Resilience to Disruption: Accessible Navigation for People with Visual Impairment

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Abstract

People with visual impairments (PwVI) increasingly rely on digital navigation tools to travel independently, yet these tools misalign with the lived realities of navigating unpredictable urban environments, especially during severe weather events. Drawing on a journey mapping workshop, we explore how PwVI combine mobile apps, Orientation and Mobility (O&M) training, and human assistance to build flexible routines that adapt to recurrent disruptions, and prioritize predictability, safety, and confidence over speed. We argue that digital navigation technologies should support resilience through considering interoperability and designing for routine breakdown and multiple temporalities. We further articulate critical design considerations to better align accessible navigation with the everyday practices of PwVI.

CCS Concepts

• **Human-centered computing → Empirical studies in accessibility**.

Keywords

Embodied Interaction, Navigation, Individuals with Disabilities, Assistive Technologies, Qualitative Methods

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1 Introduction

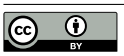
Digital navigation tools are increasingly central to how people with visual impairments (PwVI) travel independently. Yet research shows that these tools rarely align with PwVI's lived realities of navigating unpredictable urban environments [18, 28], especially during severe weather events. Snow and ice, construction and transit irregularities, wind and urban noise, and routine technical or digital breakdowns disrupt travel in ways for which existing digital tools offer limited support. Existing design imaginaries used by navigation tools often optimize for shortest time and seamless turn-by-turn routing, and ignore the situated practices of PwVI that blend technology, embodied skills, and social support.

Prior HCI and accessibility research has explored the promises and limits of navigation technologies for PwVI, including GPS-based guidance, computer vision, and beacon systems [15, 17, 39, 54, 61]. This scholarship has emphasized persistent uncertainties due to incomplete data and weak integration with transit or urban infrastructures [15, 39, 54]. Studies also show that mobility strategies differ significantly across familiar and unfamiliar routes, in relation to cognitive load, uncertainty and stress [17, 61], and depending on whether an individual is travelling on their own [6, 73].

Further, research has documented how Orientation and Mobility (O&M) training equips PwVI with embodied strategies, such as listening for traffic flow, interpreting tactile cues, or rehearsing routes, that remain foundational even when digital tools are available [3, 37]. What remains under-specified, however, is how these heterogeneous supports (digital tools, O&M, and human support) are used together, particularly when PwVI face disruptions like severe weather, and what this implies for the design of accessible navigation.

We address this gap through a journey-mapping design workshop with eleven PwVI, focusing on trips that participants undertook independently when faced with severe weather events. Participants shared details about their recent and typical journeys across pre-trip planning, in-trip decisions, and post-trip reflection. They further articulated the anticipatory redundancies they prepare, the in-situ adaptations they perform, and how their O&M skills fit into these practices. Our analysis shows that participants routinely plan for breakdowns, braid different supports, and prioritize predictability, safety, and confidence over speed.

The paper makes three contributions. First, it characterizes accessible navigation as relational work that looks to build resilience.



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Mobile apps, O&M practices, and human assistance are all continuously assembled (and re-assembled) to maintain a viable "navigation space" [73] under unpredictable or disruptive conditions. Second, it reframes breakdowns as routine, rather than exceptional, and argues that functional interoperability is a mechanism through which resilience is enacted. Third, it argues for accessible navigation to go beyond efficiency metrics (such as speed) toward supporting redundancy and multiple temporalities, including temporal interoperability. Together, we propose resilience in navigation as a relational concept that centres the work of anticipating, absorbing, and repairing disruptions through the braiding of digital tools, O&M skills, and human support, and argue that we should consider it to be an explicit goal when designing for accessible navigation.

2 Related Works

Digital navigation and wayfinding for people with PwVI is at the intersection of personal mobility practices, urban infrastructures, and assistive technologies. In this paper, we are specifically concerned with how these systems and practices hold up under disruptions. We use navigation to denote the "task of people moving through their environment to achieve a destination" [34], and wayfinding to denote embodied, situated practices of orientation and movement [34, 35, 62, 69–71]. We use the paired phrase "navigation and wayfinding" when discussing their interplay. We organise this section around three strands of relevant scholarship: navigation and wayfinding technologies for PwVI, including the persistent breakdowns and uncertainties; research on integrative navigation strategies; and disability and crisis scholarship on disruption and resilience.

2.1 Navigation & Wayfinding Technologies for PwVI

Existing research shows both the promise and limitations of digital technologies in navigation and wayfinding for PwVI, spanning beacons, computer vision, and GPS-based guidance, alongside traditional aids such as white canes. For example, prior studies have shown that navigation in smartphones (through GPS) was a major reason for their adoption and use [47–49]. However, adoption of newer technologies remains fragmented with many systems stalling at the prototyping stages [39, 54], raising questions about the sustainability and usability of technological innovation when conditions are unstable or expectations about the environment do not hold. Reviews of urban navigation tools [15] similarly find that while GPS-based and sensor-driven tools can offer new affordances, the effectiveness of these tools is undermined by environmental disruptions (e.g., construction or weather), incomplete data, and weak integration with broader mobility systems. Empirical accounts emphasize persistent uncertainties even when tools function as intended due to broader ecological factors [6, 80], such as severe weather [11, 41], leading to PwVI finding strategies to substitute for, or temporarily abandon, these tools. Further, the design of navigation systems has been found to rest too heavily on standardized assumptions, overlooking the diversity of user needs across disabilities and use cases [21]. In doing so, such designs result in partial supports and reproduce a narrow conception of wayfinding as a purely technical problem rather than an embodied and situated practice [9, 18, 21, 61] that must remain robust in the face of routine disruptions. We build on this work by treating breakdowns and environmental uncertainty not as exceptions but as routine conditions under which navigation technologies must operate.

2.1.1 Familiar vs Unfamiliar Environments. Research on navigation for PwVI has shown that the strategies employed vary significantly depending on the context of travel. Mobility in well-known settings is often anchored in stable spatial knowledge and repeated exposure, allowing individuals to move with reduced cognitive load and adapting to minor day-to-day disruptions [18]. In contrast, unfamiliar environments amplify uncertainty and place greater demands on planning and situational awareness. Navigating new routes has been found to require the integration of multiple information sources, from digital tools to transit schedules to social interactions, in order to mitigate disorientation and maintain a sense of control [9, 61]. While technologies can assist in wayfinding, they cannot fully substitute for the anticipatory practices PwVI employ, such as rehearsing routes in advance, asking for assistance, or adapting strategies mid-journey [61].

The divide between familiar and unfamiliar environments brings into focus a tension in wayfinding research: the extent to which mobility depends not only on technological systems but also on the embodied knowledge and adaptive practices of PwVI [2, 9, 18, 61]. Technologies and spatial familiarity can reduce uncertainty, but they cannot fully substitute for the skills that underpin independent travel and facilitate resiliency when faced with disruptions [11]. Foundational O&M practices, such as interpreting tactile and auditory information, using a cane in varied contexts, and maintaining situational awareness, remain essential for navigating both predictable settings and disruptive, unpredictable environments.

2.1.2 O&M and Wayfinding. O&M training teaches PwVI how to navigate safely in diverse environments. O&M skills are central to independent navigation for PwVI, and they work alongside — not in place of — digital tools. PwVI rely on low-tech aids such as the white cane, combined with highly personalized strategies cultivated through O&M training, to negotiate both familiar and unfamiliar environments [14, 37, 77]. These strategies are flexible and adaptive: individuals interpret environmental cues, adjust their movements to respond to situational demands like crowded sidewalks, unexpected obstacles, or variable weather, and constantly refine their mental maps with new experiences [26, 77]. Even when technological aids such as GPS-based applications or smartphone navigation tools are available, PwVI routinely supplement this information with personal knowledge and real-time judgment [77]. For example, route guidance provided by technology may lack the granularity needed to account for temporary or new obstacles or hazards, forcing individuals to rely on their own senses, memory, and skills to navigate safely [11, 76]. O&M skills, as well as lived experience, enable PwVI to safely and successfully reach their destination, or inform decisions to discontinue a journey even in moments when technology supports are not working as intended or disruptions in the physical environment make travel more difficult [11, 26, 77]. Taken together, this work positions O&M skills and lived mobility expertise as important resources for navigating disruptions.

2.2 Integrative Strategies of Navigation

For PwVI, technology is rarely the sole tool guiding navigation. Instead, it becomes woven into the routines that structure everyday life. Scholars in HCI and accessibility research have consistently shown that digital tools, when adopted by PwVI, are not standalone fixes but parts of practices that combine technology, embodied skills, and social negotiation [3, 17, 19, 26, 33, 44, 66, 68, 76]. This framing is particularly important for navigation, where technologies are deployed not as singular aids but integrated as resources that support the recurrent, adaptive strategies that PwVI use to move through the world. Digital tools may be thought of as secondary tools that are used in combination with white canes, guide dogs, or other supports to facilitate or enhance travel [47, 48, 51]. While a navigation app may provide directions and guidance, PwVI are also integrating information and knowledge from many sources, including auditory cues, tactile cues, past experiences, and mental maps [8, 29, 30, 32, 51].

Technological assistance is used to sustain, maintain, and support routines and skills that make daily life, and movement in particular, predictable, manageable and resilient [11, 68, 76]. PwVI describe habitual embodied heuristics, such as "just let the cane hit it," or "always being in back-up mode" that provide reliable ways of encountering the environment [11, 76]. These strategies are not improvised each time but embedded in daily practice, and digital tools and information can be used to complement and integrate with these practices [68, 76].

At the level of daily travel, PwVI often use multiple applications or tools rather than relying on a single system. They often adapt mainstream apps such as Google Maps in situ, switching between tools to access specific information and layering digital guidance with tactile cues or support from others, creating what can be described as a "navigation space" [28, 73]. Real-time narrative guidance can also be absorbed into the step-by-step flow of indoor navigation, effectively blending with routine mobility practices [17]. Technologies succeed not by replacing embodied routines but by embedding themselves within them. Context also shapes the routines through which technology is mobilized.

Across this literature, integrative navigation strategies are thus understood as a way for PwVI to make everyday mobility viable. However, these existing accounts focus on routine mobility or evaluate specific technologies, and are limited on how integrative strategies are mobilized when navigation is threatened by severe disruptions such as severe weather, construction, or technical failures.

2.2.1 Wayfinding & Temporality. In discussing how PwVI use technology to navigate, especially the routinized aspects of these practices, it is worth considering the role of temporality. As defined by West-Pavlov [74], temporality is the state of existing within or having some relationship with time. In HCI scholarship [25, 74, 75], interest in and considerations of temporality have shifted from a focus on optimization to a consideration of time as a factor in design, and to design projects which consider different conceptions of time. Through this "third wave" of how time and temporality are considered in HCI, there is expected to be an emergence of research that increasingly considers flow, pace, and rhythm in addition to objects, things, and artifacts [75]. Indeed, some existing research has begun looking into how to consider multiple temporalities in navigation, focusing on aspects such as beauty and quietness, and the potential benefits of doing so [1, 55].

For PwVI in particular, considering alternate temporalities in navigation and wayfinding may be of particular importance, especially when disruptions slow travel or introduce new uncertainties. Within Disability Studies, existing research has looked into the concept of crip time, which refers to the fact that people with disabilities may need additional time to complete tasks or may even have a non-normative experience of time, since they do not lead what is considered a "normal" life [24, 31, 81]. As Samuels [60] writes, crip time often necessitates adapting to new or non-normative rhythms and patterns and potentially involves taking breaks even when they are not otherwise desired. In the context of navigation and wayfinding, these notions of crip time may conflict with the efficiency focus of most digital tools.

2.3 Disability, Disruptions, and Resilience

Research on disability and disruption shows that vulnerability is less about impairment and more about the social and infrastructural contexts in which people live [11, 53, 63, 64]. Analyses of extreme weather and earthquake events reveal that disabled and non-disabled people cope similarly; barriers arise when emergency systems, information channels, and the built environment fail to accommodate diverse users[11, 53, 63, 64]. For people with disabilities, being resilient when faced with a disruption, such as severe weather, a physical obstacle, or malfunctioning software, requires not only enduring the disruption itself, but also having prepared for a disruption in advance or expending extra, often unseen, effort to find or create an accessible workaround or solution [11, 57, 64].

For many people with disabilities, planning for disruptions, which includes looking for available tools and strategies, becomes integrated into regular routines [11, 53]. For PwVI, this preparatory and anticipatory work often takes the form of rehearsing routes, calling ahead to a destination, or looking for more information online [20, 22, 76]. Following accounts of resilience in disability studies as a relational product created from networks of resources, relationships, and community [58], we study PwVI's responses to navigation disruptions as work of assembling and re-assembling heterogeneous supports to sustain safe, predictable, and self-directed travel under adverse or shifting conditions.

Building on this framing and on the prior sections' focus on navigation technologies and integrative strategies, the next section details our journey-mapping study of PwVI travelling during severe weather, examining how they anticipate, manage, and recover from disruptions across pre-trip anticipatory planning and in-trip adaptations.

3 Methods

This study forms part of a multi-year research program on crisis informatics and severe weather conducted by an interdisciplinary team of HCI and disaster studies scholars. We focused on PwVI because their needs remain critically under-addressed in the design of navigation technologies in the context of severe weather events. Several members of the research team have prior academic and professional collaborations with disability and social service organizations that work with PwVI, positioning us to collaborate

with these organizations and engage participants ethically and accessibly. While a plurality of perspectives exist on terminology, in following guidance from individuals with visual impairment themselves and members of the research team and partner organization who work closely with the community, we use the term people with visual impairment or PwVI to refer to this community. Within the workshop, participants variously self-identified as blind, low vision, or partially sighted. In Table 1, we retain the terms participants used about themselves, and use PwVI as an umbrella term when discussing the group as a whole. For this study, we sought to understand the everyday needs and practices of PwVI as they travel during severe weather, and to examine how critical perspectives in HCI can inform the broader design problem of accessible navigation under disruptive conditions.

To investigate the everyday navigation of PwVI in the face of severe weather events, we conducted a design workshop hosted remotely via Zoom. Conducting the workshop online enabled participation without travel and allowed the use of accessibility features (e.g., screen-reader support and live captions). In total, 11 participants participated in the workshop, which took place in February 2024. Participants were recruited through a local blind service organization with established relationships to the community. Recruitment targeted adults who self-identified as blind or low vision and who travel independently at least some of the time. We placed no restrictions on mobility aids or transport modes. Participants included cane and guide dog users, as well as people who used or combined multiple modes of travel. Recruitment messages described the purpose of the study, what participation involved, recording practices, and that involvement was voluntary. Informed consent was obtained before any study activities began.

3.1 Workshop Structure and Activities

The workshop was conducted synchronously on Zoom on a weekend in February 2024, and lasted 3.5 hours. The two main sessions of the workshop lasted for approximately 40 minutes and two hours, respectively, with time provided for an introduction to the workshop, breaks, and a debrief for the participants at the end. The participants received a gift card as compensation for the time and energy they contributed to the research.

In line with guidance for accessible remote meetings [13, 36, 45], we: enabled live captions, ensured compatibility with screen readers and keyboard navigation, offered optional phone dial-in, and shared keyboard-shortcut guides in advance. Across sessions, one primary facilitator guided each group's discussion, while additional team members were available to provide support, offer prompts, and help field questions as needed. Zoom breakout rooms were used for small-group work. The facilitation plan was designed to keep the conversation accessible and on topic while allowing participants to steer toward experiences they considered most relevant.

Two core activities anchored the workshops:

(1) Framing discussion around navigation and wayfinding: In the first session, facilitators introduced key ideas about navigation and wayfinding with vision loss (e.g., multimodal sensing; interacting with transit systems; using digital tools) that were identified in previous phases of this research or in existing scholarship to create a shared understanding and identify any incorrect assumptions or incomplete ideas that the research team had. Participants then reflected on their own routines, experiences, and habits to challenge or add nuance to the researchers' understandings.
(2) Journey-mapping exercise: In the second session, participants walked through recent or typical trips step-by-step. Mapping frameworks were structured across pre-trip, in-trip, and post-trip phases. They identified the tools they consulted (e.g., weather or transit apps, GPS, remote assistance), the cues they relied on (auditory, tactile, spatial memory), and the points at which they changed plans or sought help. Facilitators probed for what information was missing, which alternatives were considered, how decisions were made, and what participants valued when choosing among options. The journey mapping exercise produced detailed accounts of in-the-moment reasoning around safety, timeliness, cognitive load, and cost.

Audio and video of each session were recorded to capture the conversation and any references to on-screen content used during the journey-mapping activity, with the audio recordings subsequently transcribed and anonymized. Facilitators also produced field notes during and immediately after the sessions to document emergent themes, group dynamics, and potential follow-up questions or points of clarification. These notes supplemented the recordings and supported the analysis.

3.2 Data Analysis

To analyze the data collected, the research team engaged in reflexive inductive thematic analysis [4, 5]. To begin, three researchers from the team each independently coded the workshop material to generate a preliminary set of codes that reflected their interpretation of the data. The team then met to compare interpretations, consolidate overlapping codes, and develop a shared, flexible codebook to support reflexive engagement. Analytic memos and regular sense-making meetings with the broader research team supported articulation and refinement of themes, ensuring that the final analysis remained grounded in participants' perspectives and experiences. In total, four overarching themes were identified, which represent the varied ways that participants navigate independently.

4 Findings

4.1 Mobility and Transportation Mode-switching

Across workshop groups, participants described using a flexible combination of transportation modes to meet varying mobility needs. Walking with a white cane or guide dog supported everyday independence, while public transit, paratransit, and rideshare services served as complementary options when weather, distance, timing, fatigue, and other navigation and wayfinding challenges made walking impractical. Further, participants routinely made switches in modes on the day of travel to ensure timely and safe arrivals and returns, with the choices balancing independence, costs, safety, and punctuality.

Walking was the preferred mode of transportation for many participants when weather conditions allowed. P11 noted that having

Table 1: Participants & Demographic Information

P ID	Age Range	Disability Status (self-described)	Current Occupation	Type of Phone Used
P1	55 to 64	Blind	Teacher/Musician	iPhone
P2	25 to 34	Disabled	Customer Care	iPhone
P3	35 to 44	Permanent, blind	Public servant	iPhone
P4	55 to 64	Totally blind and profoundly deaf in one ear	Human Resource Coordinator	iPhone
P5	35 to 44	I have sight loss	Front line Social Services	iPhone
P6	*Not disclosed*	Visually impaired, has some sight	Financial Services	iPhone
P7	65 or Over	I have lost all my sight and am now totally blind	Retired	iPhone
P8	45 to 54	Permanent	Unemployed	iPhone
P9	35 to 44	Permanent disability of visual impairment	Specialist of Advocacy and Education	iPhone
P10	55 to 64	Totally blind, no usable vision	Digital Accessibility	iPhone
P11	35 to 44	Totally blind	Self-Employed	LG

weather information "by the minute…would change my walking plan so I would walk all the time instead of just sometimes," indicating that having more granular weather information would make it easier for them to decide to walk and less often avoid walking as a precaution. Participant descriptions of walking included mentions of the tools and strategies they needed to get to their destination safely, including canes and guide dogs. P1 said they use "a light cane" because it was easier on their wrist, but said it can be a trade-off in winter or when there is inclement weather. When there was ice, "you should have a metal, a good, heavy-duty cane so you can plant it down and not fall down" (P1). High winds also complicated cane use; the same participant described that with their lightweight cane, "[if] there's a huge gust of wind…I can hold [my cane] up, and it almost blows out of my hand across the street." Some participants also explained that a guide dog was an integral part of their mobility — "my guide dog…helps me, you know, get from point A to point B," and having the dog gives them "the advantage on somebody that is using a cane" because "the dog will always find an entrance of some kind" (P10).

Snow piled up on sidewalks could make walking impossible: during a storm, a participant found that snow plows had blocked the curb cuts and bus stop so completely that they "had to be physically in the road in order to get myself either back on a sidewalk or to cross the street" (P5). Despite these challenges, many still prioritized walking; one explained, "if there was no [snow] in the forecast, my preference would be to walk…I kill two birds with one stone; I give the dog some activity…and I can plan my timing better, whereas if I schedule [paratransit], I'm dependent on their timing" (P11).

Buses, streetcars, subways, and regional trains enabled longer trips. For those living away from the city, public transit was the preferred means of travelling. One participant, whose doctors were "in the next city over," described using multiple types of public transit: "I would hop on a [regional] train, and then from there, I would hop on a bus" (P9), thus chaining different modes of transportation together. Participants noted various reasons for opting not to walk to a destination, and when they had decided not to walk somewhere, they also sought to minimize the amount of walking involved with other modes of transportation. As one participant stated that they would "[try to] find the route with the least amount of walking, even if it will take me longer" (P6), in instances where they did not want to walk because they were going to an unfamiliar location. Participants frequently consulted navigation apps, such as Google Maps, to plan their routes and check schedules, sometimes rechecking transit times just before leaving home or when transferring between types of transit. Bad weather or construction sometimes prompted mode switches; one participant said they would "walk to the bus stop" if there was snow, but "if it is raining, then obviously I would directly catch an Uber," (P8).

Public transportation stops were also described as easy meeting points or a shared reference point for participants to meet their friends and help each other get to a specific destination: "The other option is probably just to ask one of my friends or somebody who [I am] meeting to meet me at the bus stop instead, and so we just walk there together," (P6).

4.1.1 Paratransit. Paratransit is a transit service provided by a municipality, specifically for disabled people. In the city where most participants lived or regularly travelled, this service was available after formally applying to the city's transportation authority. Several participants described using paratransit specifically for medical or time-sensitive appointments and when bad weather was expected.

Paratransit was noted as being useful as it specifically offers a free door-to-door service. As one explained, "I would probably schedule [paratransit], right?…if there's any chance of snow…I've had a really bad fall…so I don't ever want to experience that again," (P10). They further explained that construction near their destination would lead them to choose paratransit because "I have to plan the day before, and if there's construction, I don't like it," (P10).

While advance booking — participants booked appointments up to a week in advance — increased reliability, difficulties in timing a trip due to variable pick-up windows remained a persistent constraint. This was due to the service picking up and dropping off multiple individuals at many different locations, leading to uncertain pick-up times:

"You say you want to get there for 2:30 and they drop you off an hour before that, that does happen, and you're thinking to yourself, I could be doing so many other things, right?" (P5).

Recently introduced app notifications had improved this experience by "notify[ing] you 10 minutes or so in advance when your ride is coming," (P7). While this helped timing, it did not eliminate uncertainty, especially for returns after appointments: "you might see your doctor at 2:20 and be done by 2:30, and you might not get the return vehicle for another hour or even longer to go home," (P7). In these instances, participants often switched to public transit, a taxi, or rideshare for the trip home.

4.1.2 Ridesharing. Private vehicles, such as taxis or rideshare services (e.g., Uber or Lyft), filled gaps when public transit or paratransit were unreliable, unavailable, or overly inconvenient, or when participants were tired after appointments. One person said that although they normally used public transit to get to appointments, meetings, or personal events, "coming back, I would not want to take any extra obstacles…I would probably take like Uber or Lyft, or like a door-to-door transport," (P2). Another kept taxi rides to a minimum because of cost, but acknowledged, "I would rather just pay the amount of money to get back home if it's going to take me a long time" (P3), especially when paratransit could not pick them up sooner. Others treated rideshare as a last resort: if the roads and sidewalks were blocked by snow, they "would take an Uber to [the] nearest bus stop, and from there I would take a bus" (P8), balancing convenience and safety with cost.

These accounts illustrate how the PwVI involved in this study used multiple transportation modes, often chained together. Walking and public transit were preferred for their affordability and facilitation of independent travel, but paratransit and rideshare became essential when weather, construction, distance, or scheduling compromised safety, punctuality, or convenience. Participants constantly assessed their conditions — weather, construction, timing, and personal energy — often switching modes on the day of travel, to ensure they could reach appointments and return home safely. This evaluative work involved significant planning and anticipatory activities that allowed our participants to adapt to changing contexts, unknown obstacles, and other disruptions.

4.2 Disruptions: Physical, Auditory, & Technical

Throughout the workshop, participants described how they encountered disruptions while travelling that reduced the usefulness of specific strategies and demanded in-the-moment adaptation. Their accounts clustered into three interrelated categories: physical obstacles in the built environment, auditory disturbances that interfered with orientation, and breakdowns or gaps in technical tools. We separate auditory from physical disruptions because auditory cues are a primary orientation channel for PwVI; weather and urban noise can therefore undermine not only comfort but the very sensing needed for safe wayfinding.

4.2.1 Physical Barriers: Snow, Ice, and Construction. The most frequently cited barriers were snow, ice, and construction. One participant recounted a winter outing to a pharmacy two bus stops away: "I'll go outside, the snow is clear. I'll just hop on the bus…but all the snow had piled up in front of the [accessible pedestrian signal] and onto…the dip to cross the street, so I actually could not get across the street…What should have been a ten-minute trip took me almost half an hour" (P5).

Others echoed this frustration; plows clear roadways yet leave "a bus stop blocked off…This is our road" (P2). Participants also struggled with deep drifts at curb cuts and wanted better information about walking conditions, for example, advance information about sidewalk passability to choose safer routes. P2 also suggested that "it'd be helpful if there was like a way to see, like how clear the walking paths are," so they could choose a safer route.

Construction sites compounded these issues by blocking sidewalks entirely and forcing detours. A participant described arriving at an intersection only to be told by a worker that the "sidewalk['s] closed" (P10), so they had to turn around and try to identify an alternative route. P10 continued that in the downtown part of the city, "they were about to close even their scaffolding…closing pedestrian as well as street access. It's really crazy, and it's always a struggle to get around." Closures are rarely announced, and in unfamiliar areas, the effect of closures can be disorienting: "If I'm navigating alone, and you have all these closures…I definitely get turned around. You become adaptable; you either find the way, turn back around, or you find a way around, or you use technology" (P9). These physical barriers increased travel time, elevated risk at crossings, and often triggered mode switches or requests for assistance.

4.2.2 Auditory Disruptions: Wind and Urban Noise. Participants stressed that hearing is crucial for safe travel, and wind and noise routinely undermined it. High winds "affect sound, so when I'm trying to cross the street, I'm not always sure if the traffic is in my favour" (P10), and gusts blew debris that masked obstacles. The lack of wind information in mainstream weather apps also exacerbated this problem; P10 continued "I wish…it would give the wind reading for that hour, and it doesn't."

Mechanical noise from work crews posed an even more serious threat. A participant encountered a sewer-cleaning vehicle that was "very loud, and I couldn't tell if it was something on the sidewalk or if it was on the road…It just drives you crazy, and you can't move. It freezes you," (P1). They stood still rather than risk walking into machinery until a passerby offered assistance. Describing the emotional toll of such situations, P1 said the noise "hurts. It leaves a pit. It makes my heart feel like, ah…you don't know anything could happen…it's very scary when there's loud noises like that on the street and you're out there." These reports show that auditory disruptions not only obscure situational awareness but also induce fear, leading travellers to halt movement until help arrives.

4.2.3 Technical Mismatches and Breakdowns. Navigation tools sometimes failed in critical ways. Participants relied on weather apps, transit apps, GPS, and remote assistance services like Be My Eyes, yet the information often lacked the granularity needed to avoid disruptions, producing a mismatch between the physical environment and what apps described. Participants asked for proactive, accessible alerts about blocked sidewalks, snow-covered bus stops, or elevator outages: "I don't know if it already exists, but to have a clear notification method…would be nice" (P4). With respect to city construction, they asked for construction notices with timeframes: "how long the construction will go on…so that way we can navigate around it" (P4) would help travellers avoid detours. They also noted occasional map errors, such as instances where Voice Vista "doesn't recognize a particular street" (P7) that other apps identified. As mentioned earlier, live volunteer services also are not always effective; a participant found that when navigating construction, Be My Eyes volunteers could not also discern a safe path so the participant said they would instead "stop anybody [on the street] that will talk" (P11) to them.

4.3 Planning and Anticipatory Navigation

Planning and anticipatory work were central to our participants' navigation and wayfinding practices, especially how they prepared for and adapted to disruptions that they faced. Planning began well before departure and addressed unpredictable barriers such as severe weather and unreliable transit services. If paratransit, taxi, or rideshare services were needed to get them to their destination, they often booked their ride a day or more in advance. As noted earlier, one participant mentioned that paratransit must be scheduled in advance to avoid being placed on a waitlist. Booking early provided a measure of control over a mobility system that could be unresponsive or delayed.

End times for appointments and events were often less predictable than start times, so day-of coordination with paratransit introduced variability. As one participant described: "When we are waiting for the [paratransit] they may not…come for half an hour [or] one hour…we need to make sure we have space, safe space [to wait]" (P3).

Further, during inclement weather, participants preferred to wait indoors: "With all that construction and the weird weather, not knowing if it's going to be rain or snow, I think for a half an hour, I just sit in the office and listen to my downloaded music, or check my mail with their Wi-Fi…or listen to news" (P1). These strategies reflect an explicit need to find secure, safe waiting spaces when timing remained uncertain.

Pre-journey planning also involved collecting detailed information about destinations. For important appointments in new locations, participants called ahead to confirm building layout details — which floor the office was on, how to reach the elevator, and how far it was from the entrance: "I would have called. When confirming my appointment, I would have asked the receptionist…are you on the first floor? Do I need to take an elevator? How far is the elevator from the entrance?" (P6). By asking these questions, they were able to get instructions that were tailored to their needs. Knowing what to ask was a learned skill developed from each participant's previous navigation experiences. Advanced details about the building layout reduced anxiety because it provided information about an unfamiliar indoor space. Digital tools were less useful in these spaces — if lost or disoriented inside a building, participants relied on nearby people rather than technology.

Planning extended to digital tasks preparation. Participants saved important contact information in their phone's address book (for e.g., doctors' offices or transit service providers). They downloaded offline maps to reduce mobile data usage, charged spare battery packs and programmed shortcuts in voice assistants for frequently used actions. Many assembled an app repertoire where they used multiple apps concurrently, for example, weather applications to monitor conditions, general mapping tools (Google Maps or Apple Maps) for route planning, and specialized audio-based navigation applications such as Voice Vista or Soundscape for orientation. While switching between apps could be cognitively demanding, individual applications or tools did not typically meet all of an individual's needs.

When planning, participants also considered personal health and energy. Some described previous appointments that included procedures which impaired vision or caused dizziness; in those cases, they arranged to be met by friends or used a rideshare service to get home rather than using public transit.

4.3.1 Familiar Versus Unfamiliar Routes. Participants distinguished familiar from unfamiliar routes. They noted navigating familiar routes with greater confidence and reduced cognitive effort. They leveraged stable physical cues, such as carpets, smells, tactile floor changes, and the typical location of reception desks, to orient themselves. As P9 illustrated: "a perfect example with my condo…they have a long carpet laid out to the elevators. Even using my cane and following along the carpet lets me get to the door. It's so difficult when it's a new location. So I know when I'm leaving an establishment to look for the rug at the beginning." Repeated exposure turned such cues into reliable design patterns that eased wayfinding.

Familiarity also extended to digital tools, as participants learned the idiosyncrasies of apps for specific contexts and proactively adapted to them. For example, P1 reported a consistent 10-metre early arrival announcement at a pharmacy and solved it by setting a personalized beacon: "So I set my own beacon…I'll go 10 metres before Shoppers Drug Mart…and I set a beacon there. Next time I go, I will ask to go to Shoppers Drug Mart beacon." In this example, by aligning the app to embodied spatial knowledge, the participant reduced future effort and error. Overall, in familiar contexts, participants noted that because they had already encountered and resolved issues, such as unclear instructions or inaccessible entrances, subsequent trips required less multitasking and error correction.

In contrast, unfamiliar routes demanded greater attention and focus. Participants combined technology and human assistance and remained vigilant for errors. P9 explained that when travelling somewhere infrequently: "It would be using technology or even using the assistance of people…getting in that vicinity, and then asking…what street I'm currently at. So it would be a mix of…technology and asking people…because of me…wanting to

get there on time, it'd be a little bit stressful…that cognitive load of thinking about where I'm going".

Uncertainty about route choices, bus schedules, and construction increased stress. To pre-empt disorientation, participants used multiple apps — general maps for transit times, specialized audio guides for orientation and voice assistants for quick questions. Some rehearsed routes at home using Soundscape's street mode to build a cognitive map: "There was a street mode in [soundscape] and we can go block to block…I know…on my right there is King Street…[the app] has two options…go forward or… backward. If I press Go it will…tell me which one is the next intersection, and which street goes left or right" (P8). Others used Google maps to identify transit routes with the least walking or fewest transfers. These previews mitigated the risk of closures, inaccessible sidewalks, and complicated directions.

4.3.2 Reliance on Past Experiences, Memory, and Sensory Heuristics. Through accumulated experiences, participants developed heuristics that reduced dependence on visual information. The same carpet-to-elevator example cited above illustrates how repeated exposure to physical cues created a familiar pattern. They listened for specific sounds such as concierge voices, elevator dings, or streetcar engines and noticed design patterns to orient more quickly in unfamiliar layouts: "my first strategy is to listen to see if I can hear concierge or security desk…for some reason, they always set up the station to the right of the entrance…if I don't hear any of that, then I listen for the [sound] of an elevator…and hope that there's another person around in case I can't operate the buttons" (P10). Recognizing these patterns lowered cognitive load and helped in decision-making. Further, it reduced reliance on technology.

Memory and specific experiences also shaped technology use. As previously mentioned, participants remembered app idiosyncrasies (e.g., consistent 10-meter offsets). Further, they knew which apps consumed more battery or data and planned accordingly, saved offline maps based on their experiences of poor connectivity, and selected apps based on context. For example, using Voice Vista for exploration and Be My Eyes for urgent tasks. Their past experiences thus coordinated tools they used, their tactics, and expectations before they left home. Overall, anticipatory work allowed in-situ coordination across apps and O&M skills, with the preparation also allowing participants to adapt as conditions changed.

4.4 Combining Digital Tools, O&M Skills, and Human Assistance

To navigate and wayfind effectively, independently, and safely, participants combine the use of digital tools (navigation and weather apps), Orientation and Mobility (O&M) skills, and support from others. They integrate these resources before and during trips rather than relying on any single solution. Digital tools are often chained in succession, while O&M provides the foundation for independent travel through interpreting environments, and human assistance supplied situational judgment when information is missing or ambiguous, especially in the face of unexpected disruptions.

Digital technologies were integral to planning and conducting trips, but they were used selectively and strategically. The limitations of these technologies required participants to learn their unique features and constraints and make decisions about when to switch to other technologies. Tools such as weather apps, GPS navigation, online transit, and virtual live assistant services enabled planning and decision-making that would otherwise be impossible. Yet, incomplete data, high cognitive demands, and technical constraints required users to constantly evaluate when and how to rely on them. When digital technologies failed, participants turned to alternative sources, such as "ask(ing) the next person" (P9) or using services like "Be My Eyes" to resolve uncertainty. Further, participants fell back on embodied O&M rules and skills they had learned. These decisions were primarily based on pragmatism and individual safety.

Participants stressed that technology could not replace O&M training, which they viewed as foundational to safe and independent travel. One participant observed that "you can't really depend on [technology] all the time. You still kind of need that orientation" (P9). They added that learning a new route was cognitively taxing: "with my vision deteriorating…just the cognitive load of learning a new route [is huge]. If it's a route that I learned…I'll still take the streetcar or a train." They stated that if the weather was bad, they would use a taxi or rideshare for an unfamiliar route. This indicates that one's confidence in their O&M skills determined how they integrated the available modes of transportation into their route. Further, O&M skills helped participants judge how to approach and when to avoid specific environments. P10 commented that they avoided descending to concourse levels in large buildings because open spaces make it "hard to find a location." Without walls or echoes, they could not orient themselves. In dealing with inclement weather, construction, and other disruptions, participants selected equipment based on conditions: P1 carried a "heavier cane" during winter, for example.

O&M training was the foundation of how PwVI operated as independent travellers. Yet, these skills also recognized when to integrate other strategies, like asking for assistance. When O&M skills were insufficient or inconvenient, participants emphasized that asking for help was part of effective mobility. Participants turned to friends, staff, passersby, cab drivers, or, when alone, remote volunteers (e.g., Be My Eyes) when information was missing, obstacles like construction arose, or technology failed to meet their needs. These interactions reduced cognitive load, increased efficiency, and, importantly, provided reassurance, but were contingent on participants developing strategies for when and how to ask. For example, a participant relied on Google Maps to walk from a streetcar stop to a clinic but found that the app "wasn't 100% accurate" (P6). They stopped a passerby and asked, "Do you see where…this clinic is?" who responded, "Yeah, go into...building number one". Another echoed this sentiment when describing how they dealt with a barricade of unknown size, they "might be reluctant to walk around that barricade because I have no idea what I'm dealing with…I might just ask somebody…Is there a safe way around the construction?" (P7). In each case, human assistance compensated when technology or O&M skills could not provide situational awareness or judgment.

Personal attitudes towards integrating help from others varied. P8 reflected, "I don't know if it's the stubborn man in me…I hated asking for directions," but explained that exposure to other PwVI taught him that "it just makes sense. It's okay…to ask for help." He now embraced what he called a pragmatic mindset: if someone ignored his request, he "just ask the next person," because his priority

was to "get from point A to point B." Many preferred to exhaust self-navigation and wayfinding options before seeking assistance, illustrating both a desire for independence and a recognition of when additional information is necessary.

Taken together, participants employed a "mix of technology and asking people" (P9) to navigate and wayfind effectively when faced with disruptions. P7 summarized the combining of tools and skills succinctly in saying they used technology to get into the vicinity, then "try to figure it out first and then take the next best option." Participants used digital tools, their own O&M skills, and help from others in combination to navigate and find their way on a daily basis. Summarized in Table 2, using these different strategies allowed them to successfully and safely deal with the disruptions they faced regularly.

5 Discussion

This study identifies four recurring practices in the ways people with visual impairments navigate urban environments in the context of severe weather events. First, mobility entailed switching between walking, transit, paratransit, and rideshare — choices that required continuous evaluation of trade-offs among punctuality, safety, independence, and cost. Second, participants engaged in extensive anticipatory planning, which involved gathering information and preparing redundancies. Third, navigation practices braided digital tools, O&M training, and human assistance. Digital applications were valuable yet had clear limitations, leading to intermittent and selective use. O&M expertise provided the basis for interpreting environments and sustaining independence, while human assistance contributed reassurance and situational judgment when other strategies faltered. Fourth, participants routinely absorbed environmental and technical disruptions through situated repair, that is, in-situ adjustments and adaptations. Together, these are the practices through which *resilience in navigation* is enacted: disruptions are anticipated, absorbed, and repaired via the ongoing reconfiguration of digital tools, O&M skills, and human assistance.

Based on these findings, we make three arguments. First, resilience in navigation should be understood as relational, enacted through anticipatory planning, situated repair, and interoperability across people and technologies. Second, breakdowns ought to be treated as routine rather than exceptional, prompting designs that support handoffs across apps and people and that preserve trip state during switches. Third, design should attend to multiple temporalities, including crip time, moving beyond efficiency metrics such as speed toward variable pacing, pauses, and redundancy that align with lived practice.

5.1 Resilience in Navigation

HCI and design scholarship has studied resilience, especially in terms of dealing with disruptions [40, 50], with recent scholarship arguing that design needs to go beyond the individual and instead take a relational [42] and ecological approach [65, 67] that considers dynamic interactions with the broader environment. Resilience in navigation for PwVI is relational and is the outcome of ongoing negotiations between a traveller and their environments, both social and material, for the resources needed to sustain safe, self-directed mobility under adverse or shifting conditions. Participants frequently noted strategies to maintain "safe" travel, and while existing scholarship has found that what is considered safe for an individual is intersectional and influenced by multiple aspects of an individual's identity and lived experiences [6, 6, 10, 12, 38, 56, 78, 79], the participants in this study focused specifically on safety as it relates to their visual impairment.

For participants, resilience was enacted through anticipatory planning, situated repair, and the braiding of heterogeneous supports — technical systems, embodied O&M expertise, and human assistance. This conceptualization aligns with constructionist accounts of resilience in disability studies, which locate resilience "in a network of resources including material resources, relationships, identity, bodies and minds, power and control, community participation, community cohesion and social justice" [58]. Importantly, such conceptualizations push back against ableist norms of speed or seamlessness — instead, it is the ability to (re)assemble supports and (re)distribute efforts to make a trip viable. In our study, we found that predictability, safety, and confidence were prioritized over speed; breakdowns were expected and prepared for; navigation unfolded over multiple temporalities; and interoperability — the capacity to hand off tasks, state, and intent across tools and people — was an important mechanism that made this resilience actionable across contexts. Here, we distinguish *functional interoperability* (shared representations and state preservation across tools, O&M skills, and other humans) from *temporal interoperability* (alignment with external rhythms and one's own pacing). Previous studies have found that integrative navigation strategies are an important part of resilient navigation for PwVI; having access to and combining multiple tools, resources, and information sources make it possible for PwVI to navigate differing contexts and environments [2, 14, 48]. This paper extends this understanding by considering how PwVI (re)integrate and switch between available tools, strategies, and skills to successfully navigate around and through breakdowns and disruptions.

5.2 Situated Repair: Routinely Attending to Breakdowns

For the PwVI in this study, technological and infrastructural breakdowns are common and, as described in the findings, structure travel-related routines. As detailed in Section 4.2, breakdowns across digital tools, physical infrastructures, and transit services are routine rather than exceptional for our participants. Breakdowns also regularly arise at the intersection of digital systems and physical environments, when digital information does not match on-the-ground conditions — for example, digital maps missing certain streets or alleys, being directed to doors other than front entrances, and other aspects of what is called the "last-few-metres problem" [59].

Negotiating breakdown is continuous rather than episodic for the PwVI in this study. Participants described how they planned for travel and anticipated breakdowns and disruptions, and created a viable "navigation space" [73] by combining digital tools, embodied O&M skills, and support from other humans (in situ or remote). This mirrors prior work on how PwVI co-constitute a common space with a human guide [73] and extends to consider a broader ecology of support spanning people and technologies. When any

Table 2: Disruptions and how participants prepare for and manage them. Symbols: ↔ = simultaneously used; → = next action.

Disruptions	Strategies
Weather disruptions (e.g. snow, ice, etc.)	*Before:* Digital tools (weather + navigation) ↔ anticipatory planning (check forecast, choose low-walking routes, book paratransit, identify safe waiting areas, select winter cane). *During:* O&M skills (cane/guide dog, safe-waiting) → re-route with navigation app → mode switch (transit, paratransit, taxi, rideshare) ↔ in-person assistance; may discontinue if unsafe.
Construction & transit disruptions (e.g. closed sidewalks, delays, etc.)	*Before:* Navigation apps (preview routes, minimize transfers) ↔ anticipatory planning (check notices, call ahead, add buffer time, find safe waiting areas). *During:* O&M re-orientation ↔ in-person or remote assistance → re-plan with navigation apps or mode switch (transit, paratransit, taxi, rideshare); may discontinue if unsafe.
Auditory disruptions (e.g. wind, machinery, echoing spaces, etc.)	*Before:* Limited support from weather apps ↔ O&M preparation (avoid known noisy spaces; choose heavier cane). *During:* O&M skills (stop, assess, safe-waiting) → wait for noise/wind to subside → request in-person assistance → resume cautiously.
Technical mismatches & issues (e.g. GPS drift, last-few-metres, etc.)	*Before:* Assemble app repertoire (maps, audio navigation, transit) → customize tools (adjust waypoints, download offline maps, choose low-walking routes) ↔ call destinations for access info ↔ O&M heuristics. *During:* O&M skills (cane/guide dog, mental maps) ↔ embodied knowledge → in-person or remote assistance (e.g., Be My Eyes) → fallback to O&M if digital tools remain unreliable.

support breaks down, individuals adapt, adjust, and account for the disruption — situated repair — to support the maintenance and reconstitution of a viable navigation space, allowing them to continue their journey despite the disruption.

Navigation routines are integral to this maintenance and reconstitution work. Routines integrate the "backup mechanisms" or "workarounds" required to support resilience in navigation by mitigating the impacts of breakdowns [40]. While the breakdowns described are deviations from an *ideal* navigation experience, they are not rare occurrences; breakdowns in digital and physical environments and infrastructures are considered a typical — though less than acceptable — part of navigation. As described in Section 4.3, through planning, PwVI routinize anticipatory actions that explicitly account for likely breakdowns and enable in-situ re-distribution of work when conditions change. These routines also encode predictable mismatches at the digital–physical seam, allowing PwVI to compensate for inaccuracies, remember app idiosyncrasies, and treat any "uncertainties" as expected. With respect to modes, routines structured switching to preserve predictability and safety — patterns that reflected a need for confidence and control. Finally, functional interoperability is a practical mechanism through which routines absorb breakdowns. Effective travel depends on the ability to hand off tasks, trip state, and intent across digital apps, O&M techniques, and people without losing context. When systems fail to support such handoffs or silently change features that do not integrate with existing routines, it can lead to additional cognitive work and risk.

5.2.1 Designing for Routine Breakdowns. To support the navigation of PwVI, it is vital that design respects existing routines instead of disrupting them. Any changes in features, even when purported to be improvements to functionality, can disrupt carefully assembled workarounds that users rely on. Participants' accounts make clear that such surprises increase cognitive load in the moment and force a costly, in-situ "re-constitution" of the navigation space. Therefore, care should be taken to ensure that any updates that could affect navigation are communicated to users so they can suitably adjust their routines.

Additionally, designers must consider interoperability, which is the primary mechanism by which routines absorb these routine breakdowns. Digital tools should support graceful hand-offs when users switch primary strategies (e.g., app to person, app to O&M skills, app to app) and must preserve trip state and intent both during and after a switch, so that when the user returns to the app, they are not required to start over. In doing so, designers would better reflect the reality of how the PwVI in this study use navigation tools in their everyday life. Further, because breakdowns are expected, design should make redundancy easy to implement (e.g., battery-aware modes, multi-app chains, low-friction offline states). Together, these commitments enable seamful interaction [72]: the seams are acknowledged and made usable rather than hidden in ways that disrupt routines in moments of failure.

Thus, designing for breakdowns means recognizing routine disruptions across digital tools, built environments, and transit services, and enabling users to fluidly redistribute work within their existing configurations — through updates that preserve routines or communicate disruptions, graceful handoffs, and built-in redundancy.

5.3 Multiple Temporalities and Crip Time in Navigation

For PwVI, travel is organized around the rhythms of planning ahead, pausing, and adapting to disruption. Participants routinely left

early, built in buffer time, and layered multiple tools to maintain confidence while travelling. They also rerouted around construction or paused mid-journey to reorient or wait out noise or bad weather. Navigation is thus less about efficiency and minimizing clock time than maintaining resilience and safety in the face of fluctuating conditions and contexts. Travel was a result of overlapping tools and skills, with built-in redundancy, rather than the seamless linearity that navigation apps imagine and depict in their user interfaces.

Foregrounding these practices makes clear why an efficiency paradigm is misaligned with the lived experiences of PwVI. Within HCI, temporal perspectives have slowly shifted away from first-wave logics of clock time and optimization toward design approaches that recognize multiple temporalities [75]. Whereas the metrics used by navigation apps often centre around clock time and speed, the PwVI in this study evaluate routes based on predictability, safety, and confidence. Sometimes modes were chained in "inefficient" combinations (e.g., rideshare and transit) that prioritized safety needs. These and similar practices seen in the data echo Quercia et al.'s [55] demonstration that routes emphasizing qualities like beauty or quietness add little extra time but greatly improve the experience, and Agrawaal et al.'s [1] argument that the obsession with "moving fast" can erode attachment to place, which is often central to PwVI's practices.

Participants' adjustments also reflected what disability scholars describe as crip time [24, 60]: the subjective experience of time and the ways of inhabiting time that normalize slowness, rest, and detour, reframing delay as a legitimate mode of living. In our data, crip time appeared in deliberate pauses (e.g., waiting for a break in a snowstorm), early departures to absorb uncertainty, and mid-journey pauses to request assistance or wait for loud noises to subside. These moments align with calls for pacing technologies and design to go "beyond the clock" [24, 31].

When technologies failed to acknowledge multiple temporalities, there was clear frustration, highlighting the cost of navigation systems assuming a single, seamless temporal experience without disruptions. However, the lived temporality of PwVI depends on rerouting and, for example, locating specific, accessible points of entry. Such mismatches exemplify the lack of consideration for experiential qualities of time [23], and what recent HCI work on multiple temporalities [1, 24, 25, 46] encourages us to treat as a core design material rather than a flaw. Navigation for PwVI involves negotiating multiple temporalities: clock time (transit schedules, appointment times) and crip time (pauses, detours, waiting). Existing systems privilege the former, leaving users to stitch together their own workarounds to accommodate the rest. Designing for temporal multiplicity would reduce this burden and align technologies more closely with their routines.

5.3.1 Designing for Multiple Temporalities. We propose the following design recommendations to better align technologies with the accounts of PwVI in this study. First, systems should support multi-temporal route options that make trade-offs between factors such as speed, safety, and predictability, rather than defaulting to shortest-time recommendations [1, 55]. Second, navigation technologies should consider multiple temporalities and normalize flexible pacing and rest: suggesting safe waiting spaces, allowing trips to be flagged as intentionally slow, and adapting scheduling estimates and notifications accordingly [24, 60, 81]. Third, design should consider temporal interoperability, i.e., aligning systems with both external and personal rhythms, through preserving trip state across pauses and switches, synchronizing with the temporal windows of external services (e.g., paratransit), and visibilizing any schedule uncertainty so users can plan buffers.

By weaving our participants' experiences with the broader scholarship on temporality and crip time, we argue that navigation technologies should orient towards resilience, variable pacing, and information transparency. Doing so not only better supports PwVI but also advances HCI's understanding of time as plural, embodied, and relational. Designing with multiple temporalities affirms that pauses, detours, redundancies, and uncertainties are not failures but vital ways of inhabiting — and safely traversing — the world.

5.4 Limitations

Several limitations of this exploratory study should be considered when interpreting its results and recommendations. First, this study involved a single 3.5 hours online workshop conducted with n = 11 participants, who lived in, commuted to, or regularly travelled within one major Canadian city with comparatively robust public transit and paratransit, and relatively reliable access to taxis and rideshare services. Participants were recruited through a local blind services organization which provides support for developing O&M skills, and all used smart phones. As a result, the accounts report experiences of PwVI who travel independently at least some of the time, are connected to local disability services, and are comfortable with digital technologies. Thus, the findings and recommendations should be considered transferable to similar urban and infrastructural contexts, and further studies should be conducted to assess experiences in localities with different transit ecologies.

Second, the study relied on journey-mapping, which is retrospective and scenario-based, rather than in-situ observation during, or immediately after, specific severe-weather events. This approach was well-suited to eliciting participants' planning practices, typical routines, and reflections across multiple trips, but as existing research has shown [7, 16, 27, 43, 52], it may not fully capture moment-to-moment decision-making, embodied stress, or breakdowns that arise in the most acute phases of disruption. Our study thus might omit some of the details of decision-making that emerge under real-world disruptions. Relatedly, the workshop captured a single point in time rather than following participants longitudinally across seasons or multiple disruptions, which limits our ability to speak to how strategies evolve.

Third, although we report age ranges, disability status, occupation, and phone type, the study did not systematically examine participants' gender, race, sexuality, socioeconomic position, or other axes of marginalisation. We also did not analyze how intersectional identities might shape perceptions of navigation strategies, especially around safety concerns, trust in strangers, or willingness to seek help. As a consequence, the paper cannot do justice to how intersecting forms of oppression and privilege may structure navigation risks and opportunities for different subgroups of PwVI. Further, we did not sample suburban or rural contexts where limited transit, paratransit, or rideshare may significantly alter strategies.

6 Conclusion and Future Work

In the context of PwVI navigating urban spaces during severe weather events, this paper argues that accessible navigation is relational, detailing how PwVI assemble digital tools, O&M practices, and human assistance to create and maintain a viable "navigation space" [73]. Drawing on a journey-mapping workshop, we identified four recurring practices: flexible mode-switching, anticipatory planning, braiding of supports, and adapting to disruptions. Across these practices, resilience rather than efficiency defined how participants travel independently. Breakdowns were often expected, accounted for, and absorbed through routines which included situated repair.

We argue that accessible navigation must move beyond focusing on efficiency metrics. Overall, designing for resiliency in the context of navigation for PwVI means designing for breakdowns and multiple temporalities, and supporting interoperability, making safe, predictable, and self-directed travel possible.

However, while this paper provides an understanding of how PwVI manage disruptions like severe weather while navigating and wayfinding, several areas of future study exist. First, the design recommendations of this study should be implemented and evaluated with PwVI to further refine and understand how technologies can be designed to support navigation and wayfinding under real-world disruptions. A subsequent study that is part of this research project will look to use co-design processes to understand how designers can best support PwVI's navigation practices. It should also be noted that any future research investigating novel navigation tools for PwVI should give careful consideration to maintaining safe travel throughout any form of digital tool evaluation.

Second, future studies could complement retrospective accounts with methods that capture navigation as disruptions unfold. This might include in-situ or post-event interviews, or diary studies conducted across multiple severe weather events, or longitudinal engagement that tracks how individuals adjust strategies over time. These approaches would deepen understanding of real-time decision-making and repair work during disruption.

Third, there is a need for research that centres intersectional safety for PwVI — specifically, studies that purposefully sample across gender, race, sexuality, age, and socioeconomic status, and that explicitly investigate how these identities shape perceptions of risk, experiences of harassment, and strategies for seeking assistance. Such work would support more targeted design for navigation in contexts where safety is unevenly distributed.

Finally, comparative and cross-context work could examine how resilience in navigation is assembled in other urban, suburban, and rural settings, including cities with less robust transit infrastructures, different weather or climates, or different cultural norms around disability, assistance, and public space.

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