate their needs (Expert 9)		
They could include voice operation. Because for me it's nearly impossible to press a button. And that makes it prone for errors. (Expert 13)	Error prevention	
Making sure that we create digital assets that guide the user and do not create additional barriers through errors. (Expert 15)		
If I'm going to rely on a [digital] device, then it has to be 99.9% functional. (Expert 19)	Technical robustness	Providing functional fallback
Imagine you're sitting in the cinema and then the translation program doesn't work. Then you just get really annoyed because your tool, I don't know, is updating again. And you can't really understand anything. (Expert 23)		
If you're relying on technology to provide accessibility and inclusion, what's the fallback plan? My daughter wears hearing aids, that's technology she relies on for inclusion. Does it fail? Yes, it does. So, we need a backup plan. (Expert 5)	Back-up options	
Not solely relying on technology. That's a huge thing. We need to be able to do both. Because there are errors that happen, like we all know. (Expert 9)		
Note: […] indicates that additional second-order themes exist but are omitted for reasons of clarity and readability.		

Appendix G: Data Structure Evaluation (Design Cycle 4)

Table G1 presents illustrative quotes from the user and provider interviews, highlighting the relevance of the respective design principles as well as their perceived impact on the three facets of social inclusion: self-determination, belongingness, and social capital (Wass et al., 2023).

Table G1. Illustrative Quotes Mapped to Design Principles and Social Inclusion Facets

	Relevance	Self-determination	Belongingness	Social capital
[DP1] Seamless integration	*It's really seamless to use. And that's not the case with many apps. If you have to type something first, that's just impractical. Then you can just go and look for a toilet, then you don't need the app.* (User 13)	*I just use the app and go get fuel. It's that simple. And if there was an additional step, then it wouldn't be making it any easier than having somebody in your car with you. ... That seamless [integration] gives me a lot of freedom that I can just participate in the daily life on my own.* (User 8)	*You know these diabetes sensors? Some of them make a sound. We were at a presentation once and one of my colleagues had one of these and it beeped the whole time, and she was so embarrassed. A sensory trigger would have made it much easier for her.* (User 2)	Not applicable
[DP2] Bilateral interaction	*When we built the app, we built it to remove the human, and there was a reason for that, because people usually don't like to ask for help. ... But what we also see now is, that sometimes there needs to be more human interaction, because information gets lost or is not correctly understood by the petrol station staff.* (Provider – FuelAssist)	*Not applicable*	*The idea of having a two-way communication with someone inside the petrol station is priceless. Because otherwise the only way for you to communicate is by horns beeping and shouting out of the window, which is just embarrassing.* (User 8)	*What I really appreciate is that I can share the sensor data and health evaluations with my doctor through the app. So, my doctor already has a good overview before I even arrive, which makes our appointments more focused. I feel more understood and taken seriously, and I think it helps them too, because they can prepare better.* (User 17)
[DP3] Differentiated information	*The app helps me a lot, because I can just see where the barrier free toilets are.* (User 12) *That's one of the most important things for people with [constraints], preparing for travelling. ... If you know beforehand, for instance, the path is like this or that, then the individual is not totally nervous, and this makes life better.* (Provider – EasyRest)	*I always live with this uncertainty when being out with friends. And the additional information I get from the app simply gives me back a bit of freedom, which makes me more self-determined.* (User 4)	*If you have a constraint, that's always in the back of your mind. ... When you're out, you don't always can catheterize, let alone that you have access to an accessible toilet. ... [Additional information] will help me to have a certain level of security if I look at the app and see, the four hours are up, but my bladder still has 200 milliliters to fill, I'm still safe. That means I can spend another hour chatting with my friends, and I do not need to go home yet.* (User 6)	*For one thing, the better the app, the safer I feel, because I sometimes rely on the information I get, especially when I'm on holiday or when I'm simply in areas where I don't know my way around and then I simply have bowel movement problems, which sometimes leads to a certain panic when you don't know where the toilet is, where you have to go and that, so, with the app I feel much, much safer. It's helpful for my mind.* (User 12)

[DP4] Contextual personalization	*I'm trying out different biologics, and there are phases when everything really feels normal again – and then suddenly there's another flare-up, and so on. The app needs to take that into account and learn from it, because when you finally have a period of relief, unfortunately, it often doesn't last very long.* (User 14)	*In the profession I'm aiming for it's certainly not realistic that I can always go to the toilet straight away, because I might be in meetings, or on a ward round or whatever. It is therefore important to at least be able to switch it of somehow, so that I do not get any more notifications.* (User 6)	Not applicable	Not applicable
[DP5] Environmental adaptability	*We cannot force a patient to not move all day. Yes, then the measurement would be as good as possible, but the patient is not flexible. ... We want to enable flexibility in everyday life, whereby the* user *can also drive around, move around ... So, we must deal with an error rate.* (Provider – BladderSense)	*If I am in a hurry, and the app doesn't work as it should, that's an additional stress factor. That's annoying and might even stop me in my independence.* (User 14)	Not applicable	Not applicable
[DP6] Functional fallback	*... My God, you're describing my worst nightmare. I think if the app failed, then we'd all just have to go back to the old way. Which seems really like old-fashioned and such a bizarre way to do it. Now that we have the smoothness of an app that does it all for you.* (User 8)	*Most people who use this app are dependent on it, their quality of life depends on it. And the peace of mind that fallback options provide, especially for people with chronic illnesses or spinal cord injuries, is incredibly valuable.* (User 12)	Not applicable	Not applicable

About the Authors

Katharina Kneissel is a research associate at the FIM Research Center for Information Management and the Branch Business & Information Systems Engineering of Fraunhofer FIT. She is also pursuing her PhD in information systems at the University of Bayreuth. Her research focuses on digital innovation and digital transformation at the intersection with sustainability, with a particular emphasis on social sustainability.

Antonie Lockl is a research associate at the University of Bayreuth, where she also received her PhD in information systems. Previously, she worked as a researcher at the FIM Research Center for Information Management and the Branch Business & Information Systems Engineering of Fraunhofer FIT. Her areas of interest include digital transformation and twin transformation.

Anna Maria Oberländer is professor for information systems and digital transformation at the University of Bayreuth, deputy academic director of the FIM Research Center for Information Management, and holds a leading position in the Branch Business & Information Systems Engineering of the Fraunhofer FIT. Her focus in research, teaching, and transfer is on understanding and shaping digital transformation, digital innovation, and twin transformation in established organizations.

Michael Rosemann is the director of the Centre for Future Enterprise and a professor of information systems at the Queensland University of Technology. His areas of research are business process management, innovation systems, and trust. He has authored/edited 12 books and published extensively in the information systems field, including in journals such as *MIS Quarterly, Journal of the Association for Information Systems, Journal of Strategic Information Systems,* and *European Journal of Information Systems.* He serves as the vice president of Strategic Partnerships for the Association for Information Systems and is also the honorary consul for the Federal Republic of Germany in Queensland.