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Review Article

Access to Accessibility: Pre-Visit Planning by Users with Disability and Children Employing AR, VR

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ABSTRACT

Access to accessibility information in urban spaces can be a gamechanger for users with disability and for parents or caregivers planning outings to any venues. It's because existing accessibility information is often scattered across platforms which are difficult to verify and collect. This information may also be insufficient and inappropriate for diverse audiences to decide whether a route, entrance, or venue is accessible and user-friendly for the people in need. This creates anxiety not knowing whether a venue will work for them. As a foundation for this research, a mock prototype named Harmony Link has been developed for accessibility-information that lets users search and verify accessibility features of public venues before visiting.

This research proposes Harmony Link as a Human-Technology Interaction platform that combines structured, crowdsourced and AI integrated accessibility data, with a simple augmented visual info preview in context of Tampere (or any other city). The study investigates how the interface can improve pre-visit confidence, offer accurate accessibility information, reduce anxiety, and support independent planning for users with disability and parents/caregivers. The paper also introduces a lightweight accessibility digital twin. This twin visually represents a simulation of route or venue so that users with disability and parents/caregivers can familiarize with accessibility features before their visit. It makes the pre-visit decision-making easier with the help of verified accessibility data with an immersive and intuitive simulation of the urban spaces.

Methodologically, the study will use a mixed approach of research. It plans to include co-designing by involving users with disability and parents/caregivers in shaping what an accessibility digital twin shows and functions. It will result in tool that people need rather than what designers assume they need. The project also plans to develop prototype and conduct qualitative user studies with comparative analysis. The first phase will focus on transit-to-venue access in Tampere. The later plan is to scale the platform to a broader city-level accessibility infrastructure with organization like City of Tampere or Business Finland. The findings will contribute to design knowledge for accessible pre-visit planning, accessibility databases, and inclusive digital services for people navigating urban environments.

Keywords: Digital Accessibility; Accessibility Information; Accessible Navigation; AI-Integrated Accessibility; Immersive Simulation; Human-Computer Interaction; Accessibility Data; Augmented Reality; Virtual Reality; Simulated Preview; Usability Evaluation; Mixed-methods Evaluation; Accessibility Infrastructure; Digital Inclusion; Immersive Technologies; Sustainable Societies

INTRODUCTION

With the advancement of digital services across various platforms, access to reliable accessibility information has become critical for users with disability and parents or caregivers. Research on urban accessibility shows that mobility is not only a physical barrier but also an information-related issue. Users with special needs require reliable knowledge about accessible routes, entrances, public transport, and service facilities before they travel (Buhalis & Michopoulou 2013). Accessible urban planning improves independence, participation, and the ability to confidently use public spaces.

Moreover, digital accessibility platforms and crowdsourced mapping systems indicate a considerable gap between existing information and reliable usability details. This gap of knowledge of the feature and trusting the workability is a recurring source of pre-visit anxiety (Chi et al., 2023). Research on urban accessibility monitoring argues that cities need systems that can collect, verify, and update accessibility data continuously. It

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should not rely on static data or policy documents (Saha et al., 2019). Accessibility data must be validated carefully as incomplete data can reduce trust and limit adoption (Hara et al., 2013). The accessibility data is costly to collect. So, the study also
examines how human-AI collaboration, AI-assisted verification from crowdsourced submissions, photos, or municipal open data can keep digital twin accurate and trustworthy.

Considering the gap, this research proposes an interactive platform for accessible pre-visit planning. The study focuses on urban context of Tampere and examines how structured accessibility data, AI-supported verification, and an immersive simulation can support decision-making for users with disability and parents/caregivers. Rather than considering accessibility as a simple venue label, the project frames it as an interaction problem. It concerns trust, anticipation, navigation, and the practical experience of reaching and using space (Saha et al., 2019).

This research plans to emerge on idea that city digital twins can support participatory urban governance and inclusive smart-city futures. The project is themed on accessibility studies, HCI, and immersive media research to understand how users search, interpret, and interact with accessibility information before visiting the actual place. To summarize, the paper aims to explore how a verified accessibility database and a simplified AR simulation can influence users' confidence, familiarity, anxiety, perceived independence, and trust in information. It also examines how AI integration and community contribution can support the maintenance of accessibility data at a larger scale. By connecting immersive interaction with accessibility data, the study contributes to both Human-Computer Interaction research and inclusive urban information systems.

Research questions: With the research questions below, the study asks how simulated accessibility information can be helpful for the users.

How can the immersive accessibility digital twin impact pre-visit confidence, trust, and independence for users with disability and parents/caregivers?

How can AI collaboration and crowdsourced verification support the creation and maintenance of an accessible urban digital twin?

LITERATURE REVIEW

Urban Accessibility, Mobility, and Pre-Visit Information

Urban accessibility is often referred to as a question of both physical infrastructure and the quality of travel information people receive. For users with disabilities and for parents or caregivers planning visits, not just the existence of the place matters, it's the facilities that can be accessed in practice (Edward et al., 2018). Research on accessible urban environments shows that dependable information about barriers, paths, and public services promotes autonomy, participation, and safer mobility (Edward et al., 2018). This makes accessibility information the key component of inclusive life rather than a secondary service.

Simultaneously, accessibility studies on mapping and smart-city systems show that recent information is incomplete, or difficult to maintain. Crowdsourcing and participatory sensing have been widely proposed to improve this. However, researchers consistently point to the need for trust, verification, and data quality controls (Hara et al., 2013). People with disabilities, caregivers, planners, and accessibility coordinators value accessibility data for route planning and advocacy. For the users, most of the time the reliability of the information is questionable. (Saha et al., 2019). Therefore, accessibility information should be treated as an evolving socio-technical system and not just as static database.

AI generated Visuals, Algorithmic Bias and Visual Grammer

In parallel with the development of Mixed Reality, there has been research to examine how AI based visuals and algorithmic systems reshape the act of seeing and visual perception. Scholars describe this as an "algorithmic gaze," where visibility and invisibility are governed by computational decision-making. This affects images appearance, their order and the receiver (Beer, 2017). This shifts visual element from a primarily human-curated domain to one co-produced by human and machine vision.

Besides presenting information, AI-generated images actively influence public understanding of domains as varied as health, security, and the city (Szymański, 2025). Moreover, algorithmic bias literature suggests that AI systems are never purely technical. Because AI's source of information embeds historical and structural inequalities in data and model training. This consequently shows visually in outputs and interfaces (Friedman & Nissenbaum, 1996). The output of AI presents a new system of algorithmic visibility where the power to classify bodies and space whether visible or invisible is authorized to machine perception.

Further discussions of AI, perception, and bias emphasize that cognitive and cultural biases shape the way algorithms are designed and human interpret AI outputs (Jarrahi et al., 2025). Moreover, research on Human-AI collaboration argues that there is a need for the future systems to recognize human heuristics, perceptual biases, instead of solely assuming rational users (Ellis-Alicante, 2024). In urban and cultural context, AI-driven visuals participate in governance and decision-making. Features like environmental risk dashboards, and accessible city control rely on algorithmically generated images that facilitate policy discussions and public perception (Kitchin, 2016). However, scholar's warning portrays the danger of normalizing biased data and opaque decision processes. It's because their visual outputs appear authoritative or "objective" (Pasquale, 2015). This is where the importance of user and data literacy becomes essential. Users must be able to comprehend the authenticity of the produced images along with the encoded assumptions.

Interaction design, interface layouts, icons, and visual elements guide user attention, interpretation, and response (Thuy, 2017). "Micro-aesthetics," in interfaces such as animation and visual feedback structure temporal flow of looking and acting that subtly shape user perception (Shedroff, 1994). However, most of

the existing work still assumes 2D based screen interfaces focus on visual composition more than embodied, multisensory engagement. If visual grammar is optimized for normative vision, speed, multitasking and attention, users with non-normative profiles may be marginalized by design (Ellcessor, 2016). These insights present the necessity to rethink visual grammar with a heuristic approach that will particularly consider embodiment and accessibility.

Digital Twins and Accessibility Simulation

Digital twin is used for virtual representations of cities for planning, monitoring, and policy making. Digital twins in urban development are considered as dynamic models to connect physical environments with real time or recorded data, simulation (Kitchin, 2011). Recent work emphasizes that urban digital twins can involve citizens in planning and implementations. It often lacks clear human-centered governance frameworks (Wu & Guan, 2024). Whenaccessibility is included, it becomes relevant as the digital model must reflect real experience and not only geometric accuracy.

According to the accessibility-focused digital twin studies, there is strong potential for pre-visit planning and inclusive navigation. This system can promote better understanding of barriers, accessibility features and help decision-making by creating a virtual version of accessible environments. Moreover, virtual reality and digital simulation can help users engage with planned or existing urban spaces before making the visits. For this project, the digital twin is not a full city replica but a lightweight accessibility model that shows the accessibility options from transit stop to entrance and venue interior. This makes the concept feasible while still addressing an important gap in accessibility planning.

Trust, Crowdsourcing, and Human-AI Verification

Crowdsourced accessibility data can increase coverage, but users need to know whether the information is accurate to rely (Saha et al., 2019). Data should combine crowdsourced observations with authentic and structured verification methods (Mocanu et al., 2021). This is important as inaccurate accessibility detail can affect safety, mobility, or a person's willingness to travel. Human-AI collaboration provides ways to maintain large-scale accessibility information. In recent HCI and smart-city research, AI is increasingly used to detect patterns, classify data, and support verification. Scholars warn that automated systems can reproduce bias if not designed and monitored carefully (Friedman & Nissenbaum, 1996). For accessibility platforms like Harmony Link, AI should assist rather than replace human judgment especially when involving users with disabilities.

Immersive Pre-visit Planning and User Experience

Immersive interfaces are relevant as accessibility decisions are spatial and experiential. It can be beneficial for the users to pre-evaluate a route, identify the obstacles, determine the distance of venue from entrance and overall feasibility. Research in mixed and augmented reality shows that immersive visualization can help people understand spaces before entering them physically in complex and unfamil environment (Milgram & Kishino, 1994). This means a simplified simulation or spatial preview can support confidence by reducing uncertainty and making hidden barriers visible.

For users with disabilities and parents/caregivers, this can support emotional reassurance, planning efficiency, and autonomous decision-making. Users are benefited when systems reduce cognitive load, present information clearly, and offers meaningful navigation planning (Ellcessor, 2016). In the Harmony Link project, the digital twin and verified data together forms an interaction system that focuses on answering a practical question: "Can I get there and will it work for me?" That question positions the project within human-technology interaction, inclusive design, and everyday mobility research.

METHODOLOGY

The planned method of this research is to employ qualitative and design-oriented methodology to critically analyze user studies and explore prototyping. This approach is structured in three phases to address the research questions.

Phase 1: Conceptual and literature mapping

Firstly, the review published literature on urban accessibility, digital twins, crowdsourced accessibility data and human-AI verification will be reviewed. It will focus on identifying the concepts, accessibility attributes, and design requirements that are crucial for a city-oriented accessibility digital twin. Through this phase, the scope of the prototype would be defined. It will consider couple of routes or venue context in Tampere rather than the whole city at once. The phase will result in a conceptual model for the platform which would include the core data fields, user needs, and accessibility features.

Phase 2: User-centered design and prototype development

Based on the first phase data, a qualitative study will be conducted with participants experiencing MR prototypes in a lab or controlled setting. Data collection will combine:

Interviews focus on user perception, attention, and sense-making.

Data collection includes interviews, co-design workshops, and scenario-based discussions about route planning, venue access, and decision-making.

Questionnaires on users' presence, comfort, preference and perception.

Data will be analyzed thematically to understand how users experience visual grammar, how they interpret system cues, and how predictive/adaptive behaviors affect their sense of control and understanding. This phase will involve co-design and prototype development with users with disability and parents/caregivers. It will highlight on understanding the information that matters most before a visit. Based on these findings, a low-to mid-fidelity prototype of Harmony Link will be developed which will combine structured accessibility information with a lightweight digital twin.

Phase 3: Evaluating the digital twin prototype

Insights from the previous phases will be merged to develop a heuristic framework for Human-Computer Interaction. This will test the prototype through user evaluation in a controlled or sem controlled setting. Participants will be asked to use the prototype to compare a standard accessibility listing with the digital twin version of the same route or venue. Data collection may include task-based observation, interviews, and short questionnaires. It will benefit to understand the participants' pre-visit confidence, trust, perceived independence, and anxiety. The analysis will be thematic and interpretive as participants will be asked to provide descriptive comparisons across the two conditions.

CONCLUSION

The study addresses Harmony Link as more than an accessibility platform as it acts as a human-technology interaction system with verified accessibility data, AI supported maintenance, and a lightweight accessibility digital twin. The research seems feasible as it focuses on one urban context in Tampere. It still addresses crucial gap i.e., how users with disability and parents/caregivers assess the workability of a route or venue for them before visiting. The project aims to contribute to literature on inclusive society, urban accessibility, digital twins, participatory design, and inclusive interface development. It will also show how immersive pre-visit simulation can reduce uncertainty and unfamiliarity. The broader goal is to help cities move toward more inclusive and digital infrastructures where accessibility is considered as an everyday experience, not just an add-on feature to be implemented later.

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