Forging a Path Towards Equity in Smart Public Transit Systems

Ecosystems & Trust

Lynn Kirabo

B., Information Technology, Makerere University
MSc., Information Technology, Carnegie Mellon University
MSc., Human-Computer Interaction, Carnegie Mellon University

This dissertation is submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

Thesis Committee: Aaron Steinfeld (Chair), Jessica Hammer, Jeffrey Bigham, Destenie Nock, Tawanna Dillahunt (University of Michigan)

Human-Computer Interaction Institute
School of Computer Science
Carnegie Mellon University
Pittsburgh, PA. 15213

CMU-HCII-23-100
April 2023

***Keywords**: designing equity in public transit interfaces, public transit interface futures, designing adaptive user interfaces for public transit, inclusive smart transit interfaces, public transit ecosystems, public transit in the global south*

Abstract

Public transit is the heartbeat of most cities around the world. It gives communities access to employment and services like health and education. Policy recommendations, interventions, and research on public transit often focuses on drivers as the primary stakeholder. This same focus is evident in the recent proliferation of machine learning interventions in public transit technologies. They neglect the influence and impact of these machine learning interventions on other stakeholders in the public transit ecosystem. This focus runs the risk of automating inequities within future mobility systems. In this dissertation, we argue that to design for equity in public transit, we should have an understanding of the broader public transit ecosystems in which we are deploying transit AI technologies. My completed research studies traverse two geographic contexts, East Africa and North America. My work shows an underlying influence of trust on relationships within the ecosystem, and unique stakeholder appropriation of transit technologies. Conversely, we also found a suspicion of advanced smart transit interfaces. Thus, we propose that to design for equity in smart transit systems, designers and researchers should consider two dimensions of trust: trust in the interfaces and trust between stakeholders within the ecosystem. My last work focuses on the first dimension, trust in the interface. We co-created the Jacaranda Framework — a framework of concerns relevant to disabled riders' use of smart transit interfaces. We also demonstrated how principles from the framework could improve users' holistic experience with smart transit interfaces. This thesis makes the following major contributions: 1) Establishes a multidimensional connection between Trust and Ecosystems, 2) Demonstrates a need to understanding the entire ecosystem when considering new technologies, 3) Presents the Jacaranda Framework — a framework of concerns relevant to disabled riders' use of smart transit interfaces, and 4) Demonstrates how methodologies can be adapted for research in these areas.

Acknowledgements

My entire Ph.D. journey fits into the phrase: "It takes a village." I have been challenged, grown, and interacted with many people as part of this journey. This section is an attempt to thank and recall every one of you.

To my participants, none of this work would have been possible without you. Thank you for taking the time to share your lived experiences before and during the pandemic that was COVID19. To my advisor, Dr. Aaron Steinfeld, thank you for your continued mentorship these past six years and for giving me the flexibility and space to explore side projects! To my committee, Dr. Aaron Steinfeld (CMU), Dr. Jessica Hammer (CMU), Dr. Jeffrey Bigham (CMU), Dr. Destenie Nock (CMU), and Dr. Tawanna Dillahunt (UMich), thank you for the questions that have refined my work and pushed me even more to consider the tangible impact of my scholarship. To my unofficial faculty mentors, Jess Hammer, John Zimmerman, Michael Hilton, Franceska Xhakaj, Henny Admoni, Raelin Musuraca, Geoff Kaufman, Evan Peck, Heather Kelley, and Nik Martelaro, I am a better researcher, educator, and community member because of the feedback you have shared with me over the years. To the staff and admins, Queenie Kravitz, Peggy Martin, John Davis, Gail Kusbit, and Catherine Copetas, thank you for helping me with all the administrative tasks that could cause stress.

To my family, the Byabashaijas, the Katundus, and the Rwabweras – I have missed many births, birthdays, new jobs, the family runs, and funerals. Thank you for still making time for me despite the timezone differences and finding creative ways to support me. You have always profoundly believed in me, calling me "doctor" when I got my offer letter. To my nieces and nephews who have had to grow up without me around to spoil them, thank you for being patient with me whenever I called.

To my friends who exist across borders and cultures, I do not have enough space to go into detail about your positive impact on my well-being. Instead, I will list all of you with a simple thank you from the bottom of my heart: Judith Uchidiuno, Uchenna Uchidiuno, Elizabeth J. Carter, Samantha Reig, Zhi Tan, Vikram Kamath, Gierad Laput, Ivy Wainaina, Josephine Mukesha, Abdelkareem Bedri, Joan R. Nkiriki, Jasmine Kwasa, Clara Kitongo, Stephanie Valencia Valencia, Jesus Sileli, Lea Albaugh, Erica P. Cruz, Jesse T. Gonzalez, Adinawa Adjagbodjou, Lisa Egede, Abena Boadi-Agyemang, Fern Limprayoon, Tomohiro Nagashima, Cella Sum, Jaemarie Solyst, Nur Yildirim, Abhijat Biswas, Katherine Shih, Allan Wang, Cathy Jiao, Oscar J. Romero, Amber Horvath, Rediet Abebe, Margie and Bruce Krogh, Michel Bezy, Timothy X. Brown, Michael Xieyang, Yasmine Kotturi, Julia Cambre, Charles Van-Hein Sackey, Judy Oden Choi, Alexandra To, Qian Yang, Ernest and Olga Kabuye, Blessing Abeho, Dini Maghfirra, Moses Namara, Anni and Glory Otubelu, Shaq and Ruth Hagar, Heather Brown, Michal Luria, Dennis and Julia Allan, Allison and Zach Smith, Julie Gallagher, Becky Russell, Tyler and Jess Kirin, Jonathan and Kelsey Cunningham, Sarah Miner, Amber Okai, Irene Katabarwa and the boys, McKenzie Johnson, Karlie Haywood, Morgan Chloe, Gabrielle Mueller, Christine Law, Derek and Katie Long, Dan and Stella Bendit, Victor Akinwande, Rachel Mwine, Eva Muhanguzi, Viola Nuwaha, Merab Twahirwa, Vanessa K Umutoni, Crystal Rugege, Aggrey Muhebwa, Solomon Benge King, Katrina Ramirez-Meyers, Edwin and Cynthia Muhumuza, Sheila Ndomeirwe, Anna Kasunic and Sauvik Das, Paulina Jaramillo and Nestor Gomez, Remmy and Joanna Muwonge, Mary Agnes Amuti, Lylee and Kagenza Rumongi, Mihloti Williams, Tim and Brenda Rapp, Sharon Zachariah, Jaqlynne Tumusiime, Zahara Abdul, Doreen Muhereza, Ruth Aine, Della Louise Tumwebaze, Michael and Rebecca Katagaya, Kathy L. Nzesei, Andrew Pacutho, Beverly Nambozo, Joy Attmore, Joan and Amos Kiyingi, Kathy McCready, Nyla Khan, Tenacious Friends, and F4L Friends.

To the different academic and non-academic communities I belong to, RANDos over at RAND, AfroGSA, Black Women's Writing Group, Accessibility@CMU, HCIxB, Mechanism Design for Social Good, CMU Teaching community, thank you for collectively shaping my perspective while creating a space I could belong to.

To the funders that have supported my work: Many parts of this dissertation were funded under a grant from the National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR grant number 90REGE0007). Additional funding was received from the Siebel Scholars foundation.

Last but not least, thank you to God. My faith is a huge part of my life. Thank God for this work, life, ideas, collaboration, funding, and community.

This thesis is dedicated to my parents, the late Dr. Warren and Mrs. Jennifer Byabashaija.

Dad, if I had known my time with you was short, *perhaps* I would not have fought as hard as against the idea of grad school.... You always had such audacious dreams for me, Warren. Thank you.

Mummy, these last six years have been the fruit of your prayers and enduring faith. Thank you for always knowing when to call (especially those moments when I was ready to take the next bus to Kanungu). Thank you for adding laughter and joy to this journey.

Preface

Fig. 1 A wheelchair user strikes a pose in a narrow hallway in a building in Kampala. Image courtesy of Zahara Abdul.

In this section, I discuss the language that I use in this document. The populations I work with come from different geographies and hold many identities. It is my aim to represent the views and opinions of my participants with respect and dignity. In the subsections below, I cover the histories around some of the languages I will use.

Disability Models & Language

In many societies, disability models influence languages and perceptions about disability. There are six commonly used models of disability [8, 47]: moral, medical, rehabilitative, social, diversity, and minority. The moral model is one of the oldest models. Under this model, people believed that disabled people should be pitied and the object of charity. The language used makes disabled people feel less than or suggests their disability was a result of sin. The medical model came next, in the 19th century. Under this model, people are referred to solely by their impairments. This model comes under critique for elevating the disability above the person. The rehabilitative model focuses on equipping disabled people to cope with their disability. This model relies on tools and strategies. The social model, however, shifts the focus from the disability and the individual onto society. The model suggests that societies need to address social barriers that limit the participation of disabled people. Social barriers are categorized as both in people's attitudes and in the physical world. The last two models are the diversity and minority models. They are newer models that propose that disability is part of an individual's identity. They assert that disability is like demographic information, such as race.

The language and terms used to describe disabled people are borne out of the prevalence of these models. For instance, language referencing disabled people in the earlier two models often used derogatory terms. People were objectified while their disability was elevated. Person-First language focuses on placing the individual before their disability. Proponents of the Person-First language approach argued against the use of language that dehumanizes disabled people [200]. Acceptable language included phrases like "person with a disability" instead of "disabled person". This form of phrasing has been widely adopted among academic professionals in the United States. The newer models advocate for the use of Identity-First Language. As a counteraction to histories of marginalization and oppression, this model focuses on disability as an identity. This involves using phrasing like disabled people.

There is a recent effort to investigate the language preferences of disabled people. Sharif, McCall, and Bolante [178] surveyed disabled people from twenty-three countries and found a majority preference for identity-first language. They also noted that some disabled people had no preference.

For the rest of this document, I shall use identify-first language, such as disabled people, blind and low vision, motor/mobility disability, vision-related disability etc.

Geographies & Language

The work presented in this document covers multiple countries, including two in East Africa. Countries on the African continent have often been given many labels when written about in academic and pop culture settings.

These labels are often a result of geopolitics. They include third-world countries, developing countries, developing nations, the Global South, and emerging economies. Each of these labels has specific connotations attached to it. The third-world label has derogatory implications. The third world is often used synonymously with poor or destitute or the image of hunger-stricken children outside of a hut. This is an inaccurate picture of the diversity that exists within the different countries on the African continent. The next two labels (i.e., developing countries and developing nations) were then introduced in an effort to move away from derogatory terminology. However, the juxtaposition of "developing" against "developed" often raised questions about whether some countries were being unfairly measured against others. It typically sets developed nations as the goal to which developing countries should aspire.

More recent terminology has included phrasings such as the Global South and emerging economies. One definition of the Global South is "the resistant imaginary of a transnational political subject that results from a shared experience of subjugation under contemporary global capitalism" [127]. It is this term that I will use throughout this paper when collectively referring to countries on the African continent.

Positionality

There is a recent practice in academia to reflect on the biases, identities, and ideologies that researchers may unknowingly bring into their work. It is through this lens that I reflect on my positionality in this work. I am an African female who was born and raised in urban cities in East Africa. Because of this, I have a very specific lens on how individuals from this region should be represented. While this may seem obvious, I find it useful to be explicit. Secondly, I do not have a disability. As a non-disabled individual doing research in a space where I do not have first-hand experience, I have had to examine my own preconceived biases.

This will also be the last chapter that I use the pronoun "I". To honor all my collaborators, I will use "we" when describing study methodologies.

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Chapter 1

Introduction

Public transit is essential to growing cities around the world. Moreover, access to sustainable public transit is dubbed as an essential human right by the United Nations [140]. Public transit systems are composed of a diversity of elements, from physical vehicles, to infrastructure like sidewalks and roads, to mobile interfaces that provide access to information on public transit systems. Consideration of these elements is further complicated by the humans who interact with them. From drivers, to riders, to policy makers, each human group comes with their own needs, perspectives, and biases.

Public transit has a goal of providing universal access to mobility for the populations that it serves. However, past research has shown how public transit has sometimes fallen short of its goal. In North America, this is usually seen in policies that favor specific populations over others [189, 195]. This limited access to public transit inadvertently creates vulnerabilities to populations that are already marginalized and thus increase barriers in access to other services (e.g., employment [123], health [187]). In East Africa, these inequities take the shape of complex politics and policies [73], competing international interests, and the displacement of low-income communities [110].

Recent years have seen the explosion of technologies into public transit [139, 1, 39, 74, 163, 107, 160]. Across the globe, urban cities are looking for innovative ways to include cutting-edge technologies to improve the efficiency of their public transit. These technologies have included reducing barriers to public transit information by leveraging mobile phones [208, 7, 157]. Other innovative methods have included ways to diversify public transit through e-bikes and scooters as first- and last-mile vehicles [210]. Diversification through ride-share technologies has seen particular success in both North America and East Africa. These ride-share technologies have provided alternative on-demand access to mobility services that were previously reserved for people who owned vehicles. In East Africa, ride-share technologies also include access to two- and three-wheeled vehicles in addition to the standard four-wheeled cars and vans. Recently, in a bid to transition to clean energy solutions, some cities across East Africa are starting to introduce electric vehicles as part of their public transit fleet [28, 126, 75, 99, 18].

While these new technologies appear to improve efficiency and increase access to mobility, they have also been accused of being amplifiers of negative human intent. When considering how this might manifest in ride-share technologies, riders have been reported to drive off and leave passengers of color behind [65, 180], and drivers have denied disabled riders access to their vehicles [185, 116, 54]. Moreover, ride-share technologies have been known to have unfair pricing policies for populations that happen to be in rural contexts or transit deserts [156, 46]. The provision of diversified options for first- and last-mile access through e-bikes and scooters has also come under scrutiny. Critiques focus on membership costs and the placement of hub stations around cities [37] and the way these micro-mobility vehicles litter sidewalks, making the sidewalks inaccessible for disabled pedestrians [16].

The challenges at the intersection of public transit and transit technologies present and opportunity to investigate equity in public transit. Recent years have seen conversations and debate over the influence of advanced technologies on equity [9, 25, 156]. These conversations, while important, are often reactionary. They occur after systemic injustice has already been perpetuated against a marginalized group of people. This has especially been the case in some North American cities. Thus, this begs the question: how can we design for equity in future transit technologies? Users may interact with these future transit systems using different modalities (e.g., voice, touch), thus we should ensure they are designed in an inclusive manner. Our core question is the premise that motivates the studies presented in this dissertation. We present our investigation into public transit and transit technologies in two parts. In Part 1, we initiate our investigations in East Africa, a context that is at the brink of integrating diverse public transit innovations.

- **[RQ1] How can we understand the experiences of stakeholders in public transit technology ecosystems?** We maintain that without a proper understanding of stakeholder experiences within the ecosystem, we run the risk of designing public transit technologies that automate biased practices. In Chapter 4, we start our investigation into RQ1 from a broad exploratory perspective. We surveyed and interviewed public transit riders, start-up organizations at the intersection of financial services and public transit, as well as disability advocates. Our findings suggested a distrust among stakeholders related to inequities (i.e., harassment and discrimination). The findings also revealed an influence of perceived social hierarchical structures on innovation and how passengers appropriate technology to overcome challenges. In Chapter 5, we co-designed a disability ecosystem that exists within the larger public transit ecosystem. We hosted co-design sessions with disability advocates and adapted the stakeholder tokens method from the value-sensitive design framework to map the ecosystem. The key insight from this study is the identification of a new group of non-traditional core stakeholders who highlight the values of inclusion, mobility, and safety within the ecosystem.

Synthesizing across both studies, the following key points emerge: Drivers are only a part of the public transit technology ecosystem. Other key players in the ecosystem include riders (as allies and players who hold influence over drivers), disabled riders, traffic police, and technology startups. An underlying influence across these studies is trust. A distrust in traditional stakeholders influenced the creation of new stakeholders. Additionally, a similar distrust contributed to the appropriation of transit technologies (and thus a trust in said technologies) by specific players within the ecosystem.

In part 2 of my dissertation work, we then set out to understand whether these learnings were also applicable in other contexts or whether they were specific to the public transit stakeholders we collaborated with in East Africa. To do this, we focused our questions on two aspects of the ecosystem, disabled riders and public transit technologies (specifically, bus applications).

- **[RQ2] How can we characterize the navigation habits of disabled riders?** In Chapter 6, we assert that through understanding the navigation experiences of disabled riders, we are able to understand which stakeholders they engage with. We further constrained this study to investigate navigation habits during transit disruptions. Transit disruptions create temporary vulnerability, so it is important to understand how other stakeholders can be allies in these situations. Our findings pointed to the shortcomings in current services, and potential improvements to the public transit ecosystem.

- **[RQ3] How do Adaptive User Interfaces in mobile transit interfaces influence the transit experiences of disabled riders?** Transit smartphone applications are a popular form of public transit technology in North America. There have been recent efforts to augment these interfaces with AI techniques. In Chapter 7, we present two studies using DRIFT, a smart probe that we created. We designed DRIFT, an interactive design probe to simulate smart transit capabilities. DRIFT's smart interfaces was designed using Adaptive User Interface design principles. Our first study demonstrated that Adaptive User Interfaces significantly reduced the time taken to find bus information. However, evidence suggested that participants still searched the entire bus list. In our second study, we explored this behavior in an interview study with blind/low vision public transit riders. We found that this behavior was motivated by a need for complete information and a strong desire for control over adaptivity.

Both studies highlighted similar issues from Part 1, especially with a focus on the transit ecosystem and trust. We posit that there are two issues that need to be addressed when creating equity in public transit systems: 1) trust with public transit interfaces, and 2) trust between different stakeholders within the ecosystem. In the final work, we take on the former lens as an initial effort towards creating equity into public transit technologies. In our final work, we leverage Explainable AI as a tool to build trust between public transit riders and public transit technologies (specifically, transit apps). We asked the following questions:

- **[RQ4] How can we understand which categories of explanations are essential to disabled riders?** Explanations are the mechanism intelligent interfaces can use to explain their decisions. These explanations should proactively respond to users' questions about the system. In the first half of Chapter 8, we adapt the question-based framework to explore questions that blind/low vision and wheelchair users have about smart transit interfaces. We found that participants resonated with four of the eight questions from the question-based framework. Their responses generated twelve new questions relevant to their experience with smart transit applications. From the combination of their responses, we present the Jacaranda Framework — a framework of concerns pertinent to disabled riders' use of smart transit interfaces. The framework offers five important question categories to users: Justify, Accuracy, Reliability, Influence of Inputs, and Intentionality. As part of this framework, we present design patterns that look into implementing transparency in smart transit applications.

- **[RQ5] How do '*transparent*' Adaptive User Interfaces in mobile transit interfaces influence the transit experiences of disabled riders?** We define '*transparent*' Adaptive User Interfaces as smart interfaces that explain a recommendation that they are making. These recommendations are offered to users in an attempt to improve their user experiences. In the last half of Chapter 8, we present DRIFT+ — an interactive design probe to simulate smart transit capabilities infused with explainable recommendations based on the Jacaranda Framework. Our findings demonstrate that, on average, users took a similar amount of time while using the manual and adaptive interfaces on DRIFT+. They showed that when users encountered the 'transparent' smart interface, they took more factors (i.e., the explanations) into consideration. However, participants highlighted their strong preference and perceived usefulness of smart interfaces embedded with explanations. Thus 'transparent' adaptive interfaces offer users a more holistic quality of experience.

This thesis makes the following contributions:

- We demonstrate a need to understand the entire ecosystem when considering new technologies. We present a public transit technology ecosystems artifact that includes values embedded within the public transit-disability ecosystem.
- We establish a multidimensional connection between trust and ecosystem stakeholders. Our work presents justification for designing for equity in public transit technologies on two axis of human stakeholders and public transit technology.
- We present the Jacaranda Framework — a framework of concerns that are relevant to disabled riders use of smart transit interfaces. We demonstrate how user interface and user experience designers and researchers can proactively respond to these concerns in future smart transit interfaces.
- We demonstrate how methodologies can be adapted for research in multiple contexts. Our work contributes to the efforts of Global South researchers that advocate for contextual research methods.

Chapter 2

Related Work

Parts of this chapter were previously published in the scientific articles:

Kirabo, L., Carter, E.J., Barry, D., and Steinfeld A. (2021). Priorities, Technology & Power: Co-Designing an Inclusive Transit Agenda in Kampala, Uganda. *In 2021 ACM Conference on Human Factors in Computing Systems (CHI '21)*

Kirabo, L., Carter, E.J., and Steinfeld A. (2020). "You are asking me to pay for my legs": Exploring the Experiences, Perceptions, and Aspirations of Informal Public Transportation Users in Kampala and Kigali. *In ACM SIGCAS Conference on Computing and Sustainable Societies (COMPASS '20)*

2.1 Public Transportation Research (Focus on Drivers)

Transportation research in Africa has not been a popular domain for human-computer interaction (HCI) or intervention-related research [193]. In an analysis on HCI for development, Dell and Kumar [45] noted that the most prevalent domains were education, access (referring to the provision of technology, such as internet access or offline browsing experiences), and health. This finding supported previous work that noted that health and education technology interventions dominated development-focused research [33].

The vast majority of research on transportation in developing countries has a strong focus on policy. Examples include explorations on how capacity-building of operators could inform the public transport reform process [174]; the progress, process, and risks of engaging operators for public transport reform in Cape Town, South Africa [175]; policy challenges in developing countries on hybrid urban transport systems caused by the complexities and constraints of old, existing systems [55]; the organization and improved services of inner-city Matatu (taxis) and the potential for their transferability [13]; and the structuring of a user satisfaction model based on observed and unobserved variables from commuters in Nairobi, Kenya [71]. There is also literature on the role played by motorcycle taxis in providing public transit: they contribute to increased employment opportunities [151], improve access and last mile distribution [87], increase women's ridership in urban areas [167], and potentially expand urban transportation systems [49].

2.2 Disability & Public Transportation

Public transportation in cities in the Global South has been described as chaotic and a nightmare [92, 5], especially for disabled riders. These negative experiences range from overcrowded bus stations in India with little to no access to audio announcements [92] to bus parks in East Africa with no accessible infrastructure. Pedestrian walkways are littered with obstacles, such as hawkers and cyclists [136]. The lack of accessible infrastructure greatly limits the mobility of disabled people. The idea of equitable mobility advocates that transportation services should be accessible to all. Crucial to that is the understanding of the needs and aspirations of disabled riders in these cities.

Disability research specific to Kampala or Kigali has explored the intersection of gender and accessibility [155] and focused on a medical disability model [83] that is rooted in medical interventions [5, 36, 133, 206]. Studying access to transportation by disabled individuals and the influence (or lack thereof) of technology has yet to be addressed.

2.3 Public Transit Innovation

2.3.1 Accessing transit information

Until relatively recently, systems for providing real-time locations of public transit vehicles in North America were often prohibitively expensive for many municipalities [130]. Apps and websites were introduced that used crowdsourced data to provide information to riders. One of the early, high-impact services was Tiramisu Transit [208, 183]. Formulated using the results of a co-design study on how repeated interactions with a service could be stimulated [204] and using universal design principles, Tiramisu provided users with the opportunity to share the current locations of the vehicles they were riding, along with fullness, problem reports (e.g., malfunctioning stop annunciators), traffic conditions, positive experiences, and more [208]. Other efforts towards crowdsourced services included predicting bus arrival times with participatory sensing (e.g., [117, 207]), and targeted crowdsourcing has been used to determine bus size, travel times, and speeds [35]. Nandan and colleagues [138] reported that crowdsourcing this information resulted in high demands on hardware, route data availability, location accuracy, information quality, and user motivation. However, crowdsourcing of certain transit data has still been integrated into some commercial apps and can provide some information that otherwise requires coordination across different government agencies (e.g., transportation and public works [152, 31]) and app providers.

2.3.2 Examining public transit innovation across borders

As in other domains, technology has a critical role to play in enabling the collection of transportation information [169, 168] as well as improved access to vehicles. Kasera et al. [100] presented an example of this when proposing a ride-sharing system in Namibia that was optimized to support driver agency and the concept of *tempo*, referring to the pace of the driver's day. They emphasized the need for interventions to fit into the existing pace of the community. Similarly, Ahmed et al. [3] made recommendations for the redesign of Ola, a peer-to-peer technology to better serve the auto-rickshaw drivers in Bengaluru, India. Their insights found that while the drivers adopted new technology, they did not prioritize it over their traditional passengers (i.e., regulars who called them or those who hailed them from the roadside). They also pointed out that Ola did little to mitigate the uncertainty that existed in the drivers' days. In Nairobi, Klopp and colleagues [109] used information from the General Transit Feed Specification to record the complexities of the Matatu system (i.e., typical routes, stops, schedules, and fares). This type of real-time information is important for local transit applications. We also see examples of technology enabling access in rural areas through an SMS-based system that was used to solve last-mile challenges of connecting boda boda (motorcycle taxis) riders to customers in Uganda [56]. Lastly, there is an example of a smartphone-based application that had a positive impact on women's empowerment and mobility in Kampala [141].

Mainstream technologies, such as online maps and ride-share applications, have been used to improve mobility. When examined through the local context of the Global South, interesting insights emerge. For instance, Google Maps is not considered an efficient navigation tool for persons with visual impairments in India [93]. Designed for a specifically organized setting (i.e., the Global North), it is not readily applicable to urban settings in the Global South that do not follow grid layouts. Also, ride-share technology in India is characterized as "a socio-technical collaborative effort" that includes the rider with a disability, a driver, and technology [92, p. 85:3]. This collaborative effort gives rise to the notion of a nuanced idea of independence where riders can travel independently but rely on drivers where necessary.

2.4 A Lens on Equity

In HCI, there is a rising focus on discussing equity within the scope of examining methodologies and interventions. In this section, I discuss equity theory, terminologies, and their implications for the intersection of public transit interfaces, disability, and global contexts. I acknowledge that equity, justice, and fairness are sometimes used interchangeably in the literature.

2.4.1 Defining equity theories

Equity can be defined primarily as the even distribution of costs and benefits [30] (this is also referred to as distributional equity). However, many agree that the definition of "even" is a moral judgment call [30, 159]. Many theories have influenced perceptions of equity. These theories include libertarianism, Rawls' egalitarianism, utilitarianism, intuitionism, and the capability approach. In this work, I draw on the capability approach [159, 177, 144], which takes into consideration the diversity of human preferences and needs. Understanding the context in which people live is essential to the discussion on equity. This perspective also considers external factors that might influence people's actions. The capability approach calls for establishing culturally and contextually relevant thresholds for capabilities. This approach is particularly relevant because people from different social and economic contexts have different evolving needs. In this work, I draw from the capability approach by considering the needs and preferences of disabled people within the public transportation context. I also take a culturally sensitive approach to investigating preferences across two geographical contexts.

Horizontal and vertical equity are the two frameworks used to implement these theories [30]. Horizontal equity refers to the practice of treating people at the same level the same. In contrast, vertical equity looks at the redistribution of resources to provide more considerable benefits to marginalized groups who were previously left out. Both frameworks have applications in this work. For example, this research looks at the lived experiences of disabled people across different geographies. This example can be interpreted as investigating ways of ensuring that disabled people across both contexts have equal access to resources as others in their communities.

Furthermore, this work explores how public transportation interface designs can be redesigned to improve the experiences of disabled riders. This type of equity often comes under critique for prioritizing marginalized groups. However, we argue that this prioritization in design will often lead to an improved experience for everyone. This is similar to universal design [184], in that prioritizing disabled people in design will often lead to an improved experience for everyone.

2.4.2 Public transit innovation and equity

The discussion of who has the right to be included in the design process is critical, especially when working with traditionally disenfranchised communities. Scholars have used co-design methods to give more communities voices in problem definition and solution creation [161, 196]. The exploration of lived experiences is a specific avenue that provides rich insight into values and everyday occurrences that can sometimes be overlooked in evaluation studies. Extending work at the intersection of critical race and feminist theory, Pal and colleagues [155] sought to understand the experiences of disabled women in Malawi and Rwanda. In a survey conducted among women with visual impairments in the capital cities of Blantyre and Kigali, they found similar narratives of marginalization faced by visually impaired women in both cities. They noted how social exclusion impeded kinship bonds between disabled women and their communities. Furthermore, they discussed how technology unwittingly has become a double-edged sword by promoting aspirations while contributing to marginalization.

Moreover, Pal and Lakshmanan [153] observed this contrary impact of assistive technologies in other regions. On the one hand, it positively impacted participant aspirations, specifically for career goals. However, participant narratives also revealed employment-related issues among the first generation of "assistive technology users" in Bangalore, India. In their interviews, participants gave examples of misalignment between the tasks assigned to them and their ability, the lack of employment offers for more technically qualified candidates, and underpayment when they eventually succeeded in getting jobs. These descriptions of lived experiences give insights into the perceptions of stakeholders. We continue this tradition of eliciting lived experiences through conversations about the power dynamics that exist within the disability ecosystem.

Chapter 3

Setting the Context

Parts of this chapter were previously published in the scientific articles:

Kirabo, L., Carter, E.J., Barry, D., and Steinfeld A. (2021). Priorities, Technology & Power: Co-Designing an Inclusive Transit Agenda in Kampala, Uganda. *In 2021 ACM Conference on Human Factors in Computing Systems (CHI '21)*

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The work presented in this thesis was conducted in three major cities. Each are unique and have subtle characteristics that inform the research and design implications. Detailed descriptions of each city are provided here to help provide context to the reader.

3.1 Kampala, Uganda

Kampala, the capital of Uganda, has a resident population of 1.5 million people [102] and a daytime population of more than 2 million people [52]. Kampala has various forms of public transportation, ranging from Taxis to Boda Bodas, Special Hires, bicycles (with a passenger perch), and large buses [95]. Fourteen-seat minibuses are locally referred to as *Taxis*. Taxis can be considered a form of shared transportation because they provide rides to multiple unacquainted passengers at the same time. They are operated by a driver along with a conductor who collects money from passengers as they leave the vehicle. The motorcycle form of transportation is called *Boda Boda*. Boda bodas are ideally not shared by multiple passengers due to the physical constraint of seating on the motorcycle; they typically seat a driver and a single customer. However, the size constraint often does not stop additional riders. Motorcycles have a notorious reputation among the locals for driving as if they are exempt from traffic laws and are often seen breaking regulations, even in front of law enforcement. Additionally, Kampalans use a form of transportation called *Special Hires*. These are vehicles that are rented by individuals to get them to specific destinations, which might range from a shopping trip to a funeral. While the cars in this category can be any size, it is most common for them to be approximately the size and shape of an early 2000s Toyota Corolla. Another type of transportation in Kampala is the larger, 60-person bus that can travel both long and short distances.

Hailing each mode of transportation is slightly different. Outside of the city center, taxis and boda bodas can be hailed from the side of the road, while within the city center, taxis are strongly encouraged to collect passengers from designated stages (stops). For taxis, a conductor will often ask bystanders if they are interested in boarding by announcing the vehicle's destination (e.g., Kampala, Ntinda, etc.). The reverse happens when hailing a boda boda: the passenger informs the driver of their destination. Sometimes, passengers will keep the contact information of a boda boda driver and call them when they need to travel. It is also common for passengers to haggle before boarding any of the mentioned modes. Public transit also recently evolved to include ride-share services, including SafeBoda, Uber, and Taxify (now Bolt). Uber and Taxify both started with only cars in their operations, but later expanded to include boda bodas. We postulate that this is due to the observed preference of passengers in Kampala for the boda boda because of convenience. Ride-share services are hailed via the application or, in the case of the boda bodas, walking up to riders and scanning the rider's QR code to initiate the ride. Individuals can board or disembark from a vehicle from multiple places, including a *Taxi Park* or *Stage* and along the *Roadside*. A taxi park is a designated location where multiple taxis traveling to different locations might park. Fares from this location only fluctuate in rare circumstances (e.g., rain, operator strikes, riots). This is not the case for taxis that are boarded along the road, which credit fare inconsistency to "jam" (traffic). A stage is a locally known spot where taxis drop off and pick up riders; in contrast, a boda boda stage is a location where a cluster of bodas park and wait for passengers.

3.2 Kigali, Rwanda

Kigali is the capital of Rwanda and boasts a population of over 1.3 million [146]. Kigali is 500 km from Kampala, and the cities have similar modes of transportation but differing patterns, laws, and regulations. It has multiple public transit options that are similar to those in Kampala, including minibuses, large buses, motorcycle taxis, and cars [2]. The 14-seat minibuses, locally referred to as *Taxis*, are currently being phased out in favor of buses that can carry 30 to 51 passengers. Similar to Kampala, taxis and buses are a form of shared transportation. In Kigali, motorcycles are called *Motos*, and they usually do not exceed their intended rider capacity. Kigali's version of the special hires are called *Taxi Voiture*.

Relative to Kampala, Kigali has implemented additional systems to create organization on public transit. For example, Kigali has begun to implement new, more organized bus stops in different parts of the city. Also, it is required for anyone using a motorcycle in Rwanda to use a helmet; as such, moto drivers often carry an extra helmet for their passengers. As in Kampala, motos can be hailed from the side of the road or from a designated stage in a neighborhood. Unlike motos that might drive along the road looking for passengers, taxi voitures usually only depart from specific locations and will only solicit business from people who approach their vehicles or glance in their direction from across the road. In Kigali, transportation has also recently evolved to include ride-share services such as SafeMoto, YegoMoto, and Move (Volkswagen's ride-hailing service).

3.3 Pittsburgh, Pennsylvania, USA

Pittsburgh is a city with a greater metropolitan area of over 1.2 million people in Pennsylvania, United States of America [26]. Rather than relying on more informal methods of public transit, the majority of people rely on vehicles owned and managed by Pittsburgh Regional Transit (PRT, formerly named the Port Authority of Allegheny County). This public transit agency primarily operates buses, but there are a limited number of light rail routes (locally referred to as *the T*) and funiculars (called *inclines*). Standard city buses are approximately 40 feet long rigid single-deckers, with space for approximately 40 seated passengers and another 30 to 40 standing passengers. On some busy routes, PRT uses 60-foot articulated buses, which can carry approximately 120 passengers. All PRT vehicles traverse fixed routes, only deviating in cases of emergencies or construction. The T is a light rail system that runs north and south of the city into suburban areas. It is mostly above-ground and runs on tracks that can be separated from or integrated into roadways. The trains consist of two cars and can hold approximately 180 passengers. During rush hour, a second set of train cars may be added to the lead car. There are two inclines that run up and down Mount Washington; each incline has two separate cars that can hold approximately 25 people. In addition to these public vehicles, PRT provides a service called ACCESS paratransit that provides subsidized, shared, point-to-point rides in a sedan or van for individuals with certain verified disabilities or aged over 65 years. However, these rides are not available to everyone and must be planned in advance. In addition to formal public transit provided by PRT, travelers can also use taxis, ride-share services, and bicycle and electric scooter rental programs. Taxis are typically vehicles like sedans and minivans that seat five to eight people. They may be hailed via an app, reserved over the phone, or boarded at hotels and a specific location at the airport. Ride-share services include Uber and Lyft and typically include sedans, sport utility vehicles, and minivans. Travelers can also use a bike-share program, Healthy Ride. Spin e-scooters are currently (as of 2022) part of a pilot program focused on last-mile transportation and can be rented by individuals over 18 years of age [179].

For all large public vehicles operated by PRT, passengers board and disembark vehicles at marked stops only. The agency provides paper schedule and route information at stations, inside buses, and in other public places. It also maintains a website with PDF copies of schedules, service updates, useful information, lists of where to buy a transit card, online refilling of transit cards, and a link to the ACCESS paratransit service for individuals with disabilities. Additionally, it provides a mobile-friendly web app with real-time arrival information for selected routes and stops, crowding information for individual vehicles, service bulletins, and phone-based ticketing. For this region, there are also a number of other transportation and navigation apps that contain navigation to/from stops and vehicle schedule information (e.g., Google Maps or Apple Maps), real-time vehicle tracking (e.g., the Transit app), and additional information about surroundings for those with reduced sight (e.g., BlindSquare, Nearby Explorer). For other vehicles, more possibilities for embarking and disembarking exist. For example, ride-share programs like Uber and Lyft can be hailed via app for curbside pickups at any location.

Part I

Exploring Public Transit Ecosystems in East Africa

Chapter 4

Exploring "Other" Stakeholders in the Public Transit Ecosystem

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This chapter was previously published in the scientific article:

Kirabo, L., Carter, E.J., and Steinfeld A. (2020). "You are asking me to pay for my legs": Exploring the Experiences, Perceptions, and Aspirations of Informal Public Transportation Users in Kampala and Kigali. *In ACM SIGCAS Conference on Computing and Sustainable Societies (COMPASS '20)*

4.1 Overview

Research on public transit in the Global South often centers the experiences and perspectives of operators (i.e., drivers and boda riders) [96, 135, 150, 151, 164]. However, public transit technology ecosystems include more diverse groups of key stakeholders. Each stakeholder holds their own experiences, perspectives, and agendas. Even more complexity is created when new transit technologies are inserted into these ecosystems. Transit technologies range from mobile applications (i.e., ride-share and bus schedule apps) to advancements in vehicles (i.e., electric and automated vehicles). The fast-evolving nature of technology necessitates frequent examination of the ecology of potential user communities (e.g., [15, 60]) in order not to risk automating existing inequalities and robbing agency from users [53].

In this chapter, we explore the perspectives of passengers and other key informants (e.g., start-up workers, regulatory agencies, and disability activists) in the local technology ecosystem. These perspectives are necessary because passengers and local technology creators serve as direct users of public transit technologies (who have first-hand experience of any inequities in the systems) and also influence the directions in which technology will impact public transit. Therefore, there is a need to engage a diverse group of passengers and technology creators in order to reveal and discuss existing inequalities faced by different segments of the population.

According to national statistics, disabled people comprise 20% and 5% of the population for Uganda [147, p. 18] and Rwanda [148], respectively. They are viewed as among the most vulnerable people to transportation inequity; however, it is not clear how they navigate transportation and whether access to technology improves their mobility. Understanding the influence of technology on mobility is important because Kampala and Kigali are cities that are poised to see new transportation technologies: the former was chosen as the designated lead for the smart city initiative in Africa [103] and the latter because Rwanda is known as the regional leader in innovation [66]. Relatedly, these cities have seen the introduction of ride-share services, including both international (e.g., Uber, Taxify, and VW Move Ride) and local variants (e.g., SafeBoda, SafeMoto, YegoMoto, etc.). Though technology can benefit users and enable new and positive interactions among people and systems [34, 90], it also can have unexpected effects when applied to mismatched contexts [112] and even fail completely.

In our study, we administered surveys to passengers who use public transit in Kampala and Kigali and supplemented this data with in-depth interviews with key informants in the disability community and local technology ecosystems. We present the following high-level themes: the influence of ability on preferred mode of transportation and technology appropriation, discrimination and harassment faced by riders, and the influence of perceived social hierarchies. Motivated by these findings, we discuss areas where technology can and cannot mitigate existing inequities. We also look at how the findings support emergent frameworks, such as aspiration-based design, and we present potential envisioned future technologies for public transit. This work contributes a deeper understanding of the experiences, perspectives, and aspirations of passengers and industry stakeholders with the goal of informing future technologies.

4.2 Method

4.2.1 Study design and data collection

The study design was guided by our motivation to uncover passenger experiences with public transit in Kampala and Kigali and understand nuances that affect how technology can influence and possibly improve transportation for riders with different abilities. To this end, we administered surveys with passengers of public transit to understand influences around usage and adoption and followed up with in-depth, semi-structured interviews with passengers and other key informants (e.g., start-up workers, regulatory agencies and disability activists) in the local technology ecosystems. The interviews were conducted either in person or online with stakeholders who were physically unavailable. This research was approved by our university's Institutional Review Board as well as university faculty and staff in Kampala and Kigali.

We recruited participants through social media, a technology co-working space, and local university noticeboards because populations that frequented these spaces were determined to be frequent users of public transit. We required that participants were above 18 years of age, had resided in Kampala and Kigali for at least a year, and used public transportation. We used one-on-one semi-structured interviews, in-person surveys, and online meetings (audio and video). In total, we conducted 46 surveys over a 2-week period and 12 key informant interviews (5 in person and 7 online) over a period of 2 months. Our participants lived in areas outside the city and commuted to town for work or school.

Passenger patterns survey

Our survey focused on preferences in public transportation. We invited participants to hour-long sessions where survey forms were physically distributed. We conducted 7 survey sessions in Kampala attended by 25 participants and 15 sessions in Kigali attended by 21 participants. Each session started with an overview of the research topic, the informed consent process, and a high-level briefing on the survey. Participants did not receive any monetary compensation for filling out the surveys and participated due to their interest in improving public transit. Although the surveys were administered in person, we only collected demographic identifiers, such as participant gender and age. No personally identifiable information was collected.

The 9-page survey was used to collect information on eight key topics: Frequency of Use, Morning Commute, Evening Commute, Familiar Strangers, Perception of Safety, Harassment in Public Transit Spaces, Passengers with Disabilities, and Future Impact of Technology. However, only Morning Commute and Evening Commute were labeled explicitly, in order to prevent response bias. Inspired by prior work [158], we included questions on "familiar strangers", who are the people that passengers observe, but do not interact with, at a boarding location or along a commute. These questions explored if participants often boarded with the same people and would intervene on their behalf in the event of any issues.

The 25 participants in Kampala (9 female and 16 male) were almost evenly distributed in age (with 7 participants between 18-24 years old, 10 participants between 25-31, and 8 between 32-38). The majority of the participants indicated that they lived in areas in the northern part of Kampala. Of the 21 participants in Kigali (6 female and 15 male), 18 indicated that they were in the 25-31 age range, with the rest falling in the 18-24 age bracket. Again, most of the participants lived in areas north of the city.

Key informant interviews

We interviewed different stakeholders, including disabled riders, individuals in or associated with transportation in the start-up community, members of regulatory agencies, and individuals who work with disabled people.

The in-person interviews were conducted in the interviewee's office or another convenient location (2 interviews in Kampala and 3 in Kigali). These 8 participants (2 organizations opted to have group interviews) included persons who either worked for regulatory agencies or worked for organisations associated with transportation in the startup community. In-person interviewees did not receive any monetary compensation.

Our seven online interviews were conducted on Skype with participants in the disability community. These interviews lasted 1.5 hours. We modified the type of streaming (video vs. audio) based on both participant preference and whether they were using Wi-Fi or mobile data. Four participants used Wi-Fi and 3 used mobile data. To cover their data costs, online interview participants were compensated using mobile money transfer. The compensation rate was based on the average monthly rate of mobile data packages sourced from local telecommunication providers. We conducted 6 Skype interviews for participants in Kampala and 1 for a participant in Kigali. Five of our participants who work with disabled individuals self-identified as having a disability (i.e., Physical: 3; Deaf/Hearing Loss: 1; Albinism with Visual Impairment: 1). These participants shared their insights from working with disabled individuals and their own personal experiences using public transportation.

The interviews covered topics that included the current state of public transit, access to different modes by people with disabilities, and potential challenges and opportunities for technology. All interviews were audio recorded for transcription and further analysis. Researchers also maintained a daily activity log and recorded their observations and insights after every interview.

All data was transcribed by a researcher with experience living and interacting in Kampala or Kigali. This was useful for understanding colloquial expressions that have local contextual meanings and have been integrated into English speech but do not make sense to English speakers elsewhere (e.g., ...don't *disturb* people to *look for me* data...).

4.2.2 Limitations

Our research with key informants who worked with disabled individuals was conducted online rather than in person. While these informants were able to give us a wealth of knowledge, we acknowledge that this method prevented interviews with people lacking access to online meeting tools. Similarly, while English is one of the official languages of both countries, we acknowledge that there is a diversity of other spoken languages in both countries. One of the authors speaks some of the local languages, but we limited our interactions to English in order to maintain consistency. This choice also limited the breadth of participants who were able to participate in our surveys.

4.2.3 Data analysis

We used descriptive statistics to analyse our quantitative survey results and thematic analysis for the survey's free text responses and interviews [20]. Our initial analysis revealed 9 high-level themes that we later condensed to 5 themes. These include the influence of ability on preferred mode of transportation and technology appropriation, local commutes, discrimination and harassment, perceived social hierarchical structures, and technology interventions.

While reliability is a debatable notion in qualitative studies due to changes in human behavior, we attempted to ensure that our results were consistent with our data using a combination of an audit trail and triangulation (i.e., using multiple sources and including observations, reflections, and decisions made during data collection).

4.3 Findings

Here, we present themes that emerged from our survey and interviews data. All names have been changed for anonymity. For the sake of clarity, all boda bodas and motos will be referred to as motorcycles, special hires and taxi voiture will be referred to as cabs, large buses will be referred to as buses, and taxis will be referred to as minibuses.

4.3.1 The influence of ability on preferred mode and technology appropriation

Participants without disabilities in Kampala selected minibuses as their preferred mode, with motorcycles and Uber (car mode) following closely behind. These choices make sense because minibuses are considered the cheapest mode of transport covering long distances. In Kigali, however, motorcycles were the preferred mode, with buses second. Participants in both cities noted that, of all of the options, the agile motorcycles were always immediately available.

Participants who worked with disabled individuals reported that public transportation was a huge part of their stakeholders' lives. Different modes of transportation best suit different abilities, which was reflected in how passengers chose to travel.

> "*Deaf persons can use all [the available modes]. Blind people move better in buses and maybe [minibus]. Physically challenged people can use [motorcycles] preferably.*" - Wasswa, mobility-related disability.

> "*For a person with physical disability will [use a] [motorcycle] because it will take him to the final destination or the door step unlike the [minibus] for which you have to walk a distance [...]*" - Mutebi, Mobility-related disability.

The motorcycle mode was considered a favorite for passengers with some disabilities because of its flexibility and ease of access compared to minibuses. This door-to-door convenience is likely amplified by the use of app-based motorcycle services, such as SafeBoda and UberBoda. Data from the survey participants mainly supported these findings; for example, participants in Kampala reported observing people with mobility-related disabilities frequently using the motorcycles; however, a preference for buses was observed in Kigali. Participants with assistive devices noted that the devices were either tied to the back of the motorcycles or held by the driver. However, the consequence of having the current transportation options is that blind people cannot easily find transportation in areas that only motorcycles travel (e.g., streets with bad surfaces), and people with a mobility-related disability can only travel short distances easily because motorcycles do not travel as far as minibuses do without becoming excessively expensive.

The preference for motorcycles by disabled riders is also reflected in the appropriation of technology solutions targeted at public transit. When asked about technologies that they use related to transportation, five of our online interview participants mentioned motorcycle applications (e.g. SafeBoda, UberBoda, Taxify). Mutebi (KLA), a participant with a physical disability, specifically cited the independence he felt when using these applications,

> *"I can order for Uber or SafeBoda. It is easy for me, I do not disturb anyone to go and look for me a [motorcycle]."*

However, disabled participants also pointed out the shortcomings of these applications. It is common for these ride share drivers to call their passengers as they approach the pickup point, but answering these calls is particularly difficult for passengers who are deaf. Egwang (KLA), a participant who is deaf, noted that to use these applications, he needs to have someone else on hand to answer the calls. He described an incident where he tried to get help from a nearby shop; however, the shop owners were alarmed by his gestures and did not understand what he was trying to communicate and thus refused to help. Asiimwe (KLA), a participant who works with disabled individuals in camps for the internally displaced, also noted that while disabled people are using these applications, she had yet to see in-app accessibility features, such as vehicle options that were modified to cater for persons with physical disabilities. Lastly, both Mutebi and Asiimwe remarked on the exclusive nature of these solutions: users must have a smartphone and buy data to access to the Internet.

Government and transportation stakeholders are aware of these issues and some are actively working to improve transportation for disabled riders. The recent shift toward catering to the well-being and mobility of disabled individuals has led to the introduction of accessible buses in Kigali. Ishimwe (KGL), a participant with a physical disability, noted that buses are the favored form of public transportation by disabled riders and that they have improved the mobility of public transit riders in wheelchairs. For visual impaired riders, these buses are fitted with audio functionality that announces the approaching bus stations. However, he noted that there was still an opportunity for the inclusion of deaf riders, as they were not yet supported.

4.3.2 Discrimination & harassment of transportation riders

The interview data provided an interesting emphasis on the role of other passengers with disabled riders. Our interviews in Kampala revealed harassment of disabled individuals around denial of access and unfair costs. Participants reported instances where some minibuses would not stop to pick them up or operators would first inquire whether the rider would be taking their assistive device (e.g., wheelchair or crutches) with them, and then potentially drive off depending on their answer.

They reported two instances of passenger intervention. In both instances, the transport operators were attempting to deny a passenger using a wheelchair entry into minibus unless they paid extra (often another full fare) for their wheelchair. In both instances, the passengers in the vehicle came to the aid of the disabled rider, ensuring that they boarded and also arrived at their destination without further harassment.

> "*I was traveling a long distance [...] the guy was like I should pay for my wheelchair and I was refusing saying no I cannot do that saying this is my legs and he said, but it is occupying my space you have to pay and the amount that they sometimes charge is equivalent to what an individual is paying. So someone said that unless you tell everyone in this bus to pay for their legs, he is not going to pay. And then others also joined in. And then when we reached the stage, they carried my wheelchair out and said you go - let us see him following you [...].*" - Mutebi, Mobility-related disability.

An overwhelming majority of our survey participants did not observe or board with the same people daily; however, they were somewhat likely to intervene on behalf of strangers over issues (shown in Table 4.1). Some participants seemed surprised at the notion of talking to strangers at the stop; for those that interacted, it was mainly in greeting form.

Table 4.1 Distribution for recognition of familiar strangers.

	Kampala		Kigali	
	Yes	No	Yes	No
Observe the same people	5	20	1	20
Board with same people	4	21	0	21
Intervene for stranger	6	17	6	13

Passenger intervention, however, was not always the norm during trips for disabled riders. Our discussion revealed that other passengers remarked that a disabled rider would take too long to board the vehicle or outright refuse to sit next to them because of their state of dress and body odour. An unintended result of these experiences with negative attitudes left disabled passengers feeling like second-class citizens.

A similar sentiment and experience was reflected in interview data the Kigali participant Ishimwe. He blamed the existing stigma on a lack of awareness and negative naming conventions for disabled individuals that are rooted in cultural origins.

Among riders without obvious disabilities, responses concerning harassment presented a dichotomy between the two cities. In Kampala, most survey participants said they had been heckled more than once in a public transit setting. In Kigali, more than half of survey participants said they had never been heckled in these settings. When distinguishing between verbal harassment and physical gestures of groping, in Kampala, all of the female and more than half of the male participants reported having encountered both forms of harassment. Notably, the definition of harassment varied between by location. Hissing is viewed as harassment in Kampala but not Kigali.

4.3.3 The influence of perceived social hierarchical structures

In Kampala, participants noted that there was a need to understand the invisible reach that culture and norms have over adoption and perceptions regarding technology. Bugembe (KLA) noted that he rides his bicycle to work every day, but bicycles are at the bottom of the perceived transportation hierarchy, so there is a general lack of respect toward him on the road. His explanation for using a bicycle was that with the population shift from rural areas to urban city centers, there is a need to adopt clean and affordable transportation solutions. However, this mode of transportation poses an additional safety risk as there are no laws protecting bicycle riders and motorists believe that they have right of way over bicycles and do not even account for the presence of bicycles when switching lanes.

Participants hinted that the choice whether to drive a private vehicle or take a minibus was directly related to a person's socioeconomic status. A common viewpoint is that people who drive cars have simply achieved enough success to not take minibuses any more. Abaho (KLA) noted, "In a city where 1 in 4 cars has a parking spot, technology offers opportunities to find the closest parking lot or structure (several blocks away), then hop onto a [minibus] to work. However, when you propose it to Kampalans, they would rather spend another 20 minutes driving around looking for a parking spot than [be seen taking] a short [minibus] ride". Participants from Kigali did not seem to share the same status association with boarding minibuses. However, people preferred to take cabs over minibuses for comfort (minibuses in Kigali seat more people than those in Kampala).

4.3.4 Technology: (un)successful interventions

In Kampala, experiences with implementing technology solutions in the existing public transportation ecosystem highlighted negative sentiments. Abaho (KLA) noted that operators were interested in testing cashless payment, but they encountered barriers when interacting with various informal structures that characterized their day. Examples of such structures included making payments to route touts (individuals who collect "membership" dues from minibus operators) and cabals (routes that only allow drivers who have paid said dues), fuel pump attendants, and minibus owners. These findings provide evidence of a mismatch between technology solutions and their appropriateness for use in different context.

In Kigali, however, Ntwari noted that there have been successful tech-based changes due to favorable government policy, including: (i) implementations of cashless payment solutions in public buses–“Intercity buses use tap-and-go payment while buses that go outside of the city use tickets”; and (ii) an online dashboard monitoring the deployment of buses as well as enforcing speed limit regulation and providing reward incentives to drivers who adhere to regulations. Habimana (KGL), whose start-up works with motorcycle riders, noted an uptick in technology literacy among riders. Riders who previously had limited or no technology access were now becoming adept at reading maps and troubleshooting device errors.

Some participants (KLA) noted that technology can be used to improve passenger safety within vehicles, improve access to the different options, and determine trip cost. Other participants (KGL) envisioned technology being used for bus arrival predictions and scheduling, as well as improved payment systems (e.g., contactless payments). The latter was an idea expressed by our industry informants Mugisha (KGL), Keza (KGL), and Gara (KGL), who work at the intersection of public transit and financial technologies. They imagined that the future of public transit technology includes seamless payment transitions between different modes of transportation and diversification of the current payment systems across multiple domains (e.g., transportation and healthcare). They believe that technology offers a unique opportunity to add value to both passengers (e.g., manage bus fares where uncertainty exists or promote financial budgeting) and government entities (e.g., transparency through identification of revenue leakages).

4.4 Discussion

4.4.1 Aspirations through envisioned futures

Exploratory studies like ours are a good source of findings relevant to technology design and implementation. We position these results within frameworks, such as aspiration-based design, and discuss future research directions and their implications.

Opportunities for technology

The preference for specific modes of transportation based on users’ abilities should be taken into consideration when implementing functionality. For example, this could include enabling speech recognition for users with amputated limbs who are unable to use interfaces built with traditional gestural interaction. In addition, applications targeted at cabs and minibuses should take into account the requirements of users with visual impairments as these are their preferred modes of transportation. For instance, they should promote the use of digital payments (like mobile money) in Kigali, which has digital systems in place. These types of payments help avoid instances of cheating that might happen with cash payments. These requirements should also prioritise the safety of passengers (especially those with visual impairments) by providing audio updates when alternative/unfamiliar routes are taken and thereby giving them agency regarding route choice. Another opportunity to enhance agency for passengers with and without disabilities is through implementing a crowd-sourced route safety tool. This tool could provide passengers with information before they start their trip or while their trip takes an unplanned detour. An aggregated mapping might also show evidence of crime hot spots that would be useful to law enforcement. This tool could have multiple use cases outside of safety: 1) technology hubs could use this feature to educate passengers about engaging with drivers on the challenges of secondary routes, and 2) citizens who commute using bicycles could use the application to find bike-friendly routes and times.

The influence of aspirations on adoption

Prior work has argued for the importance of understanding the aspirations of potential technology stakeholders [114, 190] because these aspirations then influence adoption. In this study, we find further evidence that supports these assertions, especially among experiences shared by disabled passengers. We discuss this support based on the three main qualities of aspirations: embedded (aspirations are rooted in past experiences and local context), temporal (aspirations can be satisfied within an unspecified period of time), and mutable (aspirations have the capacity to change).

Embedded aspirations can be clearly seen in the adoption of ride-share services by disabled riders. Participants described situations where they felt like second-class citizens when using traditional methods to utilize public transit. Their technology adoption results in additional freedom from traditional social and physical accessibility barriers. The temporal boundaries within the aspirations that we found were connected to the day-to-day and long-term activities and patterns of users of public transit. The day-to-day activities that could be affected by technology include interactive bus terminal data for bus arrival and departure information (KGL) and efficient and context-dependent pricing systems (KGL, KLA). The long-term aspirations include the ability to implement integrated single-source payment systems across multiple domains (e.g., linked health and transportation systems) to increase convenience.

The fact that aspirations can change over time is reflected in their mutability. We posit that shifts will be seen as more solutions are implemented that satisfy passenger aspirations, including policy and infrastructure improvements. As needs and priorities change, so might transportation and technology preferences. For example, bicycles are currently disregarded as modes of transportation in these two East African cities, as they are the least expensive option. However, as these countries develop, it is possible that the ecological and health concerns that motivate bicycle usage in other cultures will change the impressions of bicycles in East Africa.

The nuance of engaging ability

Within the disability research community, there have been longstanding efforts to focus on user ability when designing technology [63, 197]. Our work presents some evidence of tension when integrating the notion of ability. Our findings show that taking ability into consideration goes beyond understanding a passengers' mobility. This is made evident in passengers (both without and with disabilities) preferring the boda boda mode of public transit. For the former group, the preference was rooted in efficiency (i.e., reaching the destination as fast as possible). For the latter group, participants liked how motorcycles get them from their origin point to the doorstep of their destination and the lack of additional hassle of dealing with traditional operators. Interfaces that integrate transportation routes, modes, and schedules should adapt to factors like perceived efficiency, door-to-door service, and other personal preferences.

Conversely, we identified one failure case at the intersection of technology and ability that has implications for designers and researchers. Ride-share operators are not trained and applications are not designed to consider riders with different physical disabilities. As with boda boda and special hire operators in Kampala, ride-share drivers will often call passengers to confirm that they are en route or at the gate. However, riders who are deaf had difficulty with this use case. This has recently been solved through the addition of an in-app texting platform (as seen in the Uber app), but it is unclear whether this will work across the board due to the wide variety in literacy levels for users and drivers. This reveals an opportunity for new interaction and experience designs that support lower literacy levels (e.g., read-aloud options with local options).

We also found evidence that supports prior work on the importance of offline connectivity [6, 172]. Participant responses extended the notion of ability to include connectivity. To address this, designers of mobility interfaces should be intentional about internet connectivity and consider interfaces that adapt to offline functionality when data is expensive.

The influence and appropriation of technology

Researchers have disagreed at times about the influences that ride-share technologies can have on a population as a whole [41]. Our work provides evidence that these technologies are being used to alleviate some of the social pressures that characterize users' lives, especially for those with disabilities. As previously stated, disabled riders characterize their appropriation of these technologies using terms that relate to the promotion of agency and independence. The idea of technology contributing to agency and independence is not new to researchers in the disability domain [183]. The appropriation of transportation apps by disabled riders in the Global South is especially noteworthy given that they are considered some of the world's most vulnerable populations [128].

Also, we see the influence of local contexts on technology development and dissemination, such as Uber offering boda boda ride-share options in their local application. This speaks to the context for this particular form of transportation in the region: even though some ride-share companies offer cheaper car rides, users still choose the boda boda option because they find it more efficient and convenient. Both Kampala and Kigali also have local ride-share applications solely for the boda boda form of transportation.

The notion of smart mobility eventually evokes the idea of *AI for transit*. From a user's standpoint, these systems often rely upon the concept of regularity: predictable numbers and types of vehicles on the road, schedules, etc. However, our work indicates that, in these cities, users report regularity in general terms (e.g., early morning or late at night) and public transit modes follow flexible schedules, if any. This raises the question of whether AI could, and should, be used to nudge user schedules (e.g., waiting out surge pricing, especially during the rainy season), as is the norm in cultures with specific time-based routines. Perhaps the adoption of these AI technologies would be increased if they are designed to adapt to the scheduling norms of these cities.

Lastly, pursuit of equitable mobility proposes that individuals should have equal access to transportation and travel. Our findings support prior work from different regions that found that transportation is often not equitable for disabled riders [91, 154]. In some societies, media-related campaigns (e.g., television, radio programs and advertisements) have been used to target behavior change [134]. Technology such as persuasive design and game development can be another effective method to impact behavior change [40, 80, 101], especially among operators who discriminate and harass disabled riders.

4.4.2 Exploring context & adoption

It is undeniable that for cities like Kampala and Kigali, local social influences are unique and impact the lives of citizens. Our comparisons are not meant to elevate one city over the other, but rather to explore how regions that may appear quite similar from the outside may have different factors that impact technology adoption.

While both cities have been known to celebrate innovation, it is apparent from our discussions with different key informants in the two ecosystems that the nature of each system is fundamentally different. Kampala is characterized by a grassroots approach to technological innovation: individuals come together to implement systems that might end up influencing policy. The culture fosters a communal effort towards problem solving and solution creation, and therefore it may benefit from the use of crowd-based technologies and participatory design approaches that allow for continuous public initiative and contribution to the creation of a system and its content. Having users provide real-time information about road closures, construction and incidents of theft, harassment, less-than-optimal transportation routes, etc., might be especially successful as they fit into existing community-based practices. Top-down, policy-driven initiatives such as those for cashless payment systems struggled due to the need for cash payments by operators to different players (e.g., fees, fuel, payoffs, etc.). In spite of Kampalans' interest in a cashless system similar to one in Kigali, financial technology solutions also struggle when they create obstacles to existing forms of livelihood. Because of how context can make or break adoption, new technology service models must consider the nature of the ecosystem and purposefully balance aspects to obtain buy-in from cash-based stakeholders while providing the ease of use desired by passengers.

In contrast, Kigali has an approach similar to a policy-driven model: government policies are put in place to foster and direct an ecosystem of innovation (as noted in our findings). This policy-driven approach that characterises Kigali's growing ecosystem is primed for local ready-to-go technology solutions. A good example is cashless payments, which can take the form of domain-specific smart cards, debit card transactions, and mobile money payments. Due to supportive technology policies and implemented infrastructure, Kigali has been able to design and employ cashless payment solutions within the sphere of public transit. Policies like these impact potential widespread adoption, especially within urban areas with technology-friendly populations, by creating a single, unified system that can be adopted simultaneously by all stakeholders.

Furthermore, in both cities, there is an opportunity to explore whether these policy narratives engage with the lived experiences of disabled riders. These narratives provide opportunities in which disability advocates and technology enthusiasts can engage with disabled people and their allies.

4.5 Summary

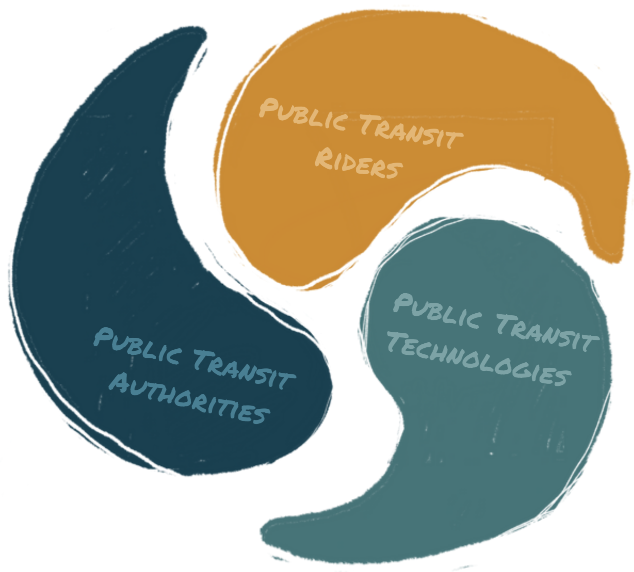

Fig. 4.1 A visual representation of the public transit ecosystem depicting three categories of stakeholders

In this chapter, we examined the experiences of different stakeholders in the public transit ecosystem. We have determined the following insights about the stakeholders (Figure 4.1) and their interactions:

- Public Transit Riders: Riders are key stakeholders in the ecosystem (in addition to operators). They can be further split into two groups (i.e., disabled riders and non-disabled riders) with unique experiences and influences.

- Public Transit Authorities: Authorities included transit operators such as drivers, boda boda riders, and conductors; and regulatory agencies
- Public Transit Technologies: The transit technologies highlighted in this chapter include ride-share technologies and an unsuccessful implementation of a cashless payment solution.

This chapter shows the negative influence of public transit authorities on public transit riders. Non-disabled riders sometimes perpetuate these negative influences. The result impeded access to public transit and influenced disabled riders' capabilities. It also created an inequitable imbalanced experience for riders that led to the eventual adoption and/or appropriation of public transit technologies (i.e., ride-share applications) by disabled riders in Kampala and Kigali. This population of riders is underrepresented in the Human-Computer Interaction scholarship. In the next chapter, we contribute towards filling this scholarship gap by exploring the experiences of disabled riders with other stakeholders within the public transit technology ecosystem.

Chapter 5

Co-designing the Disability Ecosystem

This chapter was previously published in the scientific article:

Kirabo, L., Carter, E.J., Barry, D., and Steinfeld A. (2021). Priorities, Technology & Power: Co-Designing an Inclusive Transit Agenda in Kampala, Uganda. *In 2021 ACM Conference on Human Factors in Computing Systems (CHI '21)*

5.1 Overview

Under-representation in research scholarship and populations has diverse effects on artifacts and the future of research fields. The HCI community has notably lacked representation in both scholarship [70, 69] and study populations from African countries, particularly for individuals disabled individuals. This double lack of representation can lead to the rise of solutions and findings that reveal dissatisfaction, cost mismatches, and unique appropriations to match contextual circumstances. According the United Nations, there are 80 million people on the African continent who have a disability [115]. In Uganda specifically, that number is nearly 1.4 million [147, p. 4]. It is high time that these populations are included in conversations about technology that could impact their way of living.

Design and research movements are unanimous about the importance of inclusion with specific regard to physical environments [184] and technological spaces [118, 105, 197]. However, these approaches often fail to adapt to local contexts in the Global South, including countries like Uganda, due to social-cultural differences. This issue presents the need for design movement agendas that engage with both the notion of culture and that of inclusion. One example of such a movement is included in the principles that govern the Value-Sensitive Design framework [61]. The Value-Sensitive Design framework advocates for prioritizing human values across multiple technology stakeholders. In this framework, human values represent inherent beliefs and concepts of dignity and fairness that are culturally relevant to local contexts. Situating these values across multiple stakeholders reveals nuances that technology designers and researchers should engage and grapple with as they propose methodologies and interventions. Relatedly, another example of a movement with similar principles is the Disability Interaction (DIX) Manifesto [84]. The principles of "co-created solutions" and "value use and usefulness" particularly advocate for the amplification of the voices of disabled individuals. We extend this scholarship by applying these methodologies to assistive technology contexts in the Global South (specifically, Kampala, Uganda).

In this chapter, we answer the following sub-questions:

1 How can we understand the values and relationships that exist in the public transit experiences of disabled riders?

   We adopted the Stakeholder Tokens Method [203] from the Value-Sensitive Design framework to co-design a map that represents stakeholders within the disability ecosystem and the relationships that exist between them. It is important to understand who the different stakeholders are and the influence they wield, especially when designing new interventions.

2 How can we understand the public transit gaps and challenges that they currently experience?

   We used qualitative methodologies such as interviews and design exercises to investigate the unmet transit needs of disabled riders in Kampala, Uganda. Access to safe and equitable public transit is known to increase inclusion and participation for disabled persons [194, 129]. Furthermore, there is the steady and continued proliferation of ride-share technologies that use mobile computing to provide both transit and supplementary services (e.g., package delivery).

5.2 Method

5.2.1 Study design & data collection

We conducted 6 online semi-structured interviews, each with 2 design exercises. Our goal was to elicit the unmet needs of the disability community and characterize the current and future roles of technology. First, participants completed a design exercise to identify problem areas in transportation and disability and envision possible technological solutions. In our second activity, we invited our participants to co-design a stakeholders' map that revealed underlying power structures within the disability ecosystem. All interviews were conducted over Skype. Given the constraints of an online study, we organized the activities to lessen the time and cognitive burden on our participants. This research was approved by our university's Institutional Review Board as well as by university faculty in Kampala.

We recruited our participants using social media. We invited adults who work in organisations that advocate for and work with disabled individuals to participate. Our assumption was that members of this group interacted with multiple parts of the disability ecosystem. We selected participants after the research team verified participant roles in organisations. This was solely based on the disability type and nature of the organisation. We wanted to speak to people with diverse experiences (Table 5.1). After participating in the study, participants were compensated $40 (the average local cost of 1 month of mobile data) for their time using mobile money transfer.

Table 5.1 Participant Information. Participant names have been changed to protect their identities. *SL is Sign Language and *IDP is Internally Displaced Peoples

Name	Disability	Organisation	Experience
Kagenza	Deaf/Hearing Loss	Disability NGO	>10 years
Muwonge	Mobility Impairment	Government	>10 years
Katongole	Mobility Impairment	Disability NGO	1 - 5 years
Nassiwa	Albinism/Low Vision	Disability Activist	1 - 5 years
Kunda	None	SL* Interpreter	1 - 5 years
Murungi	None	IDP* NGO	<1 years

Design exercise 1: Waving a magic wand

Our first design exercise was inspired by previous work [67]. We adapted the exercise for our context by removing magic because it can conjure associations with the occult that might make participants uncomfortable depending on their upbringings and beliefs. In this exercise, we asked participants to imagine what challenges they would solve about public transportation if they were given all the money they needed. Participants were given time to reflect, write down, and share their answers with the interviewer. Then, using the How-Might-We method [42], we probed whether technology might be used to address the challenges raised. We also asked questions to elicit further characterizations of the roles technology presently plays in accessibility and transportation (e.g., in raising awareness, reducing stigma and increasing access to services). Lastly, participants were asked to identify factors that they felt were critical to the design of inclusive technology.

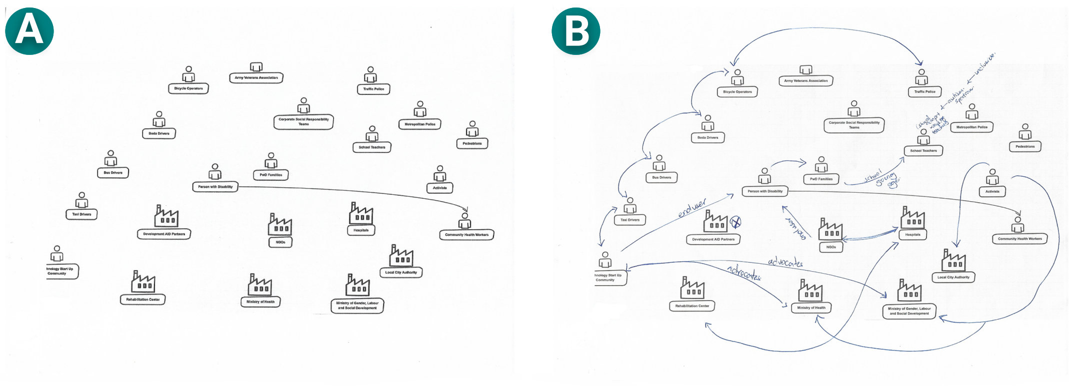

Fig. 5.1 Image A (left) was the final image of nodes presented to the participants. Image B (right) is an example of a map with some connections drawn between nodes. Connections are denoted by lines.

Design exercise 2: Map generation

We employed the stakeholder tokens method (adapted for an online study) [203] to co-design a stakeholders map. Our use of co-design is predicated on invitation and empowerment of non-designer users to contribute to the creation process [204, 205]. We were interested in creating a space where participants contributed through their own lived experiences. The stakeholder tokens method from the Value-Sensitive Design Framework [61] can be used to reveal complex sociopolitical relationships among different stakeholders. We developed an initial image of nodes (i.e., stakeholders) using existing literature about the disability community [27, 119, 125, 19, 165, 5, 36] and local knowledge. This was guided by this question: Who are the people, communities, and groups involved with persons with disabilities? As an example, a connection was drawn between a disabled individual and a health worker. At the end of each session, participants were encouraged to review the map and add/remove any connections that did not reflect their experience.

This document was piloted with three local Ugandan researchers who worked with vulnerable populations in Uganda.These researchers were asked whether the image was a representation of the current disability ecosystem. Over these iterations, 11 new nodes were added to the final map that was used with participants in the study. The final image consisted of 22 nodes: Veterans, Aid Partners, Person with Disability, Hospitals, Bus Drivers, Local City Authority, Boda Boda Drivers, Activists, Rehabilitation Centers, Community Health Workers, Technology Startup Community, Ministry of Health, Metropolitan Police, School Teachers, Pedestrians, Person with Disability's Family, Bicycle Operators, Traffic Police, Taxi Drivers, Industry Corporate Social Responsibility Teams, Non-Governmental Organisations, and the Ministry of Gender, Labour and Social Development (Figure 5.1A). The original stakeholder tokens method leverages the use of the tactile tokens [203]; our study was originally intended to mimic this by using a collaborative drawing tool. However, due to a diversity of screen sizes, resolutions and internet connections, we could not use the tool. Participants were sent the final version of the image over Skype and email in both JPG and PDF formats. They were asked if the image they were given was a complete representation of the disability ecosystem. Participants were asked to identify direct stakeholders, indirect stakeholders and entities they believed should not be on the map. Participants were also given the opportunity to add any stakeholders they thought were missing and asked to identify the relationships/connections that existed among the different stakeholders in the image. They were then encouraged to share scenarios that illustrated the various connections. The identified relationships among entities on the image were denoted by lines connecting them (Figure 5.1B). The goal of drawing these maps was to determine who participants understood the potential power brokers in the community to be as well as elicit any underlying values as described through the relationships drawn.

5.2.2 Data analysis

For our Magic Wand exercise, we used thematic analysis [20] to identify overlapping categories in participant responses. We created an aggregate map using the data from Design Exercise 2 (Figure 5.2). Due to incomplete data, one participant's map was not included in analysis. After combining the five maps, we noted the entities on the map that had no connections to other entities. We also noted instances where participants felt the need to justify the connection with example scenarios. Our map analysis led to the categorisation of stakeholders as *Core* or *Periphery*. We define Core stakeholders as entities who are central to the lived experiences of disabled individuals. Periphery stakeholders are entities with incidental or compound (through other entities) relationships to disabled individuals. We also use the term *Influential* stakeholder to refer to entities that our participants perceived as power brokers within the disability ecosystem. There were some instances where Influential stakeholders were also Core stakeholders; however, not all Core stakeholders were Influential. We discuss the different stakeholders in section 5.3.2.

5.2.3 Limitations

Due to the nature of online recruitment and participation, we acknowledge that our method limited participation to individuals who have both access to data connectivity and knowledge of online meeting tools. By limiting participation to only those individuals whose organisation affiliations could be proven, we acknowledge that this undoubtedly excluded grassroots activists who do not have any online presence and/or work in remote areas. Furthermore, while two participants mentioned travelling outside of Kampala for work, the experiences they shared were from Kampala. Nonetheless, we still believe that this work has important takeaways for growing urban populations (in Kampala and other Ugandan cities).

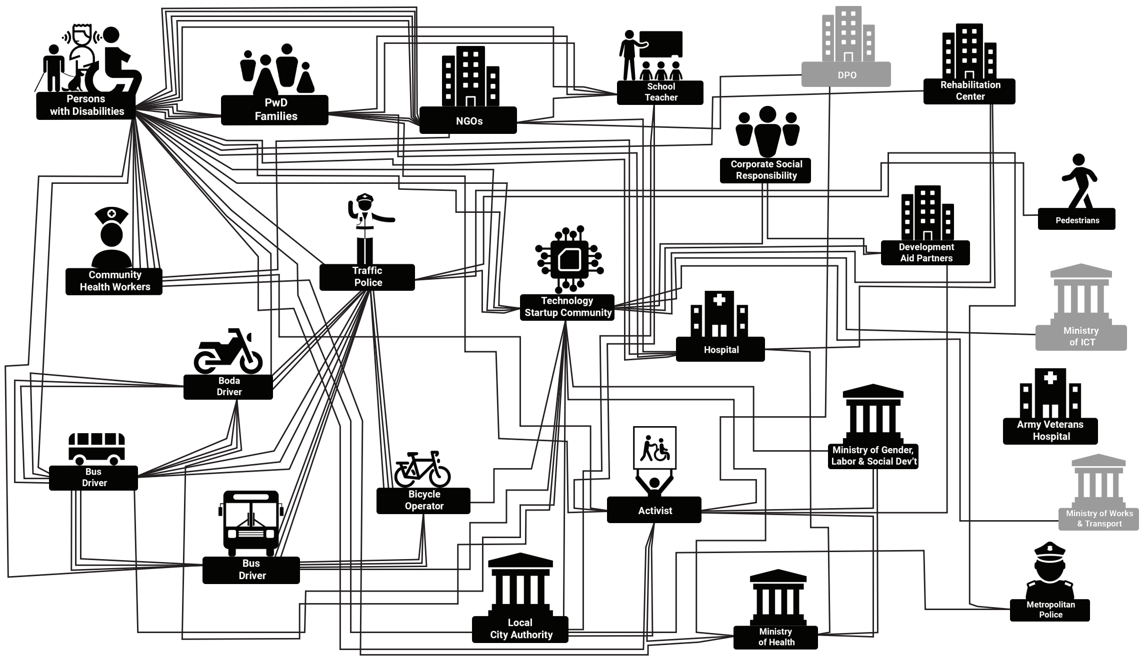

Fig. 5.2 An aggregated stakeholder map showing all of the participant-generated connections among stakeholders. The greyed shapes represent stakeholders added by only one participant

5.3 Findings

5.3.1 Participants' wish list

We present the participants' responses to the first design exercise, Waving a Magic Wand, below. In that exercise, they detailed how they would solve transportation challenges pertinent to the disability community if they were given unlimited resources. The participants' ideas are presented in the order of their priorities.

Disability awareness and understanding

Three participants mentioned the need to create programs that foster an awareness in the general public of the lived experiences of disabled individuals. Participants reflected on the daily challenges of being confronted with apathy and blatant disregard by different members of the community. These behaviors were not limited to a specific social class or situation.

> "*...Even those who are educated have that stigma because we do not understand what people are going through.*" - Murungi

> "*Change the attitude of transporters through their umbrella organisations: UTODA, Uganda Bus Owners Associations, Boda bodas have cooperatives, groups and associa-*

> *tions. It can be the first step, because even if we bring accessible buses, if people still have the attitude towards people with disabilities they will still ignore us.*" - Kagenza

Additionally, Kunda noted that even when being asked for help, bystanders often acted like disabled people were invisible. This further emphasized the need for a shift in the attitudes of people within the community, which one participant said cuts across existing social classes.

Transport infrastructure

During the sessions, three participants reflected on the state of the existing infrastructure, such as roads, pavements, and stages, noting that they were often nonexistent or inaccessible. They explained that pavements (sidewalks) are often shared with boda boda drivers who are trying to avoid traffic by riding on the pavement. They noted that it is then up to the pedestrian to carefully navigate their way, even on the pavement. This feat is challenging to blind and deaf pedestrians who navigate these sidewalks. In other extreme cases, participants noted places where pavements did not exist. In these cases, pedestrians and vehicles are forced to share the same road (often to the annoyance of vehicle drivers). In light of these challenges, participants advocated for investing their unlimited resources in building physical infrastructure that is accessible and safe.

> "*...The challenge of accessing public means, for example, it will require to ensure that we gazette properly these stages, in that people with disabilities can wait from there freely*" - Katongole

A dignity-first agenda: Accessible vehicles

Three participants talked about investing some of the money in the purchase of accessible taxis, specifically citing the installation of ramps that can be used to board and disembark the vehicle. Katongole described that when using taxis, wheelchair users are normally carried into the vehicle by one of the transport operators (who is usually of no familial relation). The wheelchair is then stored in one of three places: placed in the vehicle's boot (if available), tied to the top of the vehicle, or tied at the back of the vehicle. Katongole went further to explain the lack of dignity associated with how he was handled as well as the constant safety concern over how his property was stored.

Techno-futurism: Innovative assistive technology

Two participants also suggested using the money as an investment in specific technology ideas. Their rationale was that these ideas would support the daily commutes of disabled riders. Examples included smart embedded systems with a simple push button interface that would alert bus drivers of a blind passenger waiting for a taxi as well as audio controls on traffic lights. Muwonge specifically shared a dream of modifying his wheelchair to include a pumping mechanism that allows him to access vehicles with multiple heights.

> "*I have a dream of a wheelchair that can raise up and go down. If it raises me up, I can enter a lorry or bus. Using my own wheelchair, I pump it and I go up. It will be raised and I am at that level of that vehicle then I can sit on it and then lower it and then go.*" - Muwonge

Diversity and under-representation

While most participants agreed that technology had the potential to reduce stigma, raise awareness and increase access to services, one participant noted that there was still a lot more that should be done. Murungi noted that in many of the services that were offered (e.g., ride-share vehicles), there were few or no systems adapted to the abilities of disabled people. Murungi also noted that some disabilities, such as autism spectrum disorder, were underrepresented. Five participants noted the importance of consulting with a diverse group of stakeholders before engaging in the technology design process. One participant, Kagenza, suggested the need for actively engaging persons with different abilities in the design process itself.

5.3.2 Co-designing the disability ecosystem

Using an adapted version of the Stakeholder Tokens method, participants created an ecosystem of diverse stakeholders with both linear and complex relationships within the disability ecosystem.

The fluidity of core stakeholders

Participants were unanimous in their identification of disabled riders as core stakeholders within the ecosystem. This is consistent with the principles and strategies argued for in assistive technology literature [105, 197]. Other core stakeholders included: Families, Non-Governmental Organisations, Hospitals, Community Health Workers, Boda Boda Drivers, Bus Drivers, Taxi Drivers, Local City Authority, and Traffic Police. There were some differing opinions on whether the local technology start-up community was a core or periphery stakeholder. Only one participant argued their categorisation as core. This was because the participant had experience interacting with local technology hubs (i.e., co-working spaces that host local technology-centric events). Similarly, participants pointed out that in theory, they believe the Ministry of Health to be a core stakeholder. However, they failed to generate scenarios in which they had observed the Ministry of Health engaging with other parts of the ecosystem. This observation is particularly significant because of the position of influence the Ministry holds in terms of policy creation as well as its reputation for embracing innovative methods for service delivery [48, 145].

The relationships among the stakeholders also played a role in whether they were perceived as influential. A notable example of this are stakeholders that represented the transportation community (i.e., Boda Boda Drivers, Bus Drivers, and Taxi Drivers). In their example scenarios, participants justified their importance based on the role that they play as mobility providers. Additionally, Traffic

Police emerged as influential stakeholders in the ecosystem. Participants recounted scenarios where the traffic police acted as brokers of both security and safety.

> "*Most of the persons with disabilities have trouble accessing the roads too so Traffic Police needs sensitization on how to handle these groups of people so that they can access transportation... Through the police, transport operators have to be sensitized on how to handle PWDs that are using various means of transport....*" - Nassiwa

> "*... Traffic Police have an idea, especially on safety, transportation and also they can give us an advice....*" - Kagenza

Traditionally influential, but on the periphery

Among the stakeholders who were thought to be on the periphery of the ecosystem were: Development Aid Partners; Ministry of Gender, Labour and Social Development; and Industry Corporate Social Responsibility Teams. Participants conceded that while Development Aid Partners and Industry Corporate Social Responsibility Teams were known for donations and hosting events (e.g., charity walks/runs), there were still more opportunities for them to foster stronger involvement and relationships beyond these events, a sentiment that has long been echoed in disability movements around the world [32].

The anomaly among this group of peripheral stakeholders is the Ministry of Gender, Labour and Social Development (MGLSD). The MGLSD is the official ministry responsible for the welfare and rights of disabled individuals in Uganda [111]. There were only two connections drawn to this entity, one that indicated that activists lobby the MGLSD, and the other representing collaboration with the Ministry of Health. These two connections reveal MGLSD's perceived participation with other stakeholders within the disability ecosystem. While this shows involvement, there is still opportunity for a direct connection between disabled individuals and the MGLSD.

The promise of symbiotic partnerships

The Technology Startup Community starred at the intersection of three subgroups. Participants posited that the subgroup that included the Technology Startup Community and Government Ministries held an influential position regarding the implementation of inclusive policies. They reasoned that while it was up to the ministries to generate these policies, the Technology Startup Community should be creating products that can be used by people with a wide range of abilities anyway. The second grouping included the Boda Boda Drivers, Taxi Drivers, Bicycle Operators, Bus Drivers, and the Technology Startup Community. The theme surrounding this group was mainly a call for the creation of and advocacy for accessible transportation. Finally, the Technology Startup Community intersected with a third subgroup that also consisted of the Local City Authority and Non-Governmental Organisations. Participants noted that Non-Governmental Organisations have a history of working with disabled individuals in remote locations, while Local City Authorities have the resources to implement widespread change. Participants stated that a collaboration between these two entities and the Technology Startup Community would give voice and access to groups that are traditionally underrepresented.

A case of allies & advocates

Allyship and advocacy were two of the connecting threads that tied together stakeholder representatives from the Social and Education spheres within the disability ecosystem. There were two notable examples of this. First, family members act as advocates for the well-being of their kin with a disability. Participants stated that Family Members interacted with Schoolteachers on behalf of their Family Member with a disability. A majority of the participants agreed that while activists fight for "disabled causes", they often do not have direct access to disabled people, often choosing instead to go through Non-Governmental Organisations, Family Members, and even in some instances Schoolteachers. In contrast, most participant experiences revealed the lack of interaction between disabled riders and non-familial members of the community (e.g., denoted by Pedestrians on our map). This provides additional weight to the need (mentioned in the earlier exercise) to create awareness through changing attitudes and thereby create allies.

Eliciting implicit values: Human & technological

The disability ecosystem designed emphasizes the values of inclusion, mobility and safety. These values were noted in the expression and examples surrounding stakeholders who are core in the ecosystem, such as the Person with a Disability, the Transportation Providers, and the Traffic Police. They stressed the need for the inclusion of persons with a diverse range of abilities. They also noted the importance of including diverse types of stakeholders because each stakeholder represented interests that were pertinent to the lived experiences of disabled riders. Examples included the transportation providers for mobility, the traffic police for safety, and schoolteachers for education. This demonstrates a shift in focus from the traditional clinical model (as observed in disability literature in countries like Uganda [108]) to a preference for the social model of disability [83]. The underlying supposition around the value ascribed to technology is its capacity to do all, an assumption that was transferred and expected of the local Technology Startup Community. Katongole said that he expected the local technology start-up community to actively participate in solving challenges raised by disabled riders. For example, Katongole remarked on asking one of the local tech entrepreneurs to make for them a pair of new legs, after learning about the use of 3D prostheses in Uganda [131, 142].

> "*... Us persons with disabilities, we approach them with challenging issues. One time I went to someone and I was like could you please make for me legs....*" - Katongole

5.4 Discussion

5.4.1 Disability Justice: Engaging the lived experience

In our work, we demonstrate how the lived experiences of disabled individuals can be observed through stakeholder map generation and conversations about relationships (or the lack thereof) between different entities. Using this method, we were able to reveal unanticipated core stakeholders who regularly engaged with other members of the disability ecosystem for transportation and identify interesting relationships among known stakeholders. When seeking to change or update a complex system, it is critical to know and understand all of the key stakeholders in order to implement real, lasting changes with widespread engagement. These findings have two notable areas of impact. First, our observations are useful to HCI researchers who seek to create interventions that could be used in Global South and/or disability communities by relaying the values and relationships that are central to diabled riders in this context. Second, they underscore the importance of learning and understanding the lived experiences of disabled individuals before designing technology, rather than elevating the design of technology as a solution or cure for their problems [77].

Our method and findings are aligned with broader movements worldwide that have advocated for the awareness and inclusion of persons of disabilities across various domains and geographies (e.g., politics and policy [32], design [118, 184, 105, 197, 84], etc.). Recently, these movements have given rise to the Disability Justice movement [76], which is particularly relevant to HCI scholars and practitioners who are interested in understanding the various ways in which technology may magnify marginalization. The Disability Justice movement advocates for disabled riders who exist at multiple intersections of social categorization and promotes understanding and elevating people's lived experiences. Through our work, we reiterate the importance of understanding and exploring these values when researching or practicing HCI.

5.4.2 Positions and perceptions of power and influence

It is common practice for HCI for Development (HCI4D) practitioners and researchers to engage with multiple local stakeholders when developing, piloting, and evaluating systems [68, 81, 113, 82]. Often among these stakeholders are people who traditionally hold offices of power, such as Development Aid Partners, Industry Corporate Social Responsibility Teams, and the Ministry of Gender, Labour and Social Development. Our work revealed evidence of nontraditional brokers of power within the disability ecosystem, such as Traffic Police and Transit Operators. This was a surprise because sought-out authorities on these topics typically include government ministries and development aid organizations. It is therefore important for scholars to understand the underlying power structures that exist within communities beyond the traditional hierarchies that are socially and even culturally observed in order to engage and impact an entire system.

Notably absent from this ecosystem are academic researchers, a fact that raises two questions: Is there a current lack of accessibility research for the Kampalan context or is accessibility research that is relevant to the local context not readily shared with disabled people? This finding also raises an ethical concern that is pertinent to HCI researchers in both the Global North and the Global South regarding the distribution of research results. Many researchers would agree that participants who take part in the piloting and evaluation of HCI research should receive access to the resulting findings, but it is likely that fewer of us have considered how to transfer knowledge to a broader network of stakeholders within an ecosystem in order to ensure that our research can have impact. How can we best ensure that our work can positively benefit communities, particularly those that are typically underrepresented?

5.4.3 Two agendas: Physical infrastructure & awareness

This work identifies two agendas that emerged as important within the disability ecosystem: Accessible Physical Infrastructure and Awareness. While it may be out of the typical scope for HCI scholars to directly sponsor or change policy, there is an opportunity for researchers to engage in research that advocates for policy and social change. Specifically, researchers could focus on technological approaches to raising awareness of instances of inaccessible infrastructure [171], documenting and sharing experiences around conscious and unconscious bias as well as discrimination and harassment of disabled individuals. For example, both Project SideWalk [171] and Tiramisu [208, 183] worked with local transportation providers to improve accessibility. Taking inspiration from this, strategic partnerships between researchers and mobility stakeholders, like ride-share companies in Kampala, present the unique position and opportunity to bring awareness to inaccessible physical infrastructure. This includes but is not limited to: lack of pavements, missing manhole covers, construction, broken pavements, and streets known for traffic violations during rush hour. Ride-share companies are in a unique position because their users travel far and wide. Therefore, users could be asked to crowdsource the information either about what they observed on their commute or about their locale. This information could then be aggregated and visualized in multiple formats (e.g., maps, text, etc.). Given the widespread prevalence of inaccessible physical infrastructure, this information could be used to inform users and policymakers about neighborhoods and high priority routes (e.g., [191]). Likewise, ride-share companies could harness the power of social media as an activism tool [121, 124, 98, 132] to raise awareness of problematic neighborhoods and advocate for the intervention of local city authorities.

Finally, Kampala is in the process of drafting policies to guide its transition into Smart City status [104, 97]. This provides an opportunity for researchers to engage in work that would expose ways in which the automation of existing unconscious cultural biases [108] may threaten the livelihoods of disabled individuals. This is also an opportunity for research to have a direct impact on policy.

5.5 Summary

In this chapter, we further contribute to accessibility scholarship by characterizing the disability ecosystem that is connected to the public transit ecosystem (Figure 5.3).

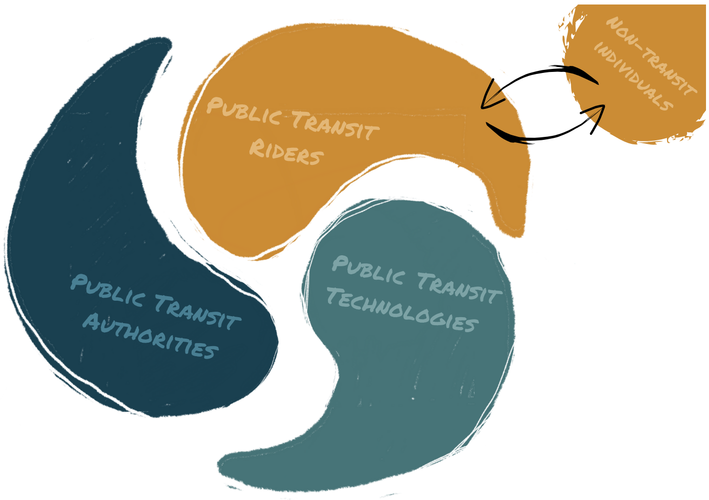

Fig. 5.3 A visual representation of the public transit ecosystem depicting an additional category of stakeholders: non-transit individuals

- Public Transit Riders: This chapter focused on exploring the interactions between disabled riders and other individuals in the disability ecosystem.
- Public Transit Authorities: The authorities highlighted in this chapter are public transit operators: bus drivers, taxi conductors, boda boda riders. In this chapter, this category also includes: traffic police officers, and city authorities.
- Public Transit Technologies: While no technological applications were mentioned, we highlight technology creators and start-up community leaders in this category.
- Non-Transit Individuals: This category included groups of individuals who were not directly related to transit: allies (i.e., schools, NGOs, and activists) and health services (i.e., hospitals)

We identified specific values (e.g., inclusion, mobility, and safety) connected to new core stakeholders (e.g., technology creators, transit operators, and traffic police). These new core stakeholders emerged through a lack of interaction and mistrust of previous traditional key stakeholders. We posit that trust is a key influence when designing for equity in public transit technologies. However, before identifying the design implications of these findings, we questioned whether this influence manifested outside of our study context. We explore the context of North America in the next three chapters of this thesis.

Part II

Exploring Public Transit Ecosystems in North America

Chapter 6

Navigating Public Transit and its Disruptions

This chapter contains an article in preparation:

Carter, E.J., Kirabo, L., Lehman, J., and Steinfeld A. (in preparation). "I'm sure there'll be a kind soul who wants to help me": How Blind and Vision-Impaired Riders Navigate Public Transit and its Disruptions.

6.1 Overview

A major difficulty in leveraging the available information for successful journeys is that transit systems—and pedestrian routes to and from their stops—are not immune to disruption. Construction, delays, accidents, weather conditions, full vehicles, complicated vehicle transfers, sidewalk issues, and vehicle problems can all contribute to last-minute changes in routes and schedules that are difficult to navigate. Disabled riders often have more difficulties adapting to unexpected shifts in their travel plans [152]. When blind or vision-impaired (BVI) individuals are faced with these scenarios, they must rely upon their own skills and hope that they can overcome inaccessible notifications, temporary signage, and voids in information.

In this chapter, we answer the research question, How can we characterize the navigation habits of disabled riders? We assert that through understanding the navigation experiences of disabled riders, we are able to understand which stakeholders they engage with and the role transit technologies may play in mitigating these barriers. We further constrained this study to investigate navigation habits during transit disruptions. Transit disruptions create temporary vulnerability, so it is important to understand whether other stakeholders can be allies in these situations. Current and future public transit technologies should be designed to respond to the extreme and mundane navigational needs public transit users.

6.2 Method

6.2.1 Study design and data collection

We performed semi-structured interviews with twelve participants. The interviews lasted one hour and were conducted either over videoconferencing software (Zoom, 10 participants) or over the telephone (2 participants). The interviews were structured around 22 questions on the following topics: frequency of public transit use before/since the onset of the COVID-19 pandemic; preferences for specific modes of transit; frequent destinations and regions of travel; preferences around travel times; trip durations; trip planning methods and route selection; planning and execution of vehicle connections; describing incidents where trips did not go as planned and recovery methods and resources; safety during regular and novel trips and disruptions; technologies used for public transit-based travel; ticketing; the impact of issues like vehicle crowding, timing problems, detours, and potholes; navigating to/between stops indoors and outdoors; and how transit technology could be improved and what it should include in the future. All interviews were performed and notes about responses were transcribed by an interviewer familiar with the various vehicles used in the local public transit system and popular apps.

6.2.2 Participants

Twelve participants were recruited and interviewed via from a list comprised of previous volunteers for other studies who had expressed willingness to participate in additional research and word of mouth. All participants were BVI adults who use public transit in our region at least once per month. Seven were over 65 years of age and eligible for the no-cost senior citizen pass for the transit system. Four participants were blind and eight had vision impairment, of whom two also had hearing impairments. Five used service dogs for navigation.

The participants completed the hour-long interviews over telephone or video call from the location of their choice. They were paid 20 USD via Venmo or online store gift card. This research was approved by our university's Institutional Review Board.

Our sample size was determined in part by saturation [166], as we received high levels of repetition in participant responses. Thus, we are confident that we have uncovered the most common problems with recovering from transit disruptions for BVI riders in our local context. This research is part of a larger project to inform local transit information accessibility solutions, particularly for BVI riders. For the first stages, it is important to impact as many of these users as possible with design changes, so we will focus on common themes.

Participants reported using public transit at least five times per week (3), at least once per week (5), and at least once per month (4) at the time of the interviews between late 2021 and late 2022. Prior to the COVID-19 pandemic, they reported using transit at least five times per week (7) and weekly (4) (NB: one participant moved from another area). All 12 participants reported taking the bus, 8 reported using the light rail system, and 5 reported using paratransit services.

6.2.3 Data Analysis

After data collection, the interviewer for each session cleaned up the data to account for questions being answered out of order, at multiple points in time, etc. All data were compiled into a single file with responses coded by participant number. For straightforward prompts (e.g., "What tools do you use to plan your trips?"), responses were tallied. For more complex prompts and ideas that carried throughout the interview (e.g., discussing how to recover from unexpected trip disruptions), two members of the research team performed reflexive thematic analysis by recording each point of the data for various prompts, looking for patterns and commonalities across these data points, and organizing the data points into common themes. With minimal revisions, the two researchers came to agreement on the themes in the dataset.

6.3 Findings

6.3.1 Influence of operators and other riders on a journey

During trips, every single participant said they asked vehicle operators for information. This included being told when they arrived at their desired stop (P107), how to find another vehicle to complete a transfer (P103), and what to do during a disrupted trip (P106). We realized that operators have unusually high power in the lives of BLV riders: a single operator can determine whether a journey succeeds or fails. P107 reported an instance where a disruption led to drivers calling each other to find out what to do, but none had enough information, so she had to disembark, cross the street, and board another vehicle. P109 reported that a paratransit driver almost left her behind and yelled at her for being in the wrong spot for pickup in a parking lot. In contrast, when P103's journey was disrupted, the vehicle operator offered to guide him herself if nobody else was available to assist him.

Participants very frequently ask other people for help throughout trips. P109 said, "The first thing to do is to see if anyone around me knows." P104 reported asking her sighted husband to check Google Maps and Street View to help her find safe intersections to cross streets during her solo journeys. P108 was new to the city and would review routes in advance with a blind friend to determine her chances of success. Participants often asked other people at bus stops to tell them when a specific vehicle arrived (e.g., P110) or asked other riders to tell them when to get off (P107). However, they noted that the people sometimes leave: "It's a pain to explain to that person, 'Let me know when my bus gets here but let me know also if you leave before me....' It's too much to ask sometimes. It shouldn't be, but it is." – P110. Often, they ask nearby people about the location of a stop when they are on foot (e.g., P108, P109, P112). Some participants even reported that they would avoid traveling to certain areas or become quite nervous during off-times like nights and Sundays because there would be nobody around to help them (P107, P109). In a number of cases, fellow riders – including familiar strangers who often travel the same routes or "travel buddies" who commute together and know each other – were the key piece of the puzzle when a travel disruption occurred. Previously described examples include P112 walking with others to a different bus stop and P106 getting a ride with fellow travelers. These scenarios were in direct contrast to the experience of many non-disabled riders who can rely on technology and eyesight to navigate their trips without speaking with anyone, often even in the case of disruptions.

6.3.2 Planning and other mechanisms to counter potential transit problems

Participants described a number of mechanisms that they used to account for and/or avoid any potential problems that could disrupt their trips. Most of the participants planned to arrive early if they had somewhere important to go and "give [themselves] a lot of time because you never know what will happen" (P101). They relied on preplanning using the port authority phone service and website as well as various travel apps. P110 reported studying his routes on GPS software. P101, P106, and P108 said that they felt nervous on unfamiliar routes; P105 and P108 tried to avoid taking them when possible. P103, P107, and P110 reported that discomfort with transfers led to them trying to minimize or avoid them. "If I have to change buses twice, I probably won't go via bus," – P107. In cases of bad weather, conditions could impact what type of vehicle was taken (P111) or whether public transit was taken at all versus paratransit or rideshare (P103). Participants were also concerned about the safety of stops (e.g., P104, P105) and whether there might be an unleashed dog nearby (P105).

Other factors that impacted planning included construction and sidewalk conditions. If participants knew in advance that construction detours were likely, they would leave earlier (P108), check for detour information in the apps (P105), walk (P102), or use BlindSquare to figure out where they are located, where they might be going, and how to describe where they are to call someone for directions (P109). Participants reported difficulties when sidewalks were absent or closed (P105), or if they were under construction (P103, P104) or blocked by temporary obstacles (P103). Participants with guide dogs reported easier recovery (P103, P104). Participants also reported avoiding certain intersections where it is busy or otherwise difficult to cross (P104, P108, P109) and would go out of the way to use safe crossings.

When they experienced a disruption, participants reported a number of methods that they used to continue their journeys. In addition to asking others for assistance, these methods included using GPS to navigate to a new spot or discover the current location (P105), using apps to find another route (P102), catching a later bus (P109), getting out and walking (P101), and calling a rideshare service (P105).

6.3.3 Impact of mobile transit technologies

Several participants noted that the improvements in transit technologies had improved their quality of trips. For example, P109 said, “The apps have definitely meant a lot of freedom. I must admit that in the past if something like that had happened, I might just have given up and gone home. I might have kind of panicked. I mean the things that I’ll do now, I could only do because I know I can make an emergency call from the phone.” Other participants appreciated knowing more accurate vehicle arrival times than could be achieved with schedules (e.g., P104, P105, P106). Multiple participants leveraged the information from vehicle annunciators to determine that they were on the wrong vehicle (P103) or going in the wrong direction. P106 uses the real-time schedule boards at some vehicle stops to make informed decisions. One app was noted to tell users when they had deviated from a route so that they would at least know that a detour was happening.

Additionally, we uncovered a number of concerns about the accessibility of our transit system, including for websites and apps, bus stops, and their overall ride experiences. P102 noted that the colors used in apps were sometimes problematic for colorblind users and buttons are often hard to find. Also, P110 said that software updates can change accessibility by moving item locations and screens unexpectedly.

Many participants thought that there were opportunities to change their experiences at bus stops. P104 recommended having the possibility of obtaining accessible schedules at each stop. P108 said that he was told there is sometimes a QR code to scan for information about a stop, but it does not provide information beyond the bus schedule. He identified the opportunity for “something in lieu of bus stop numbers that you can’t read”. Similarly, P105 suggested a QR code that could tell the user which buses were coming. P108 kept lists of bus stop numbers in her phone to use for the text messaging system.

Interestingly, participants sometimes explicitly stated that they wanted the information that sighted people already have. Both P102 and P108 wanted to know about the world around them so that they could have opportunistic interactions: if you are aware that there is a bank nearby, you can take the opportunity to go to the ATM at that moment instead of making a separate trip to a known bank location later. P104 described using BlindSquare to show nearby intersections to their destination when exploring a route, but still wanted the more extensive information available to a sighted person using Google Maps and Street View. As a technology recommendation, P103 requested the ability to leverage a smartphone camera to guide himself somewhere with his dog. The camera would be able to help him find crosswalks and traffic light colors so he would not need to rely exclusively on his own Orientation and Mobility skills. P106 and P111 also revealed that sighted people have more information available to them during trip disruptions because they can look out of the vehicle windows and see what is happening.

6.3.4 Navigating the first and last miles

A consistent theme across all of our participants was the difficulty in finding stops, particularly off the vehicle. As noted previously, there are not distinctive poles to signify stop locations and few poles have Braille information about the stop numbers. P102 and P103 noted they often don't know exactly at which corner to wait. Participants also stated that the website, apps, and even customer service did not reliably give sufficiently detailed walking directions to and from stops. For example, P105 wanted to know when to be on which side of the street. P104 and P108 wanted to know the locations of crosswalks, lights, and audible crossings for safety. P101 and P110 wished that their GPS and directions could be more precise. Additionally, P110 wanted his phone to be able to remember a few spots so that it could tell him when he was approaching them. P108, and P110 talked about problems with bus stacking, and P103 and P110 recommended some way that the phone could identify which bus was which.

6.3.5 The persistent request for accurate real-time information

Many of our participants' comments concerned a desire for complete and accurate real-time information. The local system provides vehicle location maps and estimated arrival times on their own website, via text messaging and customer service, and through a real-time API key that other developers' apps can leverage. However, the website notes its own shortcomings: delays are reflected only in arrival predictions that increase or do not count down, there is no data on vehicles that are more than 30 minutes from the stop (that could be used for accurate planning), out-of-service vehicles are simply not displayed on the tracker, and detours cannot be displayed. Notably, detoured vehicles completely disappear from the tracker until they return to the original route. Participants had noticed these problems. For example, P105 stated that a bus may be "27 minutes away but stays that way for 15 minutes." P112 noted that some of the apps do not include bus locations, including for the vehicle being ridden, which would be helpful. P108 expressed disappointment that the website could not provide sufficient information on detours, lateness, and missing vehicles. Similarly, P103, P105, P109, P111, and P112 all wanted more information about disruptions, including detours, road construction, sidewalk construction, discontinued stops, and crowding. P105 specifically wanted to know enough "to not have to ask the driver what's happening." One suggestion was to use crowdsourcing so that riders could report issues with the bus, with the caveat that people would have to be honest (P104). Overall, P109 recommended "better communication throughout the system so everything from shelter moves to detours to construction was tracked to the highest level and info was passed down effectively to customer service or apps with notifications to drivers. Communication is something that tech can definitely help with and I don't think it's being done all that effectively right now."

In order to get this information, most participants endorsed notifications via phone. P102, P108, P112 were all interested in getting text messages about travel disruptions. Eight participants wanted an option to set up push notifications on their phones, although there was some nuance to how they believed they should be implemented. P104 noted that she gets too many already, so she would need to be able to customize which she wants. P101 would want them to work for the specific route being taken, and P109 would want them for routes she takes often. P108 recommended making it an opt-in system where the user would have to specifically sign up for certain routes. P103 and P105 noted that the notifications would have to work even if the app was not open. P110 also requested a notification within the app as well, in case he missed the push notification. P102 and P110 also wanted information similar to what happens in GPS apps that provide driving directions: a notification of the disruption as well as a list of recommendations for other travel options. P111 added the recommendation of audible announcements about problems on the vehicles themselves.

6.3.6 Envisioning public transit futures

Participants envisioned a future where they often did not have to take public transit at all. Four participants (P102, P104, P107, P109) wanted a future with self-driving cars, with P109 specifying that they would also be electric. P102 was more general, saying they "would like to have an ability to travel by car alone, either having self-driving cars or a chauffeur." P108 wanted their means of travel to enable spontaneity.

6.4 Discussion

In this research, we were able to provide additional support for previous findings about how BLV public transit users navigate through journeys in general (e.g., [72, 183, 94, 152]).Moreover, we presented further data describing the shortcomings in existing systems and services. These findings highlighted the limited changes and improvements in the public transit ecosystem transportation over several years, despite improved technology. Our participants still complained about issues that were pervasive in research as early as the 1990s, even when solutions had been proposed by prior work: a lack of accurate real-time data (e.g., [183]), issues navigating transfers (e.g., [72]), difficulty finding stops and using physical infrastructure [29, 79], overcrowded vehicles (e.g., [208, 183], finding crosswalks [4], and problems traveling to and from stops on sidewalks (e.g., [171]).

6.4.1 Supporting transit disruptions

This research expanded our knowledge about how BVI individuals manage disruptions to their trips, and it confirmed previous findings from the general population of transit users about wide-ranging individual differences in recovery strategies and perceived inconvenience [162]. Our participants had experienced unplanned drop-off points, surprise transfers, detours, traffic, construction, missing or delayed vehicles, and getting on the wrong vehicle. They recommended the introduction of push notifications to inform them of issues on their route. Ideally, they would want a travel app to let them know about these disruptions before leaving their starting point so that they could change their plans as desired. However, they were also open to being notified as soon as an issue arose. Currently, there are some crowdsourcing systems that can provide some of this information (e.g., crowdedness data in Google Maps and [208]) and some notifications from the public transit systems themselves (e.g, Twitter, website updates); however, the necessary information for trip rerouting is often incomplete, inaccurate, old, or entirely absent. Participants wanted apps to provide better notifications about disruptions as well as easy methods for rerouting without having to rely on others for assistance and information. In the future, this information could be integrated into transit and navigation apps from a combination of transit agencies, drivers, riders, and sensing abnormal behaviors from vehicles.

6.4.2 Implications for AI-based solutions

The vast, persistent chasm between rider needs and available technological solutions reinforces the importance and value of innovations in this space. Our participants suggested ideas for general improvements to the current apps. These included accessible information about current vehicle locations, incorporating traffic and related information into creating more accurate trip timing, using more precise location services for finding stops, providing methods to identify specific vehicles among many, and incorporating other existing information about the surroundings.

AI could be used to provide solutions for providing current vehicle locations and more accurate arrival time predictions, as is currently done via Apple Maps, Google Maps, Waze, and other driving navigation software. It could also infer stopped vehicles, traffic along a route, or other vehicles detouring around an area, identifying potential disruptions to journeys. This information also could be integrated into transit-specific services. Also, stops could be upgraded using physical improvements to infrastructure that make them easier to locate, such as using IoT (WiFi, Bluetooth, etc.) approaches for precise location sensing the stops themselves (e.g., [59]. Additionally, they could include distinctive, high-quality signage and provide accessible information about routes and arrival times. They could also sense when people are waiting at stops and allow them to identify and signal to their desired bus. Finally, a combination of location-aware technology and crowdsourced methodologies could be used to determine which of many approaching vehicles is the desired vehicle. While these improvements might be difficult to coordinate across multiple agencies [152] and companies, they would improve experiences for all riders.

6.5 Summary

In this chapter, we examine disabled riders transit experiences during disruption events (Figure 6.1). Transit journeys

- Public Transit Riders: Primary stakeholders in this category include disabled riders, other riders in the vehicle, and pedestrians

- Public Transit Authorities: There were two main authorities that were mentioned: drivers and Pittsburgh Regional Transit phone operators

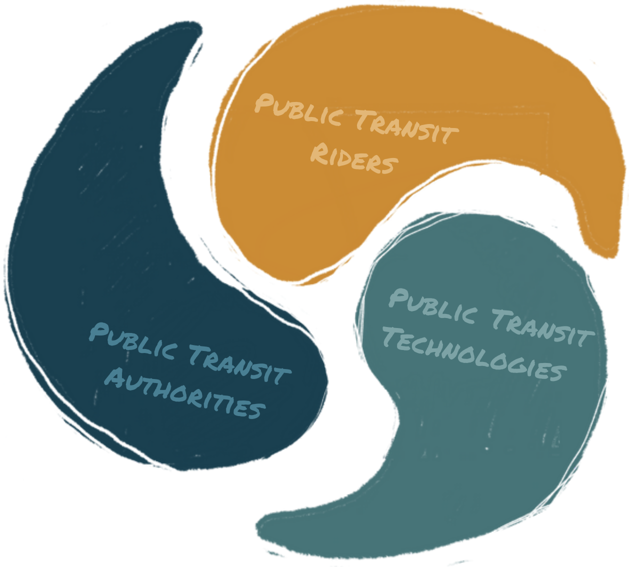

Fig. 6.1 A visual representation of the public transit ecosystem depicting three categories of stakeholders in chapter 6

- Public Transit Technologies: Transit in the North American contexts runs on schedules. As such there are a number of bus scheduling mobile and web applications that are available to use.

Our findings show that the primary stakeholders when disabled riders experience public transit disruptions are in the public transit riders and authorities categories. These experiences show that these stakeholders act as allies during disruption experiences. Understanding the role of primary stakeholders gives insight to the amount of power and influence they leverage. This influence can be further amplified by advanced technologies. In the next chapter, we examine the application of Machine Learning techniques (e.g., adaptive user interfaces) on public transit technologies (e.g., bus apps)

Chapter 7

Investigating the Influence of Mobile Adaptive User Interfaces

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This chapter contains an article in preparation:

Kirabo, L., Carter, E.J., and Steinfeld A. (in preparation). "Sometimes, I love it. Other times, I cannot stand it": Investigating the Influence of Mobile Adaptive User Interfaces.

7.1 Overview

Artificial intelligence (AI) techniques and technologies have advanced considerably in a variety of domains, aided by the proliferation of context-aware devices like mobile phones. The growth of Adaptive User Interfaces is a natural extension of this advancement. Adaptive User Interfaces are interfaces that are designed to dynamically adapt to a user's behavior, needs, or preferences [176, 89]. They have been applied in both low- [209] and high-risk [22, 106] situations. The rewards associated with these interfaces include increased user satisfaction [58], convenience [209], and precision [64]. While there is no general consensus about the success of Adaptive User Interfaces [64, 57], their fundamental strength is that they *"keep users in the loop"* [209]. This is particularly important for user interface designers because it provides an opportunity to include the preferences of users with a vast range of abilities and local contexts. I.e., Adaptive User Interfaces have the potential to enable technologies to be responsive to a specific user-ecosystem relationship.

Many design agendas underscore the importance of inclusion [184, 197, 105, 118]. Adaptive User Interfaces exist at a unique intersection of some of these agendas. For instance, the universal design principle of personalization [184] highlights the importance of incorporating opportunities for choice and the expression of individual preferences. While universal design principles were created for the built environment and static user interfaces, they can still offer insight into how to improve user experiences during interaction with AI-equipped systems. Relatedly, the Disability Interaction (DIX) Manifesto [84] highlighted the principle of value use and usefulness, which can also be implemented through Adaptive User Interfaces. This principle advocates for designing innovations that get to and are used by disabled persons.

In this work, we lean heavily on these two principles by investigating the behavior of PWDs using Adaptive User Interfaces and demonstrating the application of Adaptive User Interfaces in public transit. Public transit is of particular interest because it is a high-importance activity in the lived experiences of disabled individuals, who are less likely to drive personal vehicles [149] and often use fixed-route transportation [152]. There is a prolific amount of research and interest in accessible public transportation (e.g., on navigation [120, 170, 137, 94], sidewalk accessibility [171, 16, 17, 188], bus stop accessibility [78], and independent use [11, 108]) This work extends prior scholarship by investigating the intersection of Adaptive User Interfaces, public transit, and disability. We leverage HCI methodologies (e.g., design probe, interviews) to investigate the effectiveness of Adaptive User Interfaces and associated behaviors of disabled riders. Our findings underscore the importance of explainable artificial intelligence (XAI) that provides information about interface adaptations and decisions in the Adaptive User Interface experience of disabled riders.

7.2 DRIFT - An Interactive Design Probe for Smart Transit

7.2.1 Overview

We created DRIFT[1], an interactive design probe that simulated smart transit capabilities to our participants. Traditionally, design probes have been used in spaces as varied as service design [14], speculative investigation [21, 62], assisted therapy [88], dementia care [143], and poultry farming [85]. DRIFT leverages semi-automated Wizard-of-Oz techniques [181] to bring the voices of PWDs into the design and discussion of smart transit applications.

7.2.2 Interface Design

DRIFT's interface consisted of three screen types:

- Screen type 1: A welcome screen. This screen detailed information about the tasks that participants were to complete (Figure 7.1 A)
- Screen type 2: A scenario screen. This screen gave participants context about each task (Figure 7.1 B). The scenario description depicted the experience of using the same commute

[1] DRIFT stands for aDaptive useR Interface For Transit

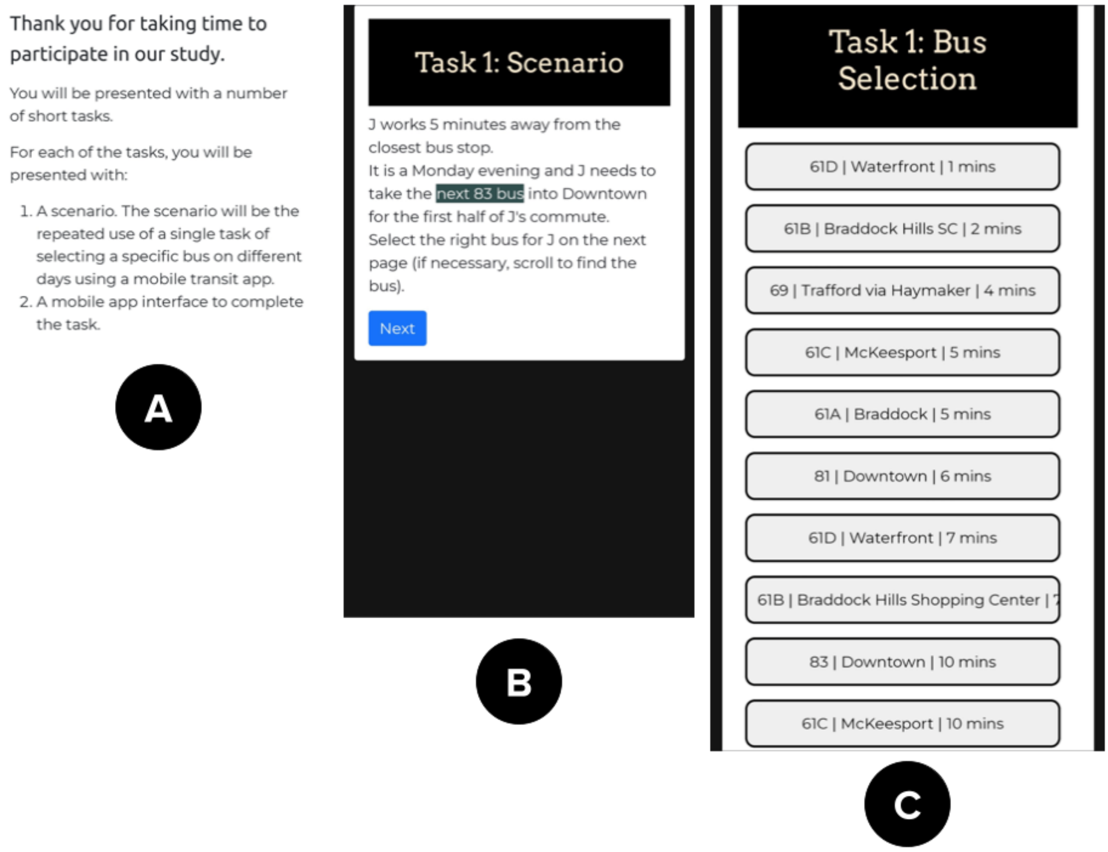

Fig. 7.1 The three types of screens in DRIFT

everyday. The only change between the different scenarios was the day of the week. The following is an excerpt of the scenario: *J works 5 minutes from the closest bus stop. It is a [Monday] evening and J needs to take the closest 83 bus into Downtown for the first half of J's commute. Select the right bus for J on the next page (if necessary, scroll to find the bus)*. There were a total of 13 scenarios presented.

- Screen type 3: A bus screen. This screen gave participants a list of buses from which to select in order to complete the task (Figure 7.1 C). The bus screen had two interface-type designs: *non-adaptive* and *adaptive*. In the non-adaptive version, participants scrolled through the list to search for the 83 bus (Figure 7.1 C). We designed the adaptive version using adaptive UX design guidelines [209, 201]. We leveraged two design patterns: Ranking and Highlight (Figure 7.2). We implemented ranking by presenting the 83 bus at the top of the screen. We chose to present participants with three options of vehicles for the required bus route. This choice followed current transit UI designs. We highlighted the 83 bus option by giving each option a darker background color than the other buses. There were a total of 13 bus screens (one for each scenario), five screens with the non-adaptive interface design and eight with the adaptive interface design.

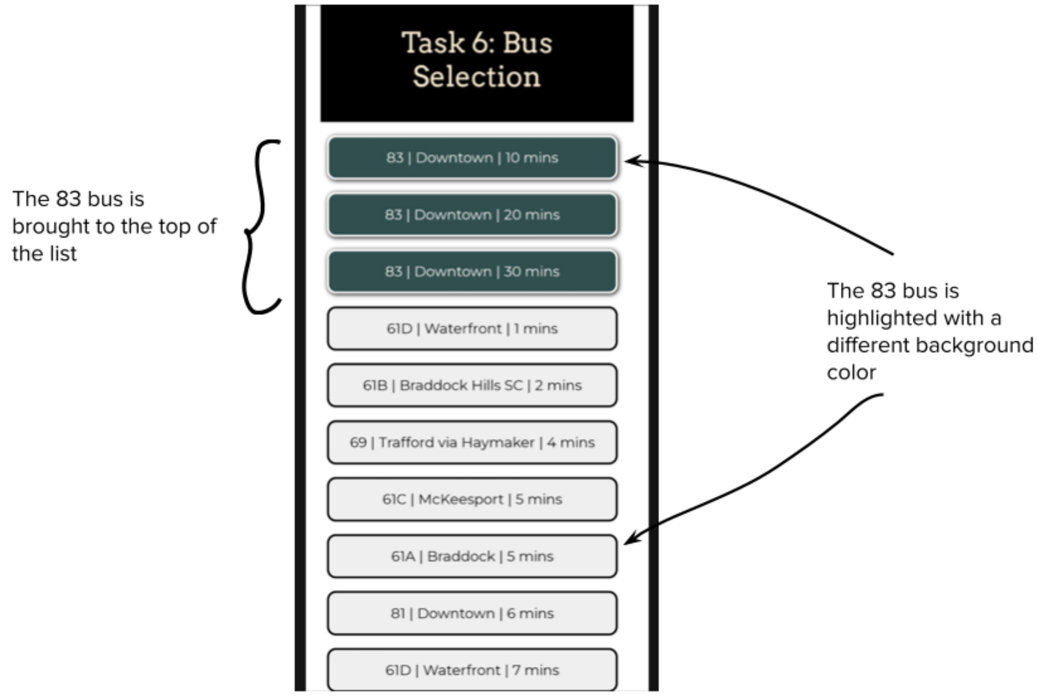

Fig. 7.2 The adaptive screen design that leverages two design patterns: ranking and highlighting

In order to adhere to our university's COVID-19 pandemic guidelines, we designed DRIFT to be a fully functional, accessible online experience. It included all of the information that participants needed, presented in a simple and clear manner. This gave all of our participants the agency to interact with the system without any involvement of the research team. However, a member of the team remained available throughout the interaction to answer any clarification questions.

7.2.3 Implementation

We created DRIFT using EJS, Node.js, CSS and JSON. These web technologies allowed us to ensure screen reader compatibility. They also gave our participants a consistent experience across different platforms. After each participant selected a bus, we logged the user, the bus they chose, and the time they took to select the bus. We hosted DRIFT on a local server and stored the logged information in a MySQL database for later analysis.

Formative Studies

We conducted two studies to investigate the influence of Adaptive User Interfaces on the transit experiences of disabled riders. Our Institutional Review Board approved both studies.

7.3 Study 4a: Interacting with DRIFT

We measured the effect of Adaptive User Interfaces on the time taken by participants to find bus information. Our research was guided by this question: How do Adaptive User Interfaces in transit applications impact the user experiences of disabled riders? We hypothesized that Adaptive User Interfaces would reduce the time taken for disabled riders to find bus information.

7.3.1 Participants

We recruited 24 participants (Male: 3, Female: 19, None: 1, Non-Binary: 1), with most indicating that they were between 18 and 34 years of age (18-24: 10, 25 - 34: 7, 35 - 44: 3, 55 - 64: 3, 65 - 74: 1). We recruited them from an online participation pool[2]. All of our participants self-identified as having a disability (Table 7.1). They were required to be fluent in English, 18 years of age or older, and use a mobile interface to complete the study. The study lasted for 1 hour and participants received $20 upon completion.

Table 7.1 Disability categories of participants in Study 1. *One participant identified as having both vision- and mobility-related disabilities.

Disability Category	Participants
Vision-related (including but not limited to: blind, low vision, colorblind)	11*
Mobility/Motor-related (including but not limited to spinal cord injury, wheelchair user, arthritis)	4*
Cognition-related (including but not limited to autism spectrum disorder, some chronic neurological conditions)	9
Other	1

[2] Prolific.co is a website used to reach diverse research participants

7.3.2 Procedure

We conducted a 2x2 mixed factorial experiment with a between-subjects factor (i.e., Order) and a within-subjects factor (i.e., Interface-type). Order had 2 levels, Latte[3] and Lure[4]. Interface-type had 2 levels, non-adaptive and adaptive.

Order refers to the sequence in which participants saw the interfaces. In the Latte level, participants saw tasks in the Adaptive User Interfaces first, while the Lure participants saw tasks in the non-adaptive interface first. The former order simulates systems where prediction uses other factors (e.g., neighborhood, time of day) or attempts to bootstrap from other users' models. However, the system may revert back to a training mode after several failed attempts. The latter order simulates a traditional, AI-enabled transit interface where the system learns from initial use and later predicts the user's preferred bus.

The two levels of the Interface-type factor were non-adaptive and adaptive. The non-adaptive interface-type showed participants a full list of buses for the relevant bus stop, and the adaptive interface-type used adaptive UX design patterns to present users with the 83 route buses first (see Section 7.2).

Each participant completed a total of 13 short tasks. For each task, participants read the associated scenario first. They then used the bus screen to find the 83 bus. Half of the participants interacted with DRIFT in Latte mode. The other half interacted with DRIFT in Lure mode. Before using DRIFT, our participants completed informed consent and provided demographic information in a pre-survey. We used this data as a validity check against demographic data in the online recruitment system. After using the interface, participants filled out a post-survey.

7.3.3 Findings

Quantitative findings

We logged the completion time for each task to examine the effect of Adaptive User Interfaces on the time taken by disabled riders to find specific bus information. We conducted a repeated-measures ANOVA on the log data collected during the study and found that interface-type had a significant main effect on the time taken to find the bus ($F(1,22) = 11.154$, $p = 0.003$). In the Latte order, the participants completed the tasks 0.24s (7%) faster with the adaptive interface than with the control interface. In the Lure order, participants completed tasks 2.6s (52%) faster using the adaptive interface. However, we found that Order (i.e., Latte & Lure) did not exhibit a significant main effect on task time ($F(1,22) = 0.060$, $p = 0.26$). We also saw a significant interaction between Interface and Order ($F(1, 22) = 7.70$, $p = 0.01$).

Our descriptive statistics also supported the findings from the repeated-measures ANOVA. They showed that the adaptive interface-type had faster task completion times (Table 7.2). A histogram of

[3]Latte is an acronym that stands for Location Aware Transit inTerfacE
[4]Lure is an acronym that stands for Learn bUs RoutEs

Table 7.2 The mean time taken across each condition in Study 1. The standard deviation is in parentheses.

	Non-Adaptive (NA)	Adaptive (A)
Lure (Order: NA, A)	5.07 (2.00)	2.43 (1.30)
Latte (Order: A, NA)	3.28 (1.720)	3.04 (1.42)

the time-taken suggests the adaptive interface-type reduces outliers (Figure 7.3). Surprisingly, we saw that participants who interacted with DRIFT in Latte mode completed all of the tasks faster, even though there was only a 7% improvement between the interface types.

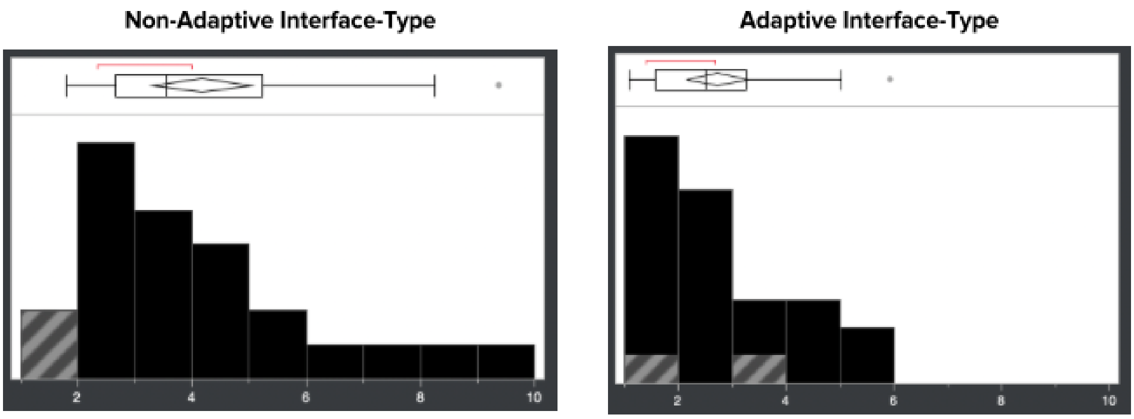

Fig. 7.3 Histogram representation of the time taken in each interface reveals cut-off outlier

In the post-survey, participants reported on 7-point rating items (higher number indicated strong agreement) that they thought that the interactions with DRIFT would be useful in their commute (Mean = 6.42, SD = 0.78) and that interactions on DRIFT were clear and understandable (Mean = 6.29, SD = 0.81). Participants also reported that they found DRIFT easy to use (Mean = 6.5, SD = 0.58) and that it enhanced their effectiveness in finding the preferred bus (Mean = 6.50, SD = 0.66).

Qualitative findings

Only one of the 24 participants indicated that they would prefer to have control over which buses were shown by the interface. The rest of the participants used positive sentiment (e.g., '*easier*', '*convenient*', '*helpful*') when describing their preference for the Adaptive User Interface in DRIFT. Participants also detailed how interfaces like DRIFT could influence their lived transit experiences.

> "*It would be much easier for me because then I would be less likely to tire out my muscles scrolling on the screen, and I would feel less stressed about finding a bus.*" - P4, mobility/motor related disability

> "*I like simple. I am older, vision impaired, and overwhelmed by choices.*" - P21, vision related disability

Participants noted specific contextual and environmental characteristics that might influence their use of similar interfaces. Two participants noted the applicability of DRIFT for commutes (e.g., taking the same bus) that involve the same routine destination (e.g., going to work). One also mentioned that the interface would only be useful until it made an error.

> "*It would be easier to find my bus that I need all the time. It might not be easier if it messes up when I need to find a different bus.*" - P20, mobility/motor related disability

7.4 Study 4b: Investigating Interaction Behavior

Our Study 1 data analysis revealed unique interaction behaviors among our participants. All but one participant still chose to scroll through the rest of a list even when the bus that they needed to find was at the top of the screen. In this study, we investigated the motivation for this behavior.

7.4.1 Participants

We recruited 7 local participants (Male: 4, Female: 3) from the disability community. Our participants were required to be fluent in English, use public transit, and be at least 18 years of age. All of our participants identified as being blind or low vision. Two participants also indicated having a hearing-related disability. After the 1 hour study, each participant received $20 compensation.

7.4.2 Procedure

After providing informed consent and completing a pre-survey, participants completed the 13 tasks presented in DRIFT. All participants interacted with DRIFT in Lure order (i.e., non-adaptive, then adaptive). After they completed the task, we conducted 1 hour individual online interviews using videoconferencing software. During the interviews, we used guiding questions to obtain a detailed walk-through of how they navigated the interfaces. We then probed participants on their daily use of transit interfaces as well as their perceptions of smart interfaces. Data from the interviews was transcribed and cleaned for analysis.

7.4.3 Findings

We analyzed our participants' responses using thematic analysis [20]. We identified 18 high-level themes that we further condensed to 5 themes. These themes were exhaustive search behavior, desired smart transit experiences, nuanced positive & negative sentiment, the elements embedded in choice/action, and envisioning transit futures. In this section, we explore each of these themes in detail.

Exhaustive search behavior

Six participants described searching through the entire list in both interface-types. They did so even after they found the necessary bus at the top of the list. Moreover, they did not express any negative sentiment about looking through the whole list.

> "*I went through the rest of the list to make sure there wasn't a sooner 83. I was thinking there might be more than one 83. There might be a sooner one than the one that said 10 min - the first option. So yeah, I scrolled down to make sure there wasn't one that is at 5 min or 2 min.*" - P1, vision-related disability, hearing-related disability.

Some participants noted that the user interface change (i.e., the 83 bus at the top of the screen) was not immediately obvious to them. Because they were unclear about whether the change would remain consistent, they kept scrolling. Furthermore, participants were unsure whether the predicted option was the best option, so they searched for a better option. Lastly, P2 pointed out their preference to know everything that was on a page before making a decision.

> "*When I am looking at any app or web page, I like to know everything on the page. There may be some information further down that would assist me in making a decision. It wouldn't take me long to maneuver through the page to see the rest of the information, then go back up and make my decision. It's pretty much on me. It's my habit.*" - P2, vision-related disability

Nuanced positive & negative sentiment

Participants' opinions on the function of Adaptive User Interfaces were both positive and negative. Like the first study's findings, participants unanimously agreed about the potential benefit of learning interfaces for public transit. They expressed this using positive sentiment, noting that Adaptive User Interfaces are helpful, more convenient, made search easier, faster. In the same breath, however, they also noted their grievances with the interfaces.

> "*Sometimes it gets in the way. I have had experiences where I want to get to a destination (one I've been to before), I know what all my options should be. But the app won't give me all of those options.*" - P2, vision-related disability

> "*Sometimes, I love it. Other times, I cannot stand it.*" - P1, vision-related disability, hearing-related disability

Three participants also expressed a general a lack of trust in Adaptive User Interfaces, questioning whether the interface was trying to trick them. Participants also expressed negative sentiment in cases where contextual information (e.g., location/neighborhood) was the basis for suggested bus recommendations. It stemmed from participants' familiarity with specific information.

> "*Just show me what I'm used to like my favorite bus stop. That would make things much easier. First come up with my default bus, so I can get [access to that] information no matter where I'm at.*" - P5, vision-related disability

Participants also discussed the appropriateness of predicted options. P3 noted that strictly adhering to predicted options would result in a constrained experience. P3 specifically pointed out that predicted options would result in a lack of spontaneity. They wanted the freedom of modifying their routes (e.g., visiting someone, discovering new routes) of their own will. In a similar vein, there were questions about whether bus predictions were *worth the hassle*.

> "*If you're only saving 5 minutes, and you know you're comfortable with the one bus route, maybe it doesn't really matter. But if you're saving a half hour or an hour... or you have a time deadline of getting somewhere. There's just a lot of variables that could be in play why it wouldn't matter which route you would take.*" - P4, vision-related disability

Desired smart transit experience

Participants consistently underscored their need for control over changes in the interface, whether these changes related to machine learning (e.g., were based on their regular route, contextual information) or application updates (e.g., adding micro-mobility options). Participants were adamant about viewing all information that was relevant to them. Participants also expressed that the interface should be explicit about its options. For example, if the first option was the best, articulate it. The idea of opting in also complemented the need for control. Other participants were hesitant about the interface choosing on their behalf. They argued that in the era of phone privacy settings, users are now conditioned to choosing things for themselves. They suggested that this should be the same for Adaptive User Interfaces.

Elements that influence transit choices

Participants highlighted important criteria that went into their route selection. Firstly, there was the nuance of time. While participants appreciated knowing when their regular bus would come, they admitted that they sometimes skipped the recommended option, perhaps to grab an extra cup of coffee or even relieve their dog. Other times, the transfer window time trumped the total trip duration in selecting a route. Participants were more interested in longer transfer windows that allowed them to make their connection. The second criteria was safety. Participants noted that they considered stop location, self-orientation, and surroundings as a priority when choosing a route.

> "*I took three buses home to avoid a particularly nasty street crossing downtown. Forbes and Stanwix is a five-way intersection and all the streets are really wide... it's difficult to keep a sense of direction. The light is not on all that long in any one direction. By the time I'm pretty sure that I have the light to cross, it's changed. It only takes one time being wrong to get squished by a car, so I'd better be safe than sorry. Sometimes I have to wait quite a while.*" - P7, vision-related disability, hearing-related disability

This finding also related to participants' preference for routes with less complexity. Lastly, participants constantly sought alternative routes to the destination. In the scenario presented, three participants suggested alternative bus lines that would get J to the destination just as efficiently. They argued that if there were other buses that could be used for a trip, the interface (and J) should not be limited to one. This also illustrated the influence of the user's mental model of the service and knowledge of the transit system as a whole.

Envisioning transit futures

When referencing the future of smart public transportation, participants targeted ways in which current applications could improve. These included consistent access to real-time information and the removal of maps. P1 expressed the desire to have these interfaces solve the problem of bus stacking, when there are multiple buses at a stop simultaneously and riders must figure out which one is their bus.

Other participant responses entered the realm of futurism. For example, P7 believed that voice assistants such as Siri should be fully integrated with these applications. Four participants denoted that the future lay in autonomous vehicles. They used advocacy language to describe these futures.

> "*I think one of the interesting things to me is that when people talk about people who have disabilities or whatever, they always assume that autonomous vehicles will be done for them, not by them. And that's just such an offensive feeling to me. Now I don't really want to own my own autonomous vehicle I don't see, I mean I don't go enough places to warrant that. But I would certainly like to be able to call the vehicle that I need, and use it and let it go on about its business.*" - P3, vision-related disability, hearing-related disability

> "*In some ways, I would like to see self-driving cars. The reason for that is the buses don't go everywhere I want to go. I've paid taxes all my life for roadways and bridges and tunnels, and I don't get to use them unless someone else is going there. With a self-driving car, I could go everywhere everybody else gets to go*" - P6, vision-related disability.

7.5 Discussion

7.5.1 XAI: The smart transit use case

The layered nuances expressed by our participants provide an opportunity to explore a role for Explainable AI (XAI) in public transit. XAI provides a way for systems to build trust with users that can influence adoption. Specifically, XAI advocates for model explainability in AI systems [186], a move away from the black-box mental model that required implicit user trust. Our second study demonstrated that expecting implicit trust of Adaptive User Interfaces creates frustrating experiences for disabled riders. These frustrating experiences create artificial barriers to accessing relevant public transit information. These barriers are in direct opposition to design movements that advocate for inclusivity [184, 84, 32]. While some of these movements were established prior to advancement of AI and machine learning technologies, they can still inform user experience. For example, the integration of XAI aligns with the Universal Design goal of Understanding [184]. This goal advocates for making methods of operation and use intuitive, clear, and unambiguous. Similar sentiment has been expressed in the Ability-based Design principle of Transparency [198]. Additionally, there has been recent work at the intersection of XAI and HCI [122, 51] that advocates for more transparency in mainstream intelligent products. We focus on extending this prior work by augmenting adaptive UX design guidelines [209] with the following accessible recommendations and considerations. We also provide justification using public transit Adaptive User Interface examples.

Accessible labels & leveraging crowd-AI for contextual information

Augmenting predicted information with relevant accessible labels may improve the experience of disabled users. For instance, route suggestions in public transit Adaptive User Interfaces should leverage accessible labels to explicitly identify why they are suggested. Examples of labels gleaned from our findings include: “Fastest”, “Regular Bus”, “Alternative Route”, “1 Transfer”, “Multiple transfers”. Limiting labels to one or two words promotes faster readability and reduces the effort needed to parse all of the information. Adaptive User Interface labels can also be generated by leveraging crowd-AI techniques (e.g., for Adaptive User Interface labels specifically associated with safety). This extends prior scholarship on using crowdsourcing to promote the accessibility of public transportation infrastructure [79, 171] Also, when this information is added to public transit Adaptive User Interfaces, it can augment the trip planning process. Examples of labels suggested by participants in this research included "5-way intersection" and "no sidewalk".

Diversify predictions & agency

Consistent past behavior influences the predictions that are offered by Adaptive User Interfaces. While the domain applicability of this outcome may vary, our findings suggest that within public transit, users do not want to be persistently confronted with a single routine. Public transit Adaptive User Interfaces therefore have the option to offer predicted routes as well as alternative routes.

Offering alternative routes supports current user mental models in our findings (i.e., exhaustive search). Additionally, providing the possibility for diverse predictions in Adaptive User Interfaces could motivate conversations on agency. In this work, we conceptualize agency in two ways. First, we consider agency to include users granting Adaptive User Interface systems/applications the permission to learn (e.g., using an opt in/out setting). This would reduce the likelihood that the initial introduction of Adaptive User Interfaces to an application would be jarring or disruptive, such as if it were added silently through system updates. Giving disabled riders the ability to opt in or out of adaptive behaviors would promote their experiences over a system's agenda. Secondly, agency can be maintained by users co-designing adaptivity with the interface. This conceptualization builds on prior knowledge about mixed-initiative interfaces [86]. For example, labels may be leveraged to further personalize a user's experience. In the public transit Adaptive User Interfaces, disabled riders who are only interested in "Fastest" routes with "up to 1 transfer" could have the option of selecting these preferences in the settings. By making this specification, a disabled rider would co-create their definition of "best" option with the system. When the best option isn't available, the Adaptive User Interface should notify the user and offer the recommendations from its default state.

7.5.2 Advocacy and technology advancement

The "Nothing about us without us" sentiment [32] was embedded in our findings related to the future of public transportation systems. While this movement has been around since the 1990s and this particular ethos is not foreign to the accessible HCI community, other computer science (CS) communities may only engage with the disability community after a system has already been created. In the realm of advancements in the automotive industry, an example is the impact that electric vehicles (their sound or lack thereof) had on pedestrians who are blind before sound was added to such vehicles. This question supports emerging research at the intersection of automated vehicles and the disability community [24, 10, 38, 23, 192]. We therefore further amplify our participants' voices by explicitly stating that disabled people should be included in any and all discussions on the advancement of technology. This is also a call for researchers in CS-related domains to engage in advocacy & awareness service.

7.6 Summary

In this chapter, we investigate the influence of adaptive user influences in the public transit experiences of disabled riders in the North American context.

- Public Transit Riders: Primary stakeholders in this category are disabled riders.
- Public Transit Authorities: There were two main authorities that were mentioned: drivers and Pittsburgh Regional Transit phone operators

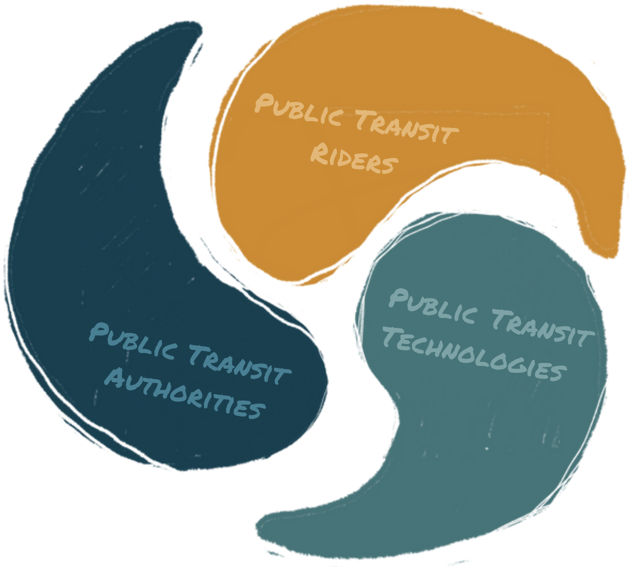

Fig. 7.4 A visual representation of the public transit ecosystem depicting three categories of stakeholders in chapter 7

- Public Transit Technologies: In this chapter, we created a design probe, DRIFT, that simulated smart transit capabilities.

In this chapter, we demonstrate that ML augmented public transit technologies significantly reduced the time taken by disabled riders to find bus information. However, there were still complex layers to their interface experiences, layers that suggest a mistrust between disabled stakeholders and public transit technologies (Figure 7.4). A distrust in public transit technologies has the potential to create frustrating experiences that become an obstacle to accessing public transit information. Relatedly, this distrust also results in inequitable experiences between stakeholders with and without disabilities, thus creating power imbalances within the public transit technology ecosystem. The appropriation of Adaptive User Interfaces and XAI can create opportunities for transparency and build trust between disabled users and public transit technologies. These findings have two notable areas of impact. Broadly, our findings present a use case for applying XAI for adaptive interfaces that will be used by disabled users of public transit applications. Within the transit domain, the findings are useful to service providers and startups that are interested in creating more accessible interfaces by centering the experience of disabled riders.

Part III

Leveraging Explainable AI to Design for Trust

Chapter 8

Co-Designing Trust in Transit User Interfaces

This chapter contains an article in preparation:

Kirabo, L., Carter, E.J., and Steinfeld A. (2023). Co-Designing Trust in Transit User Interfaces

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8.1 Overview

Trends in public transit mobile technologies show a preference for the adoption of recommendation and predictive systems. The adoption of recommendation and predictive systems is aimed at improving the transit experiences of riders. These systems are useful when finding appropriate buses or identifying the routes with the least traffic. They help increase trip planning efficiency and reduce the time taken to search for transit information.

However, public transit users do not usually have insight into how these predictions and recommendations are made. This lack of insight contributes to feelings of frustration, lack of control, and mistrust in the system (section 7.3.3). It is in this context that we assert that explanations matter [50]. Explainable AI is a growing field that emphasizes making AI models and decisions more transparent.

An explainable AI is defined as "one that produces details or reasons to make its functionality clear or easy to understand" [12, p. 85]. These explanations are either local or global in scope [43]. Local explanations give details regarding a prediction for a specific input, while global explanations base their justification on the model's process regardless of the input. There is a distinction as to whether the explanations are generated as part of the predictive process (self-explaining approach) or through additional processing (post hoc approach).

Some of the goals of these explanations include promoting trustworthiness, fairness, and privacy awareness [12]. To our knowledge, there is limited research on the intersection of explainable AI and accessibility. Wolf and Ringland [199] identified two themes at the intersection of explainable AI and accessibility: configuring explainable AI interfaces to enable alternative modes of interaction and tailoring explanations to users with diverse needs.

We extend this scholarship by understanding the explainable AI needs of disabled riders who use smart transit interfaces. In this chapter, we are interested in answering the following research questions:

1. How can we understand which categories of explanations are essential to disabled riders? (Section 8.2)

2. How do '*transparent*' Adaptive User Interfaces in mobile transit interfaces influence the transit experiences of disabled riders? (Section 8.3)

8.2 A Question-based Inquiry of Smart Public Transit Interfaces

Investigations into the importance of explainable AI are relatively new. In an effort to make AI-based systems more transparent, researchers [122] have started employing frameworks such as the question-based framework to guide design and discussions around explainability. The premise of the question-based framework is to uncover questions (or doubts) that people have when they interact with smart systems. Understanding these questions provides insight to UI/UX designers and researchers. The questions are divided into 9 categories: Input, Output, Performance, How - Global, Why, Why Not, What if, How to be that, and How to still be this.

For this study, we adopted the question-based framework designed by Liao and colleagues [122]. Given the scope of our study context, we determined that five categories of questions were immediately relevant to public transit riders interacting with an AI-enabled transit interface: Why, Why not, How, Performance, and What-if. We presented our participants with the following questions:

A. How accurate and reliable is the recommendation that the application has given me? (Performance)

B. Will the system still work correctly if I am taking a trip outside of my normal time? (What if)

C. Why did the Application recommend the 61D bus but not the 61A? (Why Not)

D. What kind of algorithm did the application use to recommend the 61D bus? (How)

E. Will the system still work correctly if I am taking a trip that is not my normal route? (What if)

F. How did the Application come up with the recommendation? What is the logic? (How)

Name	Age	Disability
Allen	77	Vision-related
Helen	75	Vision-related
Diana	67	Vision-related
Brenda	63	Vision-related
Charlie	42	Vision-related, Mobility-related
Fiona	41	Mobility-related
Elan	31	Mobility-related, Cognitive-related
Glen	28	Mobility-related, Cognitive-related

Table 8.1 Participant Information. Participant names have been changed to protect their identities.

G. Why did the Application recommend the 61D bus? (Why)

8.2.1 Participants

We recruited 8 participants who were between the ages of 28 and 77 years of age (M=53, SD=19.75, Table 8.1). We recruited participants from local and national disability organisations and participant study email lists. All our participants self-identified as having vision and/or mobility-related disabilities. They were required to be fluent in English, 18 years of age or older, and interact with a mobile interface during one portion of the study. The study lasted for 1.5 hours and participants received a total of $20 upon completion. Our Institutional Review Board approved this study.

8.2.2 Procedure

We conducted 8 workshop sessions that lasted 1.5 hours each. In each session, participants interacted with DRIFT[1], an interactive design probe created to showcase adaptive user experiences in the transit context. The smartphone application asked participants to help J choose a bus to take from a list of potential options. For the initial number of tasks, participants manually scrolled through vertically

[1] Drift stands for aDaptive useR Interface For Transit

displayed interactive buttons to look for the best bus. After selecting the bus five times, the application appeared to learned J's preferred bus and gave that bus priority by presenting it at the top of the list. We followed two AUI design guidelines such that the buttons for the preferred buses were given different background colors and ranked at the top of the list [209].

After interacting with the application, participants participated in a sorting activity. The purpose of this sorting activity was to probe participant curiosity and questions concerning the interface options. We started the session with eight questions adapted from the question-based framework. We designed multiple ways in which participants could interact with the questions (Figure 8.1): buttons, a paper list, and cards. For the first format, we embedded the questions in interactive buttons. Participants could press a physical button in order to hear an audio recording of the questions. During the sorting activity, participants had the option of moving the buttons in order of their preference. These buttons were also tagged with numbers for easy identification by the study team members, who noted the participant responses. In the second format, the questions were also printed out on an 8.5x11 sheet of paper, with the option of cutting them out and sorting them as a craft activity. In the third format, the questions were presented as 8 cards that the participants could look through, sort, arrange, and/or discard.

Fig. 8.1 For the sorting activity, participants had the option to interact with the questions in multiple ways. They would use interactive buttons, cards, or a list printed out on 8.5x11 paper. We also had a mock-up of the design journey that included the bus stop, in transit, and the destination.

During the session, participants reflected on whether they considered each question with which they had been presented. After that, participants ranked the set of questions in order of importance. We chose this ordering of activities because we did not want a participant's perception of a question's importance to influence their self-reports about the questions. Participants were also reminded that they had the option of noting that none of the questions were relevant to their interactions with the application. In order to examine the influence of the questions during the entirety of their public transit experiences, we split the journey into 4 stages: planning, in transit, at destination, and during a disruption. A disruption includes but is not limited to delays, missing a bus, construction, and detours. We asked participants to consider if any of the questions held particular influence over the different stages of using public transit technologies.

After the design session, an experimenter conducted semi-structured interviews with the participants. During the interview portion of the study, we discussed participant perceptions of recommendation and predictive systems in transit technologies. We also asked participants to envision what future smart transit systems might look like.

8.2.3 Findings

Ranking based on importance

In the analysis of the importance ranking (Figure 8.2), participants gave the questions about accuracy and reliability the highest rank (i.e., questions A, E, and F). Questions that were given middle and lower priority focused on the specific recommendation (i.e., questions C, H) and the internal workings of the algorithm (i.e., question D).

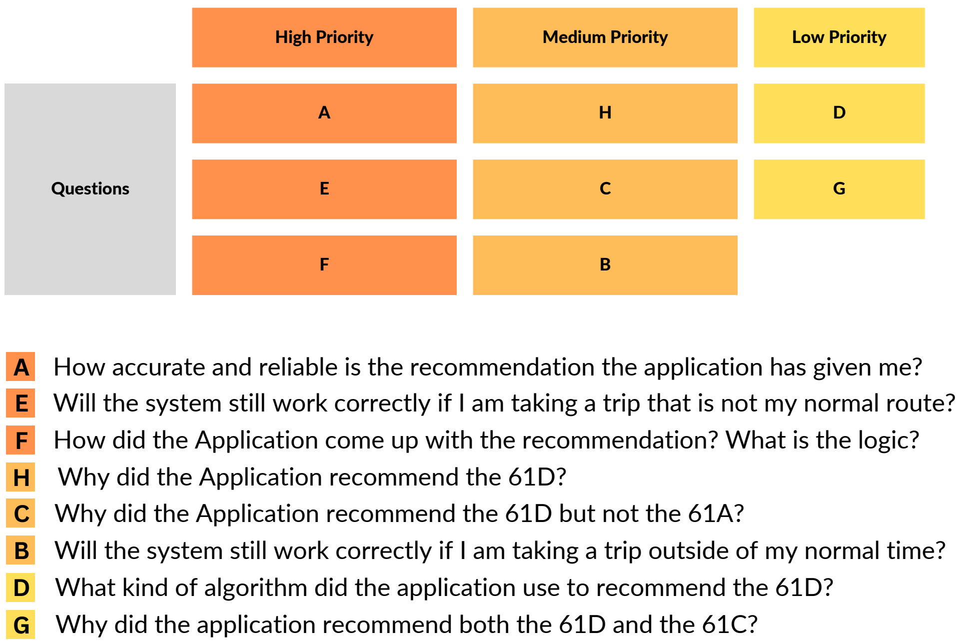

Fig. 8.2 Participants ranked the questions from the question-based framework according to high, medium, and low priority.

During the planning phase, participants highlighted A,E,F, and B as the questions that were the most important. These questions cover the accuracy, reliability, and the internal workings of the application. Participants started to question the specific recommendation (i.e., questions H, C, and G) during the in-transit phase of their journey. They reflected upon different scenarios in which these types of questions would arise, such as the bus taking another route or being overtaken by another bus heading in the same direction. Lastly, questions about the internal workings of the recommendation system (i.e., question D) became relevant during disruptions. In fact, the disruption phase made participants think about the connections between some questions.

> "*Does the algorithm know about disruptions that it can read, that it can run you onto to a different bus. And then that leads into accuracy and then also similarly both questions about which bus it shows. If it knows about it the disruption and it disrupts one kind of bus or all, then I would wanna know.*" - Charlie, mobility-related disability.

Ranking based on relevance

While participants noted the importance of the question-based framework's questions, half of them did not come up while they used the application. Participants recalled that the following four questions occurred to them while they used the application (Figure 8.3): F, How did the application come up with the recommendation? What is the logic?; E, Will the system still work correctly if I am taking a trip that is not my normal route?; B, Will the system still work correctly if I am taking a trip outside of my normal time?; and C, Why did the application recommend the 61D but not the 61A?

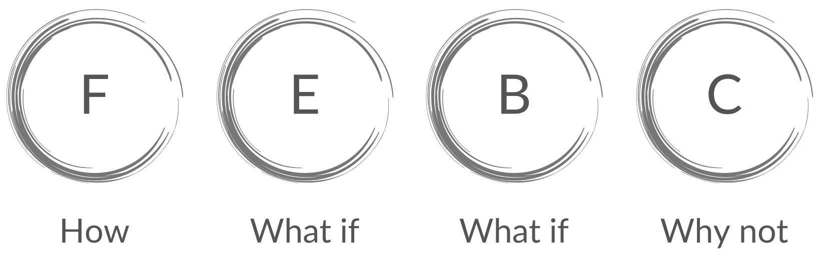

Fig. 8.3 There were only four questions from the question-based framework that participants had while they used the application. These questions represented three categories: How, What if, and Why not

Unanswered questions

Participants raised new questions that the application should answer and take into consideration. These suggestions fall into two subcategories: Failure/Recovery and Connection Accessibility.

- **How does the application handle external uncertainty?** Participants wanted to know how the application's suggestions considered events like traffic and trip cancellations. Would the application still recommend routes that were traffic-heavy, or would the system filter those out from the riders' view? Similarly, bus crowding was a feature of interest to participants. They noted that crowding was a nuanced feature. For instance, while a bus may be half full, if all the accessibility seats are taken, then a wheelchair user cannot access it. Some transit applications offer a fullness estimate but miss this contextual nuance. Participants also questioned whether smart applications could "figure out" how to identify detours. Every now and then, participant trips include detours. These detours are sometimes planned, but a number are not. Participants had a preference for this identification to happen in real time. Furthermore, it was preferable if they were alerted about the detour before they boarded the vehicle.

- **Will the application reliably handle complex trips in real time?** For trips with multiple buses, participants had specific questions about connections. They had questions about how the application would react if it detected they would miss the connection. Simply telling the rider that they will/might miss their connection was not seen to be sufficient. Smart applications should provide information that is helpful during recovery planning.

  "*...If you're like really stuck in traffic, or the bus breaks down, or whatever it'll say, like, and pop up a little alert to be like you may not make make good time to catch, you know, the 61 or whatever. Which is somewhat helpful but often just stressful, though, because you have no control over the situation, so it's like helpful to know but it's also stressful [....] Something similar to when you're driving with GPS and like a road is closed, and you go around and it like automatically reroutes? Pop up a little notification with a new trip update, or whatever whatever language new trip update, you know. Get off at this stop to catch this different bus at this time. To me, I think that would be the least stressful.*" - Glen, mobility-related disability.

- **Will the application adapt to or inform riders about local practices?** Participants also wanted to know if the smart application would take into consideration bus stacking. Bus stacking is where multiple buses arrive at a stop at the same time. These buses sometimes expect riders to walk down the line looking for their bus. This strategy is not suitable for blind/low vision riders who might rely on annunciators. Furthermore, wheelchair users expect the bus ramp to be lowered a the posted stop. Stops are usually physically located closer to the street corner and would be far way from the last bus in the queue. Additionally, most bus drivers do not wait for riders to "walk" the entire line. Another interesting practice that was mentioned is the presence of 'unfolded' strollers at the accessibility seats on buses and metro lines. Participants wanted to know whether smart applications would be smart enough to filter out these stops or, at the very least, inform riders if a route they select is notorious for these practices.

For the next section, we critiqued current systems to elicit hidden questions that disabled riders may have in addition to the questions highlighted in earlier sections of the study.

Positive sentiment for parts of the current system

Participants used positive language to explain their interaction with DRIFT. They thought it to be "useful", "sensible", and "helpful". They noted that when it offered recommendations, they did not have to think as much. Participants also reflected on positive features of current applications they use. They felt that newer interfaces should continue to use these features or find new ways of improving them. Specifically, the real-time estimated arrival times (ETAs) and GO[2] reporting found in the Transit application were appreciated. GO is useful in providing extra contextual information to their journeys. When using the GO features, their application would vibrate their phones just before their stop. This feature is particularly useful when annunciators are not working or turned off because non-visual cues are important for alerting blind riders about upcoming stops.

System inconsistencies: Will smart transit interfaces replicate current unequal experiences?

While participants positively reflected on some features, they also mentioned inconsistencies. The inconsistencies included broken stop buttons at the accessibility seating and turned-off annunciators. On some routes, annunciators are only set to call out major stops. Some disabled riders then have to rely on the driver to remember to call out the smaller stops when they need them. Smart systems should consider ways of accounting for these inconsistencies when making recommendations. Then, disabled riders would have the opportunity to choose a specific bus or avoid it. The use of maps in transit applications also offers inconsistent experiences. Most sighted users follow their journey by opening up the map section of the application and watching their vehicle move across the map. These maps are currently not accessible by screen readers. Therefore, this experience is not available to blind riders or any others who rely on screen readers. Participants speculated on the use of audio descriptions of both the journey and of the map. One participant mentioned their frustrating interactions with phantom buses. While transit applications accurately reported ETAs based on bus schedules, they were not based on the actual locations of the buses. As such, some of our participants found themselves at the bus stop waiting for buses that never came but were reported to have passed. Another participant recounted mechanisms of identifying these buses.

> "*Some of our buses at my end of the world. If there is not a driver for that bus, it will sit out at the end of the line, and you can tell [...] if it's 27 min away from more than a couple of minutes, that bus is on the system but it's not gonna move, because there's no driver.*" - Helen, vision-related disability.

Participants cautioned that future systems should not replicate these inconsistencies. Furthermore, they should provide disabled riders with the ability to report failures.

[2]GO is a real-time tracking feature that users can only enable once they get on the bus

The inevitable human-in-the-loop: How will the system integrate input from humans?

Participants' responses indicated that human operators remain a key part of their public transit experience. This can happen when they use transit applications or when riding public transit. For example, wheelchair users described sometimes having drivers strap their wheelchairs in place for safety. However, they then have to wait for drivers to remove the straps when they get to their destination. Also, visually impaired riders have to rely on drivers to call out stops when annunciators are not working. Some participants reported that a subset of drivers knew that it was their job to call out stops when the annunciators did not do so. However, one blind rider encountered a driver who was surprised when the rider exited the bus without asking for the driver's help with announcing their stop.

Alternate modalities for interaction: Will I have the same experience across modalities?

There was also a reference to the use of alternate modalities. Different modalities were most useful in specific scenarios. Typically, current smartphone applications primarily rely on touchscreen interactions. However, another potential interaction modality is the use of speech (e.g., via Siri or Google) to access transit information. One participant speculated that the use of conversational interfaces would equate to independence. Because that participant cannot use their hands, they have to rely on others to interact with applications. Another participant welcomed the use of speech as long as the interface understood her.

Defining a fuller experience, warts and all

(a) Preferred vs. fallback options: Will I still have agency when I use this system? When describing the behavior of smart transit applications, participants advocated for choice. They had specific notes about the number of recommendations offered by the application. Instead of showing only one recommendation of how to complete a journey, participants wanted to learn about multiple options. This information gave them fallback options that they could revert to if the primary option was less than ideal or did not work out. Especially in scenarios when a bus is overcrowded or when the accessibility seating is full, participants wanted to know what their other options would be. Additionally, while participants liked the idea of smart functionality, they also wanted the ability to turn it off or on. They reflected on being able to do this with other features in public transit applications (e.g., turning off bikes, scooters).

(b) Important but useless: Will the system let me tailor my experience? There were several features of current transit applications that, while important, were not useful to our participants' context. For instance, the estimated walking distance provided by most applications was not perceived to be helpful to some of the wheelchair users. One participant questioned why it was so hard to get wheelchair-specific directions when applications included bike directions. Other features that were useful but hard to navigate and understand were the detour alerts. These are often buried in the application and necessitated a commitment to seek them out. Then, participants had to determine on their own how to find and parse the information.

> "*There are already detour postings for route deviation, so that's that. That's a good thing. Sometimes if they dig for them, and we have to read through all this crap. Just say, why! Like why you can't stay on Centre Avenue to go all the way from Oakland to you know East-End*" - Diana, vision-related disability.

While the GO real time feature was applauded, it did not handle missed connections well. One participant recalled running late and the application then informed him that he would miss his connection. It provided no alternative options.

(c) Redefining the context of a journey: Will the system tell me what to expect at my destination? Participant responses also reflected their questions and concerns about the entirety of a trip. They included questions about route and connection accessibility. For example, were there audible crossings if they needed to cross the street; were there stairs or uneven sidewalks? Participants preferred to have a fuller contextual understanding of their environment as they traveled. This was further highlighted in their conversations about connections. They reflected on the need for more information on the accessibility of connection points and how to navigate them. Participants further speculated on the opportunities for interactivity at bus stops and noted a need for non-visual forms of stop identification.

(d) Limitations of access design: Is the system "disability-smart"? The critique of current accessible design was a common topic. For instance, wheelchair users often have to contend with the fact that there are only two spots for them on the bus. These two spots are shared with other disabled riders as well as individuals who use walkers and push strollers. A wheelchair user's context of a recommended bus needs to include information about space in addition to estimated time. Furthermore, the practice of strapping in wheelchairs also came under scrutiny as not all drivers know how to do this safely. Additionally, participants called for a focus on thoughtful accessibility design. One participant critiqued the proposal to use autonomous vehicles in public transportation. They pointed out that these vehicles may not have an "understanding" of the expectations of disabled riders. For example, autonomous vehicles might not be designed to know when to lower, know what part of the sidewalk to stop at, or know when to wait for a blind rider to sit.

Envisioning potential consequences: Will the system perpetuate bias?

One participant was excited about the potential of smart transit systems that offer recommendations to riders. However, they were curious about the potential impact that these systems may have on riders. The core of their questions revolved around what data the systems used to make recommendations. They questioned whether these systems would reinforce any conscious or unconscious biases that exist among riders and whether these types of systems would silo people even further. Examples of this include training smart transit application models based on choosing bus routes that pass through specific neighborhoods.

Examining assumptions and usefulness: Is the application reliable?

There was a minimum expectation that transit interfaces should work reliably. One participant noted their reliance on these applications when the weather is miserable and they needed accuracy to avoid prolonged waits in uncomfortable conditions. Others noted that these types of recommendation systems would be particularly relevant to people who were new to an area or participants who were recently disabled. Another participant noted how the local transit authority sometimes changed bus routes and names. They stated that if transit applications were updated regularly, recommendations during these types of scenarios would be beneficial.

8.2.4 The Jacaranda Framework

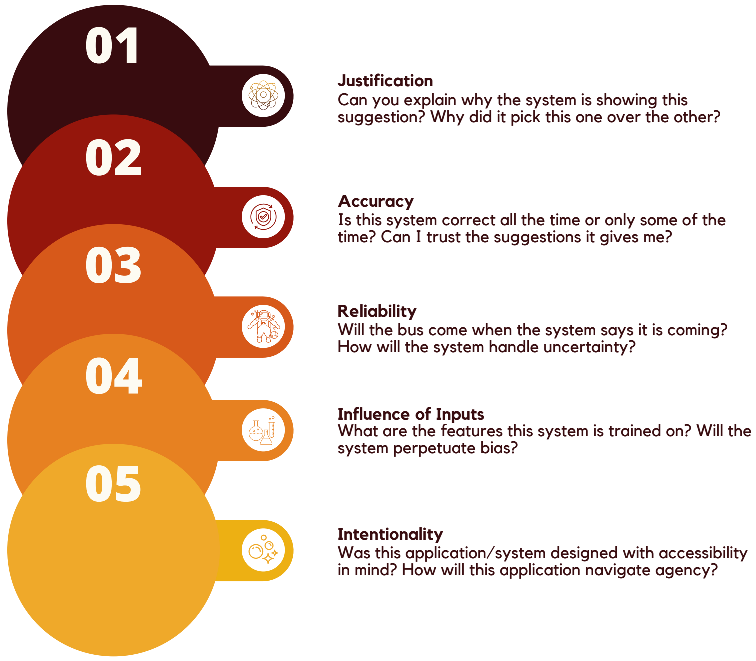

Fig. 8.4 The Jacaranda Framework — a framework of concerns that are relevant to disabled riders use of smart transit interfaces

Our findings build on past research on explainable AI [122]. The findings identify that while the questions in that work are important, most disabled riders did not think about them while they interacted with DRIFT. Additionally, the results show that from the original question-based framework, five types of questions persisted among the relevance and importance questions: F, E, B, C, A. These questions were from the question-based framework's Performance, What if, Why Not, and How categories. In addition to these questions, our participants' responses generated eleven more questions:

- How does the application handle external uncertainty?
- Will the system tell me what to expect at my destination?
- Will the application reliably handle complex trips in real time?
- Will the application adapt to or inform riders about local practises?
- Will the system let me tailor my experience?
- Will the smart transit interfaces replicate current unequal experiences?
- Will I have the same experience across modalities?
- Will I still have agency when I use this system?
- Is the system 'disability' smart?
- Will the system perpetuate bias?
- How will the system integrate input from humans?

It is at the intersection of these sets of questions that we present Jacaranda[3] — a framework of concerns that are relevant to disabled riders use of smart transit interfaces. We posit that the application of these concerns extends to any interaction with a smart system. The framework consists of 5 categories of questions: Justification, Accuracy, Reliability, Inputs, and Intentionality (Figure 8.4)). In this section, we discuss the implications of each category described as design patterns.

Justification

Two types of pre-existing questions fit into the Justification Category: F ("How did the Application come up with the recommendation? What is the logic?") and C ("Why did the Application recommend the 61D but not the 61A?"). Question F embodied the notion: "Why did you show this?" This is a valid question for every new user who interacts with a smart system. It is also a valid concern if the system presents a new suggestion (e.g., a bus route) or even an alternate one. Question C also held the idea of challenging the system. It essentially asked, "Why this one and not that one?" In the transit context, a question like this would be expected along trips that can be completed using multiple buses and routes. Essentially, these questions arise when the system has violated the user's expectations, raising doubts about a prediction. This can particularly frustrate new transit users in high-pressure scenarios (e.g., a newly disabled rider navigating a new city).

[3]Jacaranda is a tropical tree from South America with violet-like blooms. It is also loosely links to Justification AcCurAcy ReliAbility iNputs anD intentionAlity

- **Design Pattern [Content + Interface].** In both of these cases, there is an opportunity for the system to respond to these questions using the interface and or the content. Users are interested in learning why the application made the suggestion. For example, the application could state if the suggestion was made based on "past usage" or a "system suggestion" or "neighborhood popularity." Additionally, designing these cues such that they are accessible to screen readers early is important. Doing this will give screen reader users the contextual cue that these are suggestions.

Accuracy

Another pre-existing question that was important to participants concerned accuracy. Accuracy is a nuanced feature within the context of smart transit applications. It goes beyond the traditional definition of the system to get the suggestion correct. Within the context of public transportation, accuracy is influenced by estimated times of arrival information and the actual sighting of the bus. Users will judge the system's accuracy on whether the application got the bus' arrival time correct. In addition to that, they will want to have physical proof of the bus in front of them. The latter is an unintended consequence of the ghost bus phenomenon.

- **Design Pattern [Content + Interface].** There is an opportunity here to manage the expectations of users. State (in both interface design and textual content) when the application is using scheduled or actual bus location data. We focus on managing users' expectations because ensuring that buses arrive on time is out of the scope of system designers.

Reliability

The overarching theme in this category is "can the user rely on the results of the system?" Included in this category were the "What if" questions E ("Will the system still work correctly if I am taking a trip that is not my normal route?"), B ("Will the system still work correctly if I am taking a trip outside of my normal time?") from [122]; and four participant-generated questions "How does the application handle external uncertainty?", "Will the system tell me what to expect at my destination?", "Will the application reliably handle complex trips in real time?", and "Will the application adapt to or inform riders about local practices?". Users would like to know if the system would react the same way if they did something outside of their routine. Two new sub-categories of questions also contributed to the Reliability category: external uncertainty and journey-specific contexts. Under external uncertainty, issues such as detours, construction, and even traffic were common. How would smart transit interfaces react to these occurrences? As mentioned before, users wanted the assurance that the application would handle these well. Lastly, journey-specific contexts included questions about what one would find at their destination and local operator practices. These specific questions push to expand the context of smart applications beyond the route suggestions. These questions suggest that innovative transit applications should become aware of particular environments. From the accessibility of surroundings to operator practices, disabled riders want a clear picture of where they are heading.

- **Design Pattern [System + Interface].** There is an opportunity to leverage local contextual information into the suggestion model. If specific connection points are known for bus stacking, then the model should be able to remove those points from its suggestions or indicate the likelihood of a problem. However, it should also alert the user that it has done so. They should then have the option of looking at the discarded features or ignoring the alert. Secondly, there is also an opportunity to tag the suggested routes with these contextual cues.

Influence of inputs

Questions about the influence of system inputs on users fall into this category (i.e.,). Inputs include the data that is being used to build the system. This is a concern that is not specific to public transit interfaces only. There has been a general critique about the potential for new intelligent systems to contain biases. New innovative transit systems have the opportunity to be transparent about how their models are built. The second concern in this category was about designing these systems to include human intervention. The findings suggest that our participants' experiences often included other human beings. This was especially the case during fail states (i.e., a system breakdown).

- **Design Pattern [Scenario casting].** There is an opportunity for system engineers and user experience designers to investigate possible worst-case scenarios. While these exercises will not influence the model's performance, they can be indicators of its influence when used. In these worst-case scenarios, utopian and dystopian viewpoints can be leveraged for thoroughness. Secondly, there should be opportunities to engage with human feedback. There were early research efforts to do this using photo and textual reports [182], however such features are not always readily accessible in production-ready transit applications

Intentionality

This category is almost purely focused on users' interactions with the smart (transit) interfaces. Five participant-generated questions focused on whether the interfaces were disability-smart or accessibility-aware. There were questions about whether the smart interface would replicate unequal user experiences or whether the interfaces could be used across multiple modalities. The terms disability-smart and accessibility-aware refer to whether system designs are aware of the diverse needs of different user populations (e.g., disabled persons, older populations). If focusing on disabled populations, identifying which specific sub-population is important because each will have different demands of systems. Additionally, there were concerns about navigating user agency. The perceived reliance on smart systems gives off the idea that users will have little choice in their experiences. Thus, questions about the ability for users to tailor their experience or even disregard suggestions remain essential.

- **Design Pattern [Interface].** There are three opportunities related to intentionality: designing for choice, considering a broad audience, and providing consistent experiences. These opportunities focus on allowing the user to view both suggested and other options. This gives them the agency to select their preferred route. This opportunity also complements the Unremarkable AI design perspective [202]. The perspective calls for smart systems to offer recommendations in an unobtrusive manner. Additionally, smart systems should also expand on the nuanced nature of the fullness feature by including an accessible seating option. Users can specify which features best suit their journey experience in their system settings. Lastly, there is an implicit understanding within these opportunities that these new systems will be tested with broad audiences (e.g., disabled users, elderly users, etc.).

8.3 Prototyping for Transparency in Adaptive Transit Interfaces

In this section, we prototyped a 'transparent' Adaptive User Interface for transit. We define '*transparent*' Adaptive User Interfaces as smart interfaces that explain a recommendation that they are making. These recommendations are offered to users in an attempt to improve their user experiences. The sole purpose of this work was to answer RQ5 – How do 'transparent' Adaptive User Interfaces in mobile transit interfaces influence the transit experiences of disabled riders? To this end, we improved DRIFT by applying design patterns from the Jacaranda Framework.

8.3.1 DRIFT+: Interface design

To avoid confusion, we named this version of the interface DRIFT+. In DRIFT+, participants interacted with five manual interfaces. Manual interfaces required users to scroll to find the desired bus. Each manual interface was slightly different (i.e., bus ETAs and route numbers, Figure 8.5). This difference reflects transit applications that show slightly different routes and ETAs when opened.

We implemented three of the five design patterns outlined in the Jacaranda Framework (section 8.2.4) to guide DRIFT+'s Adaptive User Interface design.

- Justification focuses on explanations rooted in the validity of the suggestions shown to users. These questions can include but are not limited to "Why did the application show me this recommendation and not the other" and "How did the application come up with this recommendation." To proactively respond to these questions, we labeled two of the three suggestions as "Suggestion based on past choices." The last bus recommendation was labeled "System suggestion." We placed this explanation first to give screen reader users quick access to this connection information.

- Intentionality prioritizes carefully considering specific users when understanding questions about Adaptive User Interfaces. In this study, we focused on implementing two sub-themes of promoting user agency and being 'disability-smart.' For the former, the interfaces showed

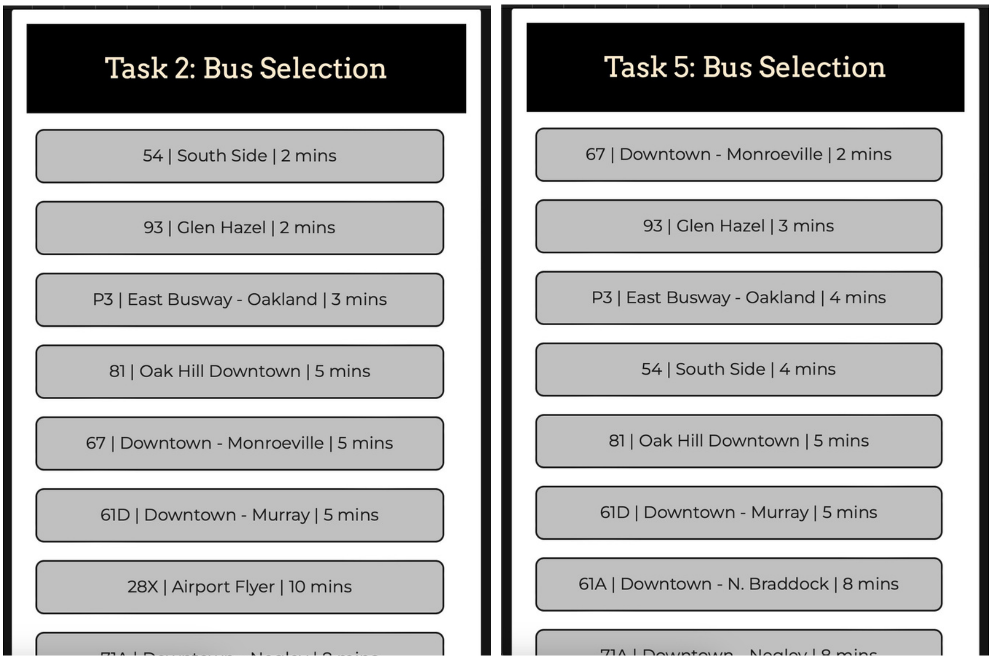

Fig. 8.5 DRIFT+'s manual scroll interfaces. The interfaces also show the slight variability in the bus list shown. This difference reflects transit applications that show slightly different routes and ETAs when opened.

another 61 bus (i.e., 61A) and other downtown buses right after the suggested 61 buses (i.e., 61D, 61C). This design choice allowed the user to decide between the suggested and non-suggested bus routes. We expanded on bus fullness for the latter theme by adding an accessible seating estimation. To understand the influence of this feature, we varied the availability of seats on each of the recommended buses (Figure 8.6). We also decided to keep choices without accessible seats based on anecdotal data about categories of disabled riders who said they almost always get a seat.

- Accuracy extends the traditional focus of getting the suggestion correct and merges it with the physical representation of a bus showing up where the system says it should be. There are multiple ways to implement this feature — including lateness estimations, real-time estimations, percentage of times the bus is on time. We condensed these by focusing on representing accuracy by noting that the bus was running on time.

Participants interacted with five adaptive interfaces. The adaptive interfaces showed suggested buses at the top of the screen. We implemented the three design patterns mentioned earlier in addition to the AUI design guidelines from Zimmerman and colleagues [209]. Each of the five interfaces showed three suggested buses at the top of the screen and displayed additional information on why each bus was shown to the user. The information indicated whether it was a "system suggestion" or whether it was a suggestion based on the rider's past preferences. Additionally, suggestions were based on the availability of accessible seating and the vehicle's reputation for on-time arrivals. For each interface, we manipulated the number of suggested buses with available accessible seats. One interface had accessible seating on all three suggestions, two interfaces had two suggestions with accessibility seats, one interface had one suggestion, and the last interfaces had no accessible seats on any of the suggested buses (Figure 8.6).

Fig. 8.6 DRIFT+'s 'transparent' Adaptive User Interfaces. They show the implementation of three design patterns from the Jacaranda Framework: Justification, Intentionality, and Accuracy.

8.3.2 Participants

We recruited 57 participants, 7 of whom were excluded because they were outside the eligibility criteria (Figure 8.7). Of the 50 participants who completed the experiment, 24 were male, 20 were female, and 6 were non-binary. Participants indicated that they were between the ages of 22 and 75 years (Mean=40.16, SD=13.27, Figure 8.8). We recruited participants using an online recruitment platform called Prolific. All of our participants self-identified as having vision and/or mobility-related disabilities (22 and 28, respectively).

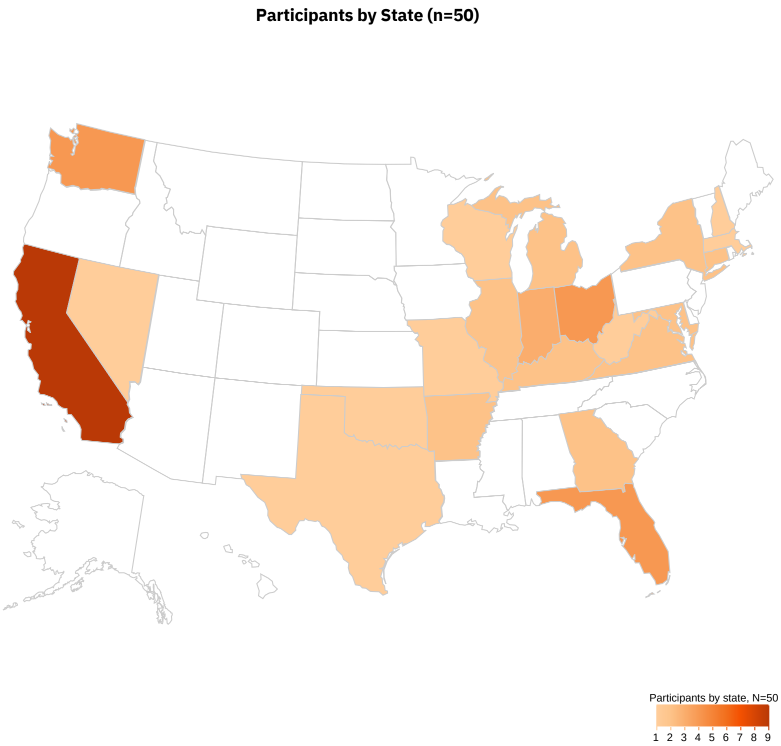

Fig. 8.7 A map of the United States showing participant distribution by state

Within Prolific, we created two separate studies focused on recruiting from each disability category. We used a rolling approach to publish each study, adding a small number of participants slots at a time. To limit duplicate submissions, we excluded participant IDs from completing more than one of the studies. We used our demographic data as an additional check against duplicate submissions. Participants were required to be fluent in English, 18 years of age or older, and interact with a mobile interface during one portion of the study. The study lasted for 1 hour and participants received $20 upon completion.

8.3.3 Procedure

Prior to the experiment, our participants completed informed consent and provided demographic information in a pre-survey. We used this data as a validity check against demographic data in the online recruitment system.

We replicated the task used in our initial study with DRIFT+ (see chapter 7). We conducted a 2x2 mixed factorial experiment with a between-subjects factor (Order) and a within-subjects factor (Interface type). Order had 2 levels, Latte and Lure. Interface type had 2 levels, non-adaptive and adaptive.

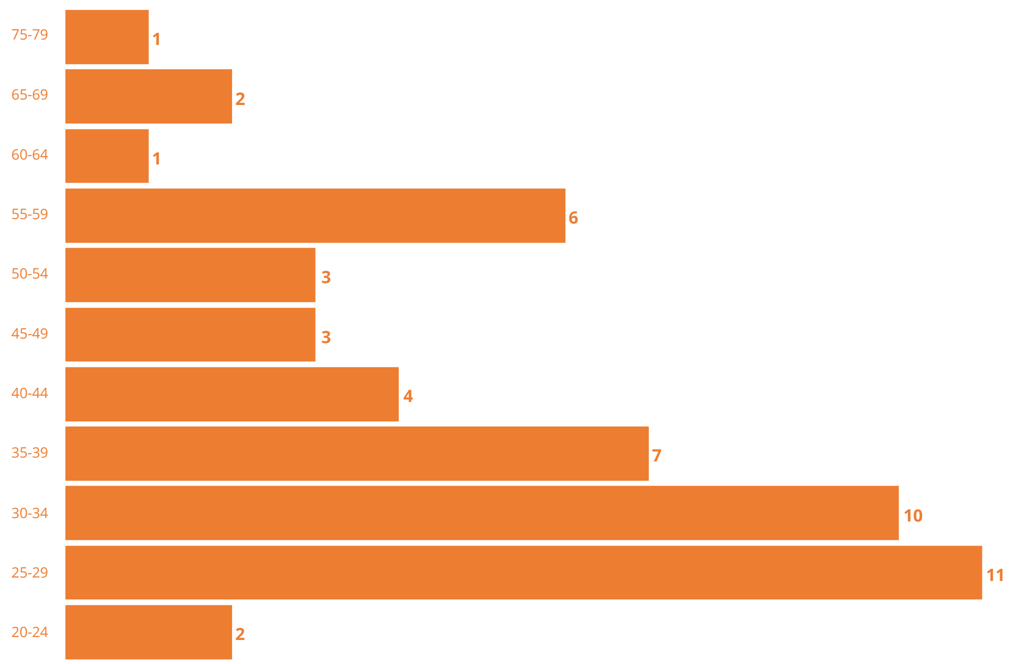

Fig. 8.8 Participants' age groups

As with before, Order refers to the sequence in which participants saw the interfaces. In the Latte level, participants saw tasks in the AUIs first, while the Lure participants saw tasks in the non-adaptive interfaces first. The former order simulates systems where prediction uses other factors (e.g., neighborhood, time of day) or attempts to bootstrap from other users' models. However, the system may revert back to a training mode after several failed attempts to provide a desired vehicle. The latter order simulates a traditional, AI-enabled transit interface where the system learns from initial use and later predicts the user's preferred bus.

The two levels of the Interface-type factor were non-adaptive and adaptive. The non-adaptive interface type showed participants a full list of buses for the relevant bus stop, and the adaptive interface type used adaptive UX design patterns to present users with the desired buses at the top of the screen (see section 8.3.1). Our new interface design also included the contextual cues with the suggestions (Figure 8.6).

Each participant completed a total of 10 short tasks. For each task, participants read the associated scenario first, which included choosing J's bus to take from a list of potential options. They then used the bus screen to find the appropriate 61 bus. Half of the participants interacted with DRIFT+ in Latte mode. The other half interacted with DRIFT+ in Lure mode. After using the interface, participants filled out a post-survey. In our post survey, we asked participants: what factors went into choosing a bus for J; which 'explanations' were important to them; how many 'explanations' they remembered; their perceptions of learning/smart interfaces in transit; and questions from the Technology Acceptance Model [44] and the System Usability Scale [173].

8.3.4 Findings

We logged participant completion times for each task. We used this data to determine whether DRIFT+'s transparency had an impact on the time taken to find information about the buses.

We conducted a repeated-measures ANOVA on the log data and found that, unlike in Study 4, the within-subjects factor (i.e., Non-Adaptive versus Adaptive) did not have an effect on the time taken to find the bus ($F(1,48) = 0.869$, $p = 0.356$). On average, participants spent almost the same duration completing tasks using the Non-Adaptive and Adaptive interfaces, respectively. However, we found that Order (i.e., Latte versus Lure) had a significant main effect on task completion time ($F(1,48) = 0.089$, $p = 0.04$). Participants in the Lure condition completed the exercise 6s faster than those in the Latte condition. While Non-Adaptive was unaffected by ordering, completion time for Adaptive was slower when not preceded by a Non-Adaptive experience. We also saw a significant interaction between Task completion time and Order ($F(1,48) = 15.23$, $p = 0.0003$). The completion times are displayed in (Table 8.2).

	Non-Adaptive (NA)	Adaptive (A)
Lure (Order: NA, A)	10.85 (6.40)	6.46 (4.29)
Latte (Order: A, NA)	10.46 (5.75)	13.17 (7.67)

Table 8.2 The mean time (in seconds) taken across each condition in the study. The standard deviation is in parentheses.

Analysis of our participants post-survey data revealed six themes that support and complement our quantitative findings.

The trade-off between time and speed

Most participants reported taking more features into consideration when they were using the adaptive interface. Nineteen participants indicated that suggestions based on the availability of accessible seats was the most important feature (i.e., 17 mobility-related disability and 2 vision-related disability). Seventeen participants indicated a preference for the on-time feature (i.e., 12 vision-related disability and 5 mobility-related disability), and thirteen participants preferred the system suggestion feature (i.e., 8 vision-related disability and 5 mobility-related disability).

> "*Based [my decision] on the suggestion and time. Knowing that it offered handicap [seats] in case I may need it that day was a huge bonus.*" - Kizzy, vision-related disability

> "*I chose the routes based on if accessible seating was full or not, and when accessible seating was taken on each route, I picked based on which bus would likely be less crowded.*" - Kia, mobility/motor-related disability

> "*I chose the 61 bus with the shortest time, the fact that it said I had previously used it, and that it had available accessible seating.*" - Kay, mobility/motor-related disability

Unexpected confusion & dissatisfaction

Participants who experienced the Latte version (the adaptive interface before the manual interfaces) expressed dissatisfaction with their experience. Because the manual interface did not include features tailored to their experience, participants filled in the missing contextual information by focusing on the arrival time estimates offered in the app. They noted this lack of contextual information in their responses.

> "*Since I couldn't find wheelchair-accessible seating, I just looked for a 61 downtown bus that would arrive in 5 minutes.*" - Khloe, mobility/motor-related disability

> "*Wild guess.*" - Kimberly, mobility/motor-related disability

> "*I tried to choose the top one at all times but realized they did not all have services I need, availability, etc. My mom usually helps with that stuff. I went with previous choices most of the time when applicable.*" - Kendrick, vision-related disability

The perceived usefulness of adaptive interfaces in transit

A majority of our participants indicated that they would prefer a public transit application that learned their transit preferences and was transparent about it's choices. Participants used positive terms such as "helpful" and "easier" to describe their interaction with the application. On the whole, they felt that 'transparent' adaptive interfaces had the potential to complement their public transit experiences.

> "*I would like an app that learns my schedule and makes recommendations for my route. I have frequent doctor visits and live in a rural area, my wife takes me the 8 miles to the first bus stop on her way to work, my schedule has to match hers. I need an accessible seat, that also comes in on time, and I would like the app to plan the route.*" - Kale, mobility/motor-related disability

> "*As an individual with walking limitations, I would prefer a transit app that learns my bus preference over time and presents it to me. This would save me time and energy in having to search through a list of buses at the bus stop, and it would make the process of using public transportation more convenient and efficient for me. Additionally, having a personalized and tailored experience would provide me with a greater sense of independence and control.*" - Kizzy, vision-related disability

> “*It would make things much easier for me. I struggle with memory issues from a past stroke. I become nervous and agitated when I forget important things pertaining to my use of public transit. An app on my phone that saves my past trips would be a very welcome addition to my daily commute!*” - Kenji, mobility/motor-related disability

> “*Having a app like this is something many people have been asking for a long time*” - Keaton, mobility/motor-related disability

These findings were further supported by the analysis that we ran on the Technology Acceptance Model instrument. A linear regression analysis of the influence of perceived ease of use on user’s perceived usefulness of DRIFT+ showed that perceived ease of use had a significant positive effect on perceived usefulness ($F(1, 48) = 19.51$, $p \leq .0001$, Figure 8.9). In other words, the more easy-to-use the interface was perceived to be, the more useful participants found it to be.

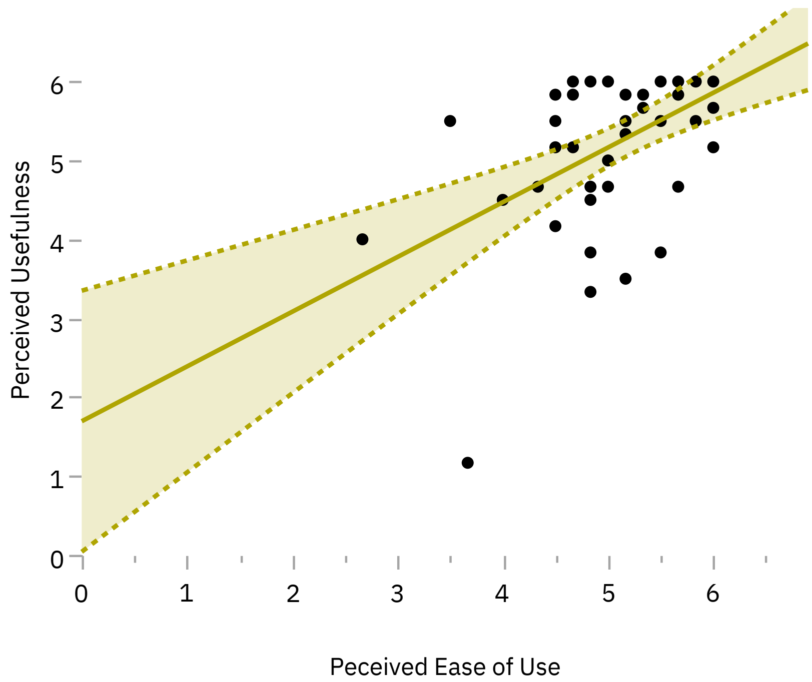

Fig. 8.9 The relationship between perceived usefulness and perceived ease of use

Data privacy and ownership

Four participants expressed a hesitancy to embrace applications that would learn their preferences. These participants cited concerns that are similar to critiques of learning systems outside the scope of public transit applications. They specifically highlighted issues around data ownership and security.

One participant recounted a recent hacking experience and was therefore hesitant to have their public transit information harvested online by other bad actors. Another participant recalled the monetization practice of embedding ads and selling personal data to third parties. They were okay using these types of applications as long as their data would not be used in any of those aforementioned practices.

Transactional experience

While some participants reflected on negative experiences they have been exposed to due to data-harvesting opportunities, others chose to embrace it. Their claim was that data harvesting is going to happen anyway, they might as well benefit from it.

> "*Although I don't love giving more info out, at this point it's pretty much everywhere and I may as well make my life easier.*" - Kourtney, vision-related disability

Another participant thought that the application of a learning system made sense in the context of public transportation. They expressed a frustration with learning systems in other domains that were not readily evident to users or easily manipulable by users.

Doubtful about unexpected events

Participants reiterated one of the questions that our past study participants had: "What happens when I take an unexpected trip?" Participants felt that while they saw the usefulness of the application with regard to routine events, they were not confident that the application would perform well if they did not have or deviated from a routine. The definition of unexpected events spans multiple contexts. Participants' examples included going to a new location, having to pick different buses for each day of the week, transit delays, and riders running late.

> "*I like all the busses displayed because I like to have a choice. Busses runs late a lot, and I run late too, so it is important to know all my bus availability. Sometimes I take a different timed bus because it runs faster then my normal bus. Listing all the busses also lets me choose alternate transportation if I am in a hurry, and the next bus takes too long.*" - Khalid, mobility/motor-related disability

Relatedly, participants also reinforced an earlier finding about choice (section 8.2.3) and shared their ideas on preferred interface behavior. Participants expressed that interfaces should have obvious or easily accessible buttons to turn behaviors on and off. They wanted the ability to choose their own routes when they felt like it.

8.3.5 Discussion

Our findings demonstrate that users took a similar amount of time on average while using the manual and adaptive interfaces on DRIFT+. However, users took more factors (i.e., the explanations) into consideration when they encountered the 'transparent' smart interface. The findings also highlighted our participants' preferences and perceived usefulness of the 'transparent' smart interfaces.

The tensions around measuring the impact of 'transparent' Adaptive User Interfaces

The traditional measurements of the impact of user interfaces in human-computer interaction include analyses that reveal statistical significance. In this study, however, our findings showed similar completion times per interface. Even though most participants' responses revealed a general enthusiasm for 'transparent' Adaptive User Interfaces, this was indicated in the qualitative responses and the analysis of the responses in the Technology Acceptance Model. Thus, we question whether a particular measurement of speed (i.e., logs of time taken to complete the task) is sufficient to understand the impact of 'transparent' Adaptive User Interfaces. In traditional interfaces experiments, time taken to complete tasks between interfaces designs can be an indicator of the influence of interfaces changes. However, this does not generalize across different users populations – specifically disabled users. This argument is not an endorsement of poor design but rather an encouragement for using complementary data that measures the quality of the experiences. In this study, participants' engagement with the explanations and preferences for certain approaches, emphasized a potential benefit to future 'transparent' Adaptive User Interfaces.

The boundaries of 'transparent' Adaptive User Interfaces: Persistent or unresolved questions

This work also portrays the current boundary of smart interfaces in the public transit domain. This boundary is defined by two things: bad experiences with technology that users will bring to the application (e.g., victims of any form of data hacking) and edge cases that are a part of their experience (e.g., questions from Jaracanda's Reliability category). For the former, transparent Adaptive User Interfaces will have to proactively find opportunities to share information on the data they use to make suggestions, recommendations, and predictions. These opportunities can be pop alerts and card user interfaces interactions on application load. Furthermore, having a persistent location in the applications settings for data source provenance might go a long way in rebuilding trust with these users. For the latter, users whose transit experiences exist in edge cases (e.g., all their transit journeys are sporadic and have no learnable pattern) provide a unique challenge to how these interfaces are trained. In the context of public transit, the current recommendation model for such a user might start with neighborhood-based suggestions similar to the DRIFT+'s Latte version (i.e., routes that are a favorite among riders). However, quantitative and qualitative data showed that users had a poor experience interacting with Drift+'s Latte. Thus, this remains an open question: how can transparent Adaptive User Interfaces improve the experiences of disabled riders who have a lot of variability in their routines?

Part IV

Discussion & Implications

Chapter 9

Contributions, Implications, and Future Work

9.1 Contributions

Using the capability approach as a guide, we explored and investigated the lived transit experiences of disabled users of public transit in two geographical contexts. Our findings across both contexts highlighted a specific distrust that riders had within the ecosystem. In the East African context, disabled riders expressed a distrust of the human stakeholders, which led to the creation of new stakeholders. The inverse was confirmed in the North American context, where disabled riders expressed a distrust of the technology stakeholder and a preference for human stakeholders. We selected the latter context as the focus of this our final work. Using a question-based strategy, we created the Jacaranda Framework — a framework of concerns relevant to disabled riders' use of smart transit interfaces. We designed DRIFT+, an interactive design probe to simulate smart transit capabilities infused with explainable recommendations based on the Jacaranda Framework. We learned that while participants took a similar amount of time navigating both the manual and 'transparent' adaptive user interfaces, the latter interface provided users with a more holistic quality of experience.

On these grounds, this thesis makes the following claim: *Designing for equity is a process that involves continuously assessing a community's context before considering any interventions.* We assert that equity is not a destination that can be achieved; instead, it is a process that should be embraced. In this work, we embrace this ethos by continuously investigating the lived transit experiences of our participants — within their local contexts and experiences related to their identities. These lived experiences gave us unique insights that characterized relationships and nuances within each public transit ecosystem.

In summary, this thesis makes the following contributions:

- We demonstrate a need to understand the entire ecosystem when considering new technologies. We present a public transit technology ecosystems artifact that includes values embedded within the public transit-disability ecosystem.
- We establish a multidimensional connection between Trust and Ecosystems. Our work presents a justification for designing for equity in public transit technologies on two axes of stakeholders and public transit technology.
- We present the Jacaranda Framework — a framework of concerns relevant to disabled riders' use of smart transit interfaces. We demonstrate how user interface and user experience designers and researchers can proactively respond to these concerns in future smart transit interfaces.
- We demonstrate how HCI methodologies can be adapted for research in multiple contexts. Our work contributes to the efforts of Global South researchers that advocate for contextual research methods.

9.2 Implications

The Jacaranda Framework offers a unique opportunity to engage with other stakeholders who influence the experiences of disabled riders.

9.2.1 Implications for user experience researchers and designers

In this work, we posit that 'Design for equity as a process' and 'the Jacaranda Framework' are an ethos and tool that could benefit user experience researchers and designers. User experience researchers and designers who work with traditionally underrepresented populations often have to deal with the inequitable legacies of many technological methods and interventions. The 'Design for equity as a process' ethos provides a design space that accepts variability and change. A space that engages with and provides the tools for constant reflection and evaluation. Relatedly, the Jacaranda Framework presents a tool to help user experience researchers and designers engage with transparent smart systems. As machine learning capabilities are further embedded into different socio-technical systems, there will be a need to answer users' questions proactively. The Jacaranda Framework offers a perspective for user experience researchers and designers to engage with these questions.

9.2.2 Implications for policy makers

The findings from both geographical contexts offer a perspective from disabled citizens' lived experiences. Policymakers working at the intersection of public transit and equity can use them as an initial primer in the discourse around improving equitable experiences. Our later work in this dissertation focused heavily on the transit experiences of public transit riders who identified as having a vision-related and/or motor/mobility-related disability. We encourage policymakers to expand this population by including riders' voices from other disability categories. Furthermore, both geographical contexts have interesting population trends (i.e., an aging population with new needs and a young population with new ambitions). Examining the influence of our findings across these changing population dynamics might provide a new direction to impact equity.

9.3 Future Work: Returning to the East Africa context

Our findings from the East African context revealed a distrust between the human stakeholders within the ecosystem. We considered the potential influence of the Jacaranda Framework in this context. We saw three potential audiences of the Jacaranda Framework in our East Africa work: 1) with a focus on disabled public transit riders, 2) with a focus on non-disabled public transit riders, or 3) with a focus on non-traditional stakeholders. We picked the third due to the power influence described in our findings. We envision leveraging the Jacaranda framework for this context in the following way:

- Justification: Highlights questions focused on stakeholders' familiarity with an issue: "Do stakeholders understand why an issue is important?", "Can they articulate its significance back to you?"
- Accuracy: Attempts to examine the intent behind a stakeholder's decision: "Are stakeholders basing their decisions on the truth or cultural norms?", "Are stakeholders able to identify the difference?"
- Reliability: Probes the uncomfortable reality behind lived experiences. It asks: "Can stakeholders trust the information that is given to them?", "How will they handle unexpected accounts?"
- Influence of Inputs: Points to the completeness of the information used to make decisions. It includes questions like: "What variables or factors do stakeholders think about before they make a decision?"
- Intentionality: Calls attention to representation by asking: "Who has the agency to voice their concerns?"

Our future work will involve returning to the East African context and embedding these principles in a transformational game with the non-traditional stakeholders that we identified. A *transformational game* is a game that is designed to influence the way players think. Our original findings indicated an unconscious bias among stakeholders that influenced their interactions with disabled public transit users. A transformation game based on the Jacaranda framework will be designed to make stakeholders aware of their biases and present tools to improve their interactions with each other.

Part V

Conclusion

Chapter 10

Conclusion

The right to access public transit is a universal need for citizens' access to essential services. As such, interventions should be designed with multiple contexts and stakeholders in mind. Policy recommendations, interventions, and research on public transit often focuses on drivers as the primary stakeholder. This same focus is evident in the recent proliferation of machine learning interventions in public transit technologies. They neglect the influence and impact of these machine learning interventions on other stakeholders in the public transit ecosystem. This focus runs the risk of automating inequities within future mobility systems. In this dissertation, we have illustrated the need to understand the ecosystem before implementing interventions. We conducted various studies in two geographical contexts: two urban cities in East Africa and one metropolitan city in North America. Our initial investigations in the East African context were guided by the question: "How can we understand stakeholders' experiences in public transit technology ecosystems?" Our findings indicated a distrust among stakeholders related to inequities (i.e., harassment and discrimination). This distrust created a new group of non-traditional core stakeholders who highlight the values of inclusion, mobility, and safety within the public transit ecosystem. We conducted follow-up investigations into the lived experiences of disabled riders in the second geographical context. Our findings showed disabled riders' preference for engaging with human stakeholders and distrust of public transit technologies. Studies from both regions pointed toward two unique solutions. To move towards equity, we needed to engage with human stakeholders in our East African work, while our North American work pointed towards engaging with public transit technologies. In last work, we took on the latter challenge — engaging with public transit technologies. We looked at improving the relationship between public transit technologies and disabled riders. Using the Jacaranda Framework, we designed a 'transparent' adaptive user interface that improved a disabled rider's holistic quality of experience when interacting with a transit application.

References

[1] Jeffrey L Adler and Victor J Blue. Toward the design of intelligent traveler information systems. *Transportation Research Part C: Emerging Technologies*, 6(3):157–172, 1998. ISSN 0968-090X. doi: https://doi.org/10.1016/S0968-090X(98)00012-6. URL https://www.sciencedirect.com/science/article/pii/S0968090X98000126.

[2] Rwanda Utilities Regulatory Agency. Road transportation, 2001. URL http://www.rura.rw/index.php?id=81.

[3] Syed Ishtiaque Ahmed, Nicola J. Bidwell, Himanshu Zade, Srihari H. Muralidhar, Anupama Dhareshwar, Baneen Karachiwala, Cedrick N. Tandong, and Jacki O'Neill. Peer-to-peer in the workplace: A view from the road. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, CHI '16, page 5063–5075, New York, NY, USA, 2016. Association for Computing Machinery. ISBN 9781450333627. doi: 10.1145/2858036.2858393. URL https://doi.org/10.1145/2858036.2858393.

[4] Dragan Ahmetovic, Roberto Manduchi, James M Coughlan, and Sergio Mascetti. Zebra crossing spotter: Automatic population of spatial databases for increased safety of blind travelers. In *Proceedings of the 17th International ACM SIGACCESS Conference on Computers & Accessibility*, pages 251–258, 2015.

[5] Sharon Eva Ahumuza, Joseph KB Matovu, John Bosco Ddamulira, and Florence Kyoheirwe Muhanguzi. Challenges in accessing sexual and reproductive health services by people with physical disabilities in kampala, uganda. *Reproductive health*, 11(1):59, 2014. doi: 10.1186/1742-4755-11-59. URL https://doi.org/10.1186/1742-4755-11-59.

[6] Ganesh Ananthanarayanan, Sean Blagsvedt, and Kentaro Toyama. Oweb: A framework for offline web browsing. In *2006 Fourth Latin American Web Congress*, pages 15–24. IEEE, 11 2006. doi: 10.1109/LA-WEB.2006.25.

[7] Ruth E. Anderson, Anthony Poon, Caitlin Lustig, Waylon Brunette, Gaetano Borriello, and Beth E. Kolko. Building a transportation information system using only gps and basic sms infrastructure. In *2009 International Conference on Information and Communication Technologies and Development (ICTD)*, pages 233–242, 2009. doi: 10.1109/ICTD.2009.5426678.

[8] Erin E Andrews, Anjali J Forber-Pratt, Linda R Mona, Emily M Lund, Carrie R Pilarski, and Rochelle Balter. # saytheword: A disability culture commentary on the erasure of "disability". *Rehabilitation psychology*, 64(2):111, 2019.

[9] Julia Angwin, Jeff Larson, Surya Mattu, and Lauren Kirchner. Machine bias. In *Ethics of Data and Analytics*, pages 254–264. Auerbach Publications, 2016.

[10] Ashratuz Zavin Asha, Christopher Smith, Lora Oehlberg, Sowmya Somanath, and Ehud Sharlin. Views from the wheelchair: Understanding interaction between autonomous vehicle and pedestrians with reduced mobility. In *Extended Abstracts of the 2020 CHI Conference on*

Human Factors in Computing Systems, CHI EA '20, page 1–8, New York, NY, USA, 2020. Association for Computing Machinery. ISBN 9781450368193. doi: 10.1145/3334480.3383041. URL https://doi.org/10.1145/3334480.3383041.

[11] Shiri Azenkot, Sanjana Prasain, Alan Borning, Emily Fortuna, Richard E. Ladner, and Jacob O. Wobbrock. Enhancing independence and safety for blind and deaf-blind public transit riders. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '11, page 3247–3256, New York, NY, USA, 2011. Association for Computing Machinery. ISBN 9781450302289. doi: 10.1145/1978942.1979424. URL https://doi.org/10.1145/1978942.1979424.

[12] Alejandro Barredo Arrieta, Natalia Díaz-Rodríguez, Javier Del Ser, Adrien Bennetot, Siham Tabik, Alberto Barbado, Salvador Garcia, Sergio Gil-Lopez, Daniel Molina, Richard Benjamins, Raja Chatila, and Francisco Herrera. Explainable artificial intelligence (xai): Concepts, taxonomies, opportunities and challenges toward responsible ai. *Information Fusion*, 58: 82–115, 2020. ISSN 1566-2535. doi: https://doi.org/10.1016/j.inffus.2019.12.012. URL https://www.sciencedirect.com/science/article/pii/S1566253519308103.

[13] Roger Behrens, Dorothy McCormick, Risper Orero, and Marilyn Ommeh. Improving paratransit service: Lessons from inter-city matatu cooperatives in kenya. *Transport Policy*, 53:79–88, 2017. doi: 10.1016/j.tranpol.2016.09.003. URL https://doi.org/10.1016/j.tranpol.2016.09.003.

[14] Anaëlle Beignon, Emeline Brulé, Jean-Baptiste Joatton, and Aurélien Tabard. *Tricky Design Probes: Triggering Reflection on Design Research Methods in Service Design*, page 1647–1660. Association for Computing Machinery, New York, NY, USA, 2020. ISBN 9781450369749. URL https://doi.org/10.1145/3357236.3395572.

[15] Genevieve Bell. No more sms from jesus: Ubicomp, religion and techno-spiritual practices. In *UbiComp 2006: Ubiquitous Computing*, pages 141–158, Berlin, Heidelberg, 2006. Springer Berlin Heidelberg. ISBN 978-3-540-39635-2. doi: 10.1007/11853565_9.

[16] Cynthia Bennett, Emily Ackerman, Bonnie Fan, Jeffrey Bigham, Patrick Carrington, and Sarah Fox. Accessibility and the crowded sidewalk: Micromobility's impact on public space. In *Designing Interactive Systems Conference 2021*, DIS '21, page 365–380, New York, NY, USA, 2021. Association for Computing Machinery. ISBN 9781450384766. doi: 10.1145/3461778.3462065. URL https://doi.org/10.1145/3461778.3462065.

[17] N. Bolten, S. Mukherjee, V. Sipeeva, A. Tanweer, and A. Caspi. A pedestrian-centered data approach for equitable access to urban infrastructure environments. *IBM J. Res. Dev.*, 61(6):10:1–10:12, nov 2017. ISSN 0018-8646. doi: 10.1147/JRD.2017.2736279. URL https://doi.org/10.1147/JRD.2017.2736279.

[18] MJ Booysen, CJ Abraham, AJ Rix, and Innocent Ndibatya. Walking on sunshine: Pairing electric vehicles with solar energy for sustainable informal public transport in uganda. *Energy Research & Social Science*, 85:102403, 2022.

[19] Johan Borg, Anna Lindström, and Stig Larsson. Assistive technology in developing countries: national and international responsibilities to implement the convention on the rights of persons with disabilities. *The Lancet*, 374(9704):1863–1865, 2009. URL https://doi.org/10.1016/S0140-6736(09)61872-9.

[20] Virginia Braun and Victoria Clarke. Using thematic analysis in psychology. *Qualitative research in psychology*, 3(2):77–101, 2006. doi: 10.1191/1478088706qp063oa.

[21] Kirsten Bray and Christina Harrington. Speculative blackness: Considering afrofuturism in the creation of inclusive speculative design probes. In *Designing Interactive Systems Conference 2021*, DIS '21, page 1793–1806, New York, NY, USA, 2021. Association for Computing Machinery. ISBN 9781450384766. doi: 10.1145/3461778.3462002. URL https://doi.org/10.1145/3461778.3462002.

[22] Adrián Bresó, Juan Martínez-Miranda, Elies Fuster-García, and Juan Miguel García-Gómez. A novel approach to improve the planning of adaptive and interactive sessions for the treatment of major depression. *International Journal of Human-Computer Studies*, 87:80–91, 2016.

[23] Julian Brinkley. Using personas with visual impairments to explore the design of an accessible self-driving vehicle human-machine interface. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, volume 65, pages 337–341, Los Angeles, CA, 2021. SAGE Publications.

[24] Julian Brinkley, Earl W. Huff, Briana Posadas, Julia Woodward, Shaundra B. Daily, and Juan E. Gilbert. Exploring the needs, preferences, and concerns of persons with visual impairments regarding autonomous vehicles. *ACM Trans. Access. Comput.*, 13(1), apr 2020. ISSN 1936-7228. doi: 10.1145/3372280. URL https://doi.org/10.1145/3372280.

[25] Joy Buolamwini and Timnit Gebru. Gender shades: Intersectional accuracy disparities in commercial gender classification. In *Conference on fairness, accountability and transparency*, pages 77–91. PMLR, 2018.

[26] United States Census Bureau. Us census bureau quick facts: Allegheny county, pittsburgh city. URL https://www.census.gov/quickfacts/alleghenycountypennsylvania.

[27] Patrick Businge. Disability and armed conflict: A quest for africanising disability in uganda. *Disability and the Global South*, 3(1):816–842, 2017. ISSN 2050-7364.

[28] Jacob Calzavara, Thomas Courtright, and Junghoon Park. Environmental and social impact assessment of electric motorcycles in kampala, uganda. 2021.

[29] Megan Campbell, Cynthia Bennett, Caitlin Bonnar, and Alan Borning. Where's my bus stop? supporting independence of blind transit riders with stopinfo. In *Proceedings of the 16th international ACM SIGACCESS conference on Computers & accessibility*, pages 11–18, 2014.

[30] Rosalia Camporeale, Leonardo Caggiani, and Michele Ottomanelli. Modeling horizontal and vertical equity in the public transport design problem: A case study. *Transportation Research Part A: Policy and Practice*, 125:184–206, 2019.

[31] Raymond Chan and Joseph L Schofer. Role of social media in communicating transit disruptions. *Transportation Research Record*, 2415(1):145–151, 2014.

[32] James I Charlton. *Nothing about us without us: Disability oppression and empowerment*. Univ of California Press, Oakland, CA, 2000.

[33] Christopher Chepken, Raymond Mugwanya, Edwin Blake, and Gary Marsden. Ictd interventions: Trends over the last decade. In *Proceedings of the Fifth International Conference on Information and Communication Technologies and Development*, ICTD '12, pages 241–248, New York, NY, USA, 2012. ACM. ISBN 978-1-4503-1045-1. doi: 10.1145/2160673.2160704. URL http://doi.acm.org/10.1145/2160673.2160704.

[34] George Hope Chidziwisano and Susan Wyche. M-kulinda: Using a sensor-based technology probe to explore domestic security in rural kenya. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, CHI '18, pages 10:1–10:13, New York, NY, USA, 2018. ACM. ISBN 978-1-4503-5620-6. doi: 10.1145/3173574.3173584. URL http://doi.acm.org/10.1145/3173574.3173584.

[35] Albert Ching, C Zegras, Stephen Kennedy, and M Mamun. A user-flocksourced bus experiment in dhaka: New data collection technique with smartphones. *Transportation Research Record: Journal of the Transportation Research Board*, 2013.

[36] Regis Chireshe, Edward Ntare Rutondoki, and Paul Ojwang. Perceptions of the availability and effectiveness of hiv/aids awareness and intervention programmes by people with disabilities in uganda. *SAHARA-J: Journal of Social Aspects of HIV/AIDS*, 7(4):17–23, 2010. doi: 10.1080/17290376.2010.9724973.

[37] Aysha Cohen. Equity in motion: Bikeshare in low-income communities. 2016.

[38] Mark Colley, Marcel Walch, Jan Gugenheimer, Ali Askari, and Enrico Rukzio. *Towards Inclusive External Communication of Autonomous Vehicles for Pedestrians with Vision Impairments*, page 1–14. Association for Computing Machinery, New York, NY, USA, 2020. ISBN 9781450367080. URL https://doi.org/10.1145/3313831.3376472.

[39] Pieter Colpaert, Alvin Chua, Ruben Verborgh, Erik Mannens, Rik Van de Walle, and Andrew Vande Moere. What public transit api logs tell us about travel flows. In *Proceedings of the 25th International Conference Companion on World Wide Web*, WWW '16 Companion, page 873–878, Republic and Canton of Geneva, CHE, 2016. International World Wide Web Conferences Steering Committee. ISBN 9781450341448. doi: 10.1145/2872518.2891069. URL https://doi.org/10.1145/2872518.2891069.

[40] Sunny Consolvo, David W. McDonald, and James A. Landay. Theory-driven design strategies for technologies that support behavior change in everyday life. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '09, page 405–414, New York, NY, USA, 2009. Association for Computing Machinery. ISBN 9781605582467. doi: 10.1145/1518701.1518766. URL https://doi.org/10.1145/1518701.1518766.

[41] Christopher Csikszentmihalyi, Jude Mukundane, Gemma F. Rodrigues, Daniel Mwesigwa, and Michelle Kasprzak. The space of possibilities: Political economies of technology innovation in sub-saharan africa. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, CHI '18, page 1–13, New York, NY, USA, 2018. Association for Computing Machinery. ISBN 9781450356206. doi: 10.1145/3173574.3173880. URL https://doi.org/10.1145/3173574.3173880.

[42] Rikke F. Dam and Teo Y. Siang. Define and frame your design challenge by creating your point of view and ask "how might we", 2017. URL https://www.interaction-design.org/literature/article/define-and-frame-your-design-challenge-by-creating-your-point-of-view-and-ask\-how-might-we.

[43] Marina Danilevsky, Kun Qian, Ranit Aharonov, Yannis Katsis, Ban Kawas, and Prithviraj Sen. A survey of the state of explainable AI for natural language processing. In Kam-Fai Wong, Kevin Knight, and Hua Wu, editors, *Proceedings of the 1st Conference of the Asia-Pacific Chapter of the Association for Computational Linguistics and the 10th International Joint Conference on Natural Language Processing, AACL/IJCNLP 2020, Suzhou, China, December 4-7, 2020*, pages 447–459. Association for Computational Linguistics, 2020. URL https://aclanthology.org/2020.aacl-main.46/.

[44] Fred D. Davis. Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 13(3):319–340, 1989. ISSN 02767783. URL http://www.jstor.org/stable/249008.

[45] Nicola Dell and Neha Kumar. The ins and outs of hci for development. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, CHI '16, pages 2220–2232, New York, NY, USA, 2016. ACM. ISBN 978-1-4503-3362-7. doi: 10.1145/2858036.2858081. URL http://doi.org/10.1145/2858036.2858081.

[46] Tawanna R. Dillahunt, Vaishnav Kameswaran, Linfeng Li, and Tanya Rosenblat. Uncovering the values and constraints of real-time ridesharing for low-resource populations. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, CHI '17, page 2757–2769, New York, NY, USA, 2017. Association for Computing Machinery. ISBN 9781450346559. doi: 10.1145/3025453.3025470. URL https://doi.org/10.1145/3025453.3025470.

[47] Dana S Dunn and Erin E Andrews. Person-first and identity-first language: Developing psychologists' cultural competence using disability language. *American Psychologist*, 70(3): 255, 2015.

[48] eHealth Technical Working Group. Uganda national ehealth policy, November 2016. URL https://tmcg.co.ug/wp-content/uploads/2019/04/Uganda-National-eHealth-Policy-2016-.pdf.

[49] Daniel Ehebrecht, Dirk Heinrichs, and Barbara Lenz. Motorcycle-taxis in sub-saharan africa: Current knowledge, implications for the debate on "informal" transport and research needs. *Journal of Transport Geography*, 69:242–256, 2018. doi: 10.1016/j.jtrangeo.2018.05.006. URL https://doi.org/10.1016/j.jtrangeo.2018.05.006.

[50] Upol Ehsan, Q. Vera Liao, Michael Muller, Mark O. Riedl, and Justin D. Weisz. Expanding explainability: Towards social transparency in ai systems. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, CHI '21, New York, NY, USA, 2021. Association for Computing Machinery. ISBN 9781450380966. doi: 10.1145/3411764.3445188. URL https://doi.org/10.1145/3411764.3445188.

[51] Malin Eiband, Hanna Schneider, Mark Bilandzic, Julian Fazekas-Con, Mareike Haug, and Heinrich Hussmann. Bringing transparency design into practice. In *23rd International Conference on Intelligent User Interfaces*, IUI '18, page 211–223, New York, NY, USA, 2018. Association for Computing Machinery. ISBN 9781450349451. doi: 10.1145/3172944.3172961. URL https://doi.org/10.1145/3172944.3172961.

[52] Nathan Emuron, Henry Magala, Florence B Kyazze, Donald Kugonza, and Connie Kyarisiima. Factors influencing the trade of local chickens in kampala city markets. *Livestock Research for Rural Development*, 22, 04 2010.

[53] Virginia Eubanks. *Automating inequality: How high-tech tools profile, police, and punish the poor*. St. Martin's Press, 2018.

[54] Cyrus Farivar. Blind users with service animals: Uber refuses to serve us [updated], 04 2015. URL https://arstechnica.com/tech-policy/2015/04/blind-users-with-service-animals-uber-refuses-to-serve-us/.

[55] Pablo Salazar Ferro, Roger Behrens, and Peter Wilkinson. Hybrid urban transport systems in developing countries: Portents and prospects. *Research in Transportation Economics*, 39(1):121 – 132, 2013. ISSN 0739-8859. doi: 10.1016/j.retrec.2012.06.004. URL https://doi.org/10.1016/j.retrec.2012.06.004.

[56] Silvia Figueira, Michael Brew, Bryant Larsen, Pratyusha Joginipally, Sowmya Chandrashekarappa, and Ty Van Herweg. Text for a ride, in uganda. In *Proceedings of the 2015 Annual Symposium on Computing for Development*, DEV '15, page 75–76, New York, NY, USA, 2015. Association for Computing Machinery. ISBN 9781450334907. doi: 10.1145/2830629.2835220. URL https://doi.org/10.1145/2830629.2835220.

[57] Leah Findlater and Krzysztof Z Gajos. Design space and evaluation challenges of adaptive graphical user interfaces. *AI Magazine*, 30(4):68–68, 2009.

[58] Leah Findlater and Joanna McGrenere. Impact of screen size on performance, awareness, and user satisfaction with adaptive graphical user interfaces. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '08, page 1247–1256, New York, NY, USA, 2008. Association for Computing Machinery. ISBN 9781605580111. doi: 10.1145/1357054.1357249. URL https://doi.org/10.1145/1357054.1357249.

[59] German H Flores and Roberto Manduchi. A public transit assistant for blind bus passengers. *IEEE Pervasive Computing*, 17(1):49–59, 2018.

[60] Jodi Forlizzi, Carl DiSalvo, and Francine Gemperle. Assistive robotics and an ecology of elders living independently in their homes. *Human–Computer Interaction*, 19(1-2):25–59, 2004. URL https://www.tandfonline.com/doi/abs/10.1080/07370024.2004.9667339.

[61] Batya Friedman and David G Hendry. *Value sensitive design: Shaping technology with moral imagination*. MIT Press, Cambridge, MA, 2019.

[62] Julie M. Funk, Matthew Lakier, Marcel O'Gorman, and Daniel Vogel. Exploring smartphone relationships through roland barthes using an instrumented pillow technology probe. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, CHI '21, New York, NY, USA, 2021. Association for Computing Machinery. ISBN 9781450380966. doi: 10.1145/3411764.3445548. URL https://doi.org/10.1145/3411764.3445548.

[63] Krzysztof Z. Gajos, Jacob O. Wobbrock, and Daniel S. Weld. Automatically generating user interfaces adapted to users' motor and vision capabilities. In *Proceedings of the 20th Annual ACM Symposium on User Interface Software and Technology*, UIST '07, page 231–240, New York, NY, USA, 2007. Association for Computing Machinery. ISBN 9781595936790. doi: 10.1145/1294211.1294253. URL https://doi.org/10.1145/1294211.1294253.

[64] Krzysztof Z. Gajos, Jacob O. Wobbrock, and Daniel S. Weld. Improving the performance of motor-impaired users with automatically-generated, ability-based interfaces. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '08, page 1257–1266, New York, NY, USA, 2008. Association for Computing Machinery. ISBN 9781605580111. doi: 10.1145/1357054.1357250. URL https://doi.org/10.1145/1357054.1357250.

[65] Yanbo Ge, Christopher R Knittel, Don MacKenzie, and Stephen Zoepf. Racial and gender discrimination in transportation network companies. Working Paper 22776, National Bureau of Economic Research, October 2016. URL http://www.nber.org/papers/w22776.

[66] Chris Giles. African smart cities: A high-tech solution to overpopulated megacities?, 2018. URL https://www.cnn.com/2017/12/12/africa/africa-new-smart-cities/index.html.

[67] Dennis A Gioia. If i had a magic wand: Reflections on developing a systematic approach to qualitative research. *Standing on the shoulders of giants: Traditions and innovations in research methodology*, 11:27–37, 2019.

[68] Shikoh Gitau and Gary Marsden. Fair partnerships – working with ngos. In *Human-Computer Interaction – INTERACT 2009*, pages 704–707, Berlin, Heidelberg, 2009. Springer Berlin Heidelberg. ISBN 978-3-642-03655-2.

[69] Shikoh Gitau, Paul Plantinga, and Kathleen Diga. Ictd research by africans: Origins, interests, and impact. In *Proceedings of the 4th International Conference on Information and Communication Technologies and Development ICTD*, pages 13–16, New York, NY, USA, 2010. Association for Computing Machinery.

[70] Shikoh Gitau, Paul Plantinga, Kathleen Diga, and David Hutchful. African ictd research (or the lack thereof). *interactions*, 18(4):74–77, 2011. URL https://doi.org/10.1145/1978822.1978837.

[71] John Ngatia Githui, Toshiyuki Okamura, and Fumihiko Nakamura. The structure of users' satisfaction on urban public transport service in developing country: the case of nairobi. In *Proceedings of the Eastern Asia Society for Transportation Studies Vol. 7 (The 8th International Conference of Eastern Asia Society for Transportation Studies, 2009)*, pages 232–232. Eastern Asia Society for Transportation Studies, 2009.

[72] Reginald G Golledge, James R Marston, and C Michael Costanzo. Attitudes of visually impaired persons toward the use of public transportation. *Journal of Visual Impairment & Blindness*, 91(5):446–459, 1997.

[73] Tom Goodfellow and Kristof Titeca. Presidential intervention and the changing 'politics of survival' in kampala's informal economy. *Cities*, 29(4):264–270, 2012.

[74] Markus Guentert. Improving public transit accessibility for blind riders: A train station navigation assistant. In *The Proceedings of the 13th International ACM SIGACCESS Conference on Computers and Accessibility*, ASSETS '11, page 317–318, New York, NY, USA, 2011. Association for Computing Machinery. ISBN 9781450309202. doi: 10.1145/2049536.2049626. URL https://doi.org/10.1145/2049536.2049626.

[75] Themistocle Hakizimana. Rwanda's switch to electric public transport, 10 2021. URL https://www.dw.com/en/rwandas-switch-to-electric-public-transport/av-59113096.

[76] Aimi Hamraie. *Building Access: Universal Design and the Politics of Disability*. University of Minnesota Press, Minneapolis, MN, 2017. ISBN 9781517901646. URL http://www.jstor.org/stable/10.5749/j.ctt1pwt79d.

[77] Aimi Hamraie. Contra* design with bess williamson and elizabeth guffey, June 2020. URL https://www.mapping-access.com/podcast/2020/6/22/contra-podcast-episode-212-contrahistory-2-with-elizabeth-guffey-and-bess-williamson.

[78] Kotaro Hara, Vicki Le, and Jon Froehlich. Combining crowdsourcing and google street view to identify street-level accessibility problems. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '13, page 631–640, New York, NY, USA, 2013. Association for Computing Machinery. ISBN 9781450318990. doi: 10.1145/2470654.2470744. URL https://doi.org/10.1145/2470654.2470744.

[79] Kotaro Hara, Shiri Azenkot, Megan Campbell, Cynthia L. Bennett, Vicki Le, Sean Pannella, Robert Moore, Kelly Minckler, Rochelle H. Ng, and Jon E. Froehlich. Improving public transit accessibility for blind riders by crowdsourcing bus stop landmark locations with google street view: An extended analysis. *ACM Trans. Access. Comput.*, 6(2), mar 2015. ISSN 1936-7228. doi: 10.1145/2717513. URL https://doi.org/10.1145/2717513.

[80] Pedro Hernández-Ramos, Christine M Bachen, Chad Raphael, John Ifcher, and Michael Broghammer. Experiencing poverty in an online simulation: Effects on players' beliefs, attitudes and behaviors about poverty. *Cyberpsychology: Journal of Psychosocial Research on Cyberspace*, 13(3), 2019. URL http://dx.doi.org/10.5817/CP2019-3-1.

[81] Melissa R. Ho, Emmanuel K. Owusu, and Paul M. Aoki. Claim mobile: Engaging conflicting stakeholder requirements in healthcare in uganda. In *Proceedings of the 3rd International Conference on Information and Communication Technologies and Development*, ICTD'09, page 35–45, New Jersy, US, 2009. IEEE Press. ISBN 9781424446629.

[82] Melissa R Ho, Thomas N Smyth, Matthew Kam, and Andy Dearden. Human-computer interaction for development: The past, present, and future. *Information Technologies & International Development*, 5(4):1–18, 2009.

[83] Andrew J Hogan. Moving away from the" medical model": The development and revision of the world health organization's classification of disability. *Bulletin of the History of Medicine*, 93(2):241–269, 2019.

[84] Catherine Holloway. Disability interaction (dix): A manifesto. *Interactions*, 26(2):44–49, February 2019. ISSN 1072-5520. doi: 10.1145/3310322. URL https://doi.org/10.1145/3310322.

[85] George Hope Chidziwisano, Alex Mariakakis, Susan Wyche, Vitumbiko Mafeni, and Esau Gideon Banda. Nkhukuprobe: Using a sensor-based technology probe to support poultry farming activities in malawi. In *ACM SIGCAS Conference on Computing and Sustainable Societies*, COMPASS '21, page 275–287, New York, NY, USA, 2021. Association for Computing Machinery. ISBN 9781450384537. doi: 10.1145/3460112.3471962. URL https://doi.org/10.1145/3460112.3471962.

[86] Eric Horvitz. Principles of mixed-initiative user interfaces. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '99, page 159–166, New York, NY, USA, 1999. Association for Computing Machinery. ISBN 0201485591. doi: 10.1145/302979.303030. URL https://doi.org/10.1145/302979.303030.

[87] John Howe. 'filling the middle': Uganda's appropriate transport services. *Transport Reviews*, 23(2):161–176, 2003. doi: 10.1080/01441640309890. URL https://doi.org/10.1080/01441640309890.

[88] Kevin Huang, Patrick J. Sparto, Sara Kiesler, Asim Smailagic, Jennifer Mankoff, and Dan Siewiorek. A technology probe of wearable in-home computer-assisted physical therapy. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '14, page 2541–2550, New York, NY, USA, 2014. Association for Computing Machinery. ISBN 9781450324731. doi: 10.1145/2556288.2557416. URL https://doi.org/10.1145/2556288.2557416.

[89] Anthony Jameson. Adaptive interfaces and agents. In *Human-Computer Interaction*, pages 123–148. CRC Press, Florida, USA, 2009.

[90] Esther Jang, Mary Claire Barela, Matt Johnson, Philip Martinez, Cedric Festin, Margaret Lynn, Josephine Dionisio, and Kurtis Heimerl. Crowdsourcing rural network maintenance and repair via network messaging. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, CHI '18, pages 67:1–67:12, New York, NY, USA, 2018. ACM. ISBN 978-1-4503-5620-6. doi: 10.1145/3173574.3173641. URL http://doi.acm.org/10.1145/3173574.3173641.

[91] Jasmine Jones and Joyojeet Pal. Counteracting dampeners: Understanding technology-amplified capabilities of people with disabilities in sierra leone. In *Proceedings of the Seventh International Conference on Information and Communication Technologies and Development*, ICTD '15, New York, NY, USA, 2015. Association for Computing Machinery. ISBN 9781450331630. doi: 10.1145/2737856.2738025. URL https://doi.org/10.1145/2737856.2738025.

[92] Vaishnav Kameswaran, Jatin Gupta, Joyojeet Pal, Sile O'Modhrain, Tiffany C. Veinot, Robin Brewer, Aakanksha Parameshwar, Vidhya Y, and Jacki O'Neill. "we can go anywhere": Understanding independence through a case study of ride-hailing use by people with visual impairments in metropolitan india. *Proc. ACM Hum.-Comput. Interact.*, 2(CSCW), November 2018. doi: 10.1145/3274354. URL https://doi.org/10.1145/3274354.

[93] Vaishnav Kameswaran, Maulishree Pandey, Michigan Josh Guberman Hrishikesh Rao, and Michigan Sile O'Modhrain. Experiences of mobility in the global south: Lessons from people with visual impairments in india, 2019. URL http://vaikam.people.si.umich.edu/docs/HackingBlindNav.pdf.

[94] Vaishnav Kameswaran, Alexander J. Fiannaca, Melanie Kneisel, Amy Karlson, Edward Cutrell, and Meredith Ringel Morris. Understanding in-situ use of commonly available navigation technologies by people with visual impairments. In *The 22nd international ACM SIGACCESS conference on computers and accessibility*, pages 1–12, 2020.

[95] Visit Kampala. Transport in kampala, 2017. URL https://visitkampala.net/transport-in-kampala/.

[96] Regina Kamuhanda and Oliver Schmidt. Matatu: A case study of the core segment of the public transport market of kampala, uganda. *Transport Reviews*, 29(1):129–142, 2009.

[97] Eronie Kamukama. Turning kampala into a smart city, 2019. URL https://www.monitor.co.ug/Business/Prosper/Turning-Kampala-into-a-smart-city-/688616-5122426-qke75t/index.html.

[98] Ayesha Karamat and Ayesha Farooq. Emerging role of social media in political activism: Perceptions and practices. *South Asian Studies (1026-678X)*, 31(1):381–396, 2016.

[99] Thuku Kariuki. Electric buses for better air quality in nairobi, 05 2022. URL https://www.dw.com/en/electric-buses-for-better-air-quality-in-nairobi/av-61692409.

[100] Joseph Kasera, Jacki O'Neill, and Nicola J. Bidwell. Sociality, tempo & flow: Learning from namibian ridesharing. In *Proceedings of the First African Conference on Human Computer Interaction*, AfriCHI'16, page 36–47, New York, NY, USA, 2016. Association for Computing Machinery. ISBN 9781450348300. doi: 10.1145/2998581.2998582. URL https://doi.org/10.1145/2998581.2998582.

[101] Geoff Kaufman and Mary Flanagan. A psychologically "embedded" approach to designing games for prosocial causes. *Cyberpsychology: Journal of Psychosocial Research on Cyberspace*, 9(3), 2015. doi: 10.5817/CP2015-3-5. URL https://doi.org/10.5817/CP2015-3-5.

[102] KCCA. National population and housing census 2014 area specific profiles, 2010. URL https://www.ubos.org/onlinefiles/uploads/ubos/2014CensusProfiles/KAMPALA-KCCA.pdf.

[103] KCCA. Kampala edges 12 african cities to claim lead role in the africa smart towns network (aston), 2019. URL https://www.kcca.go.ug/news/344/kampala-edges-12-african-cities-to-claim-lead-role-in-the-africa-smart-towns\-network-aston#.Xs1-JVNKjmE.

[104] KCCA. Ict department, 2019. URL https://www.kcca.go.ug/ict.

[105] Simeon L. Keates and John Clarkson. *Countering Design Exclusion: An Introduction to Inclusive Design*. Springer, New York, USA, 2004. ISBN 9781447100133.

[106] Inayat Khan and Shah Khusro. Towards the design of context-aware adaptive user interfaces to minimize drivers' distractions. *Mobile Information Systems*, 2020, 2020.

[107] Jee-Eun Kim, Masahiro Bessho, Noboru Koshizuka, and Ken Sakamura. Enhancing public transit accessibility for the visually impaired using iot and open data infrastructures. In *Proceedings of the First International Conference on IoT in Urban Space*, URB-IOT '14, page 80–86, Brussels, BEL, 2014. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering). ISBN 9781631900372. doi: 10.4108/icst.urb-iot.2014.257263. URL https://doi.org/10.4108/icst.urb-iot.2014.257263.

[108] Lynn Kirabo, Elizabeth J. Carter, and Aaron Steinfeld. *"You Are Asking Me to Pay for My Legs": Exploring the Experiences, Perceptions, and Aspirations of Informal Public Transportation Users in Kampala and Kigali*, page 136–147. Association for Computing Machinery, New York, NY, USA, 2020. ISBN 9781450371292. URL https://doi.org/10.1145/3378393.3402269.

[109] Jacqueline Klopp, Jackson Mutua, Dan Orwa, Peter Waiganjo, Adam White, and Sarah Williams. Towards a standard for paratransit data: Lessons from developing gtfs data for nairobi's matatu system. Technical report, Transportation Research Board, 2014.

[110] Jacqueline M Klopp. Towards a political economy of transportation policy and practice in nairobi. In *Urban forum*, volume 23, pages 1–21. Springer, 2012.

[111] Pia Korpinen. Inclusion of people with disabilities in uganda, October 2009. URL https://www.ilo.org/wcmsp5/groups/public/---ed_emp/---ifp_skills/documents/publication/wcms_115099.pdf.

[112] Kenneth L Kraemer, Jason Dedrick, and Prakul Sharma. One laptop per child: vision vs. reality. *Communications of the ACM*, 52(6):66–73, 2009. doi: 10.1145/1516046.1516063.

[113] Neha Kumar and Nicola Dell. Towards informed practice in hci for development. *Proceedings of the ACM on Human-Computer Interaction*, 2(CSCW):1–20, 2018. URL https://doi.org/10.1145/3274368.

[114] Neha Kumar, Marisol Wong-Villacres, Naveena Karusala, Aditya Vishwanath, Arkadeep Kumar, and Azra Ismail. Aspirations-based design. In *Proceedings of the Tenth International Conference on Information and Communication Technologies and Development*, ICTD '19, pages 2:1–2:11, New York, NY, USA, 2019. ACM. ISBN 978-1-4503-6122-4. doi: 10.1145/3287098.3287117. URL http://doi.acm.org/10.1145/3287098.3287117.

[115] Stanley Kwenda. Africa's disabled will not be forgotten. *Africa Renewal*, 24(1):18–21, 2010. URL https://doi.org/10.18356/2d84257f-en.

[116] Issie Lapowsky. Uber's business isn't built to help disabled people, 08 2015. URL https://www.wired.com/2015/08/uber-disability/.

[117] John Kah Soon Lau, Chen-Khong Tham, and Tie Luo. Participatory cyber physical system in public transport application. In *2011 Fourth IEEE International Conference on Utility and Cloud Computing*, pages 355–360. IEEE, 2011.

[118] Jonathan Lazar. *Universal Usability: Designing Computer Interfaces for Diverse User Populations*. John Wiley & Sons, Inc., Hoboken, NJ, USA, 2007. ISBN 0470027274.

[119] Bridget Leadbeater. How disability studies and ecofeminist approaches shape research: exploring small-scale farmer perceptions of banana cultivation in the lake victoria region, uganda. *Disability and the Global South*, 2(3):752–776, 2017. ISSN 2050-7364.

[120] Je Seok Lee, Heeryung Choi, and Joonhwan Lee. Talkingcane: Designing interactive white cane for visually impaired people's bus usage. In *Proceedings of the 17th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct*, MobileHCI '15, page 668–673, New York, NY, USA, 2015. Association for Computing Machinery. ISBN 9781450336536. doi: 10.1145/2786567.2793686. URL https://doi.org/10.1145/2786567.2793686.

[121] Hanlin Li, Disha Bora, Sagar Salvi, and Erin Brady. Slacktivists or activists? identity work in the virtual disability march. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, CHI '18, page 1–13, New York, NY, USA, 2018. Association for Computing Machinery. ISBN 9781450356206. doi: 10.1145/3173574.3173799. URL https://doi.org/10.1145/3173574.3173799.

[122] Q. Vera Liao, Daniel Gruen, and Sarah Miller. *Questioning the AI: Informing Design Practices for Explainable AI User Experiences*, page 1–15. Association for Computing Machinery, New York, NY, USA, 2020. ISBN 9781450367080. URL https://doi.org/10.1145/3313831.3376590.

[123] Sara Lichtenwalter, Gary Koeske, and Esther Sales. Examining transportation and employment outcomes: Evidence for moving beyond the bus pass. *Journal of Poverty*, 10(1):93–115, 2006.

[124] Chris Linder, Jess S Myers, Colleen Riggle, and Marvette Lacy. From margins to mainstream: Social media as a tool for campus sexual violence activism. *Journal of Diversity in Higher Education*, 9(3):231, 2016. URL https://doi.org/10.1037/dhe0000038.

[125] Malcolm MacLachlan, Gubela Mji, Tsitsi Chataika, Margaret Wazakili, Andrew K Dube, Moses Mulumba, Boniface Massahm, Dagnachew Wakene, Frank Kallon, and Marcella Maughan. Facilitating disability inclusion in poverty reduction processes: group consensus perspectives from disability stakeholders in uganda, malawi, ethiopia, and sierra leone. *Disability and the Global South*, 1(1):107–127, 2017. ISSN 2050-7364.

[126] Lisa Magloff. Nairobi develops green public transport, 02 2022. URL https://www.springwise.com/innovation/mobility-transport/kenyas-rapid-transit-buses-to-be-powered-by-electricity.

[127] Anne Garland Mahler and Eugene O'Brien. Oxford bibliographies in literary and critical theory. 2017.

[128] Hasheem Mannan, Joanne McVeigh, Mutamad Amin, Malcolm MacLachlan, Leslie Swartz, Alister Munthali, and Gert Van Rooy. Core concepts of human rights and inclusion of vulnerable groups in the disability and rehabilitation policies of malawi, namibia, sudan, and south africa. *Journal of Disability Policy Studies*, 23(2):67–81, 2012. doi: 10.1177/1044207312439103. URL https://doi.org/10.1177/1044207312439103.

[129] DAC Maunder, CJ Venter, T Rickert, and J Sentinella. Improving transport access and mobility for people with disabilities. In *CILT Regional Conference, International Logistics and Transport: The Challenges Ahead, Number PA4061/04, Dubai, UAE. Transport Research Laboratory*, 2004.

[130] Aditi Misra, Aaron Gooze, Kari Watkins, Mariam Asad, and Christopher A Le Dantec. Crowdsourcing and its application to transportation data collection and management. *Transportation Research Record*, 2414(1):1–8, 2014.

[131] Cory Mogk. A repeatable 3d printing process for low-cost prosthetics, March 2015. URL https://autodeskresearch.typepad.com/blog/2015/03/repeatable-3d-printing-process-for-low-cost-prosthetics.html.

[132] Rosa Morris. ‘unjust, inhumane and highly inaccurate’: the impact of changes to disability benefits and services–social media as a tool in research and activism. *Disability & Society*, 28 (5):724–728, 2013.

[133] Moses Mulumba, Juliana Nantaba, Claire E Brolan, Ana Lorena Ruano, Katie Brooker, and Rachel Hammonds. Perceptions and experiences of access to public healthcare by people with disabilities and older people in uganda. *International Journal for Equity in Health*, 13(1):76, 2014. doi: 10.1186/s12939-014-0076-4.

[134] Elaine M Murphy, Margaret E Greene, Alexandra Mihailovic, and Peter Olupot-Olupot. Was the “abc” approach (abstinence, being faithful, using condoms) responsible for uganda’s decline in hiv? *PLoS medicine*, 3(9), 2006. doi: 10.1371/journal.pmed.0030379.

[135] Kenda Mutongi. Thugs or entrepreneurs? perceptions of matatu operators in nairobi, 1970 to the present. *International African Institute*, 76(4):549–568, 2006. doi: 10.3366/afr.2006.0072. URL https://doi.org/10.3366/afr.2006.0072.

[136] Alon Mwesigwa. Disabled persons’ agony of criss-crossing city roads, 03 2013. URL https://www.observer.ug/features-sp-2084439083/57-feature/24050-disabled-persons-agony-of-criss-crossing-city-roads.

[137] Anirudh Nagraj, Ravi Kuber, Foad Hamidi, and Raghavendra SG Prasad. Investigating the navigational habits of people who are blind in india. In *The 23rd International ACM SIGACCESS Conference on Computers and Accessibility*, ASSETS ’21, New York, NY, USA, 2021. Association for Computing Machinery. ISBN 9781450383066. doi: 10.1145/3441852.3471203. URL https://doi.org/10.1145/3441852.3471203.

[138] Naveen Nandan, Andreas Pursche, and Xing Zhe. Challenges in crowdsourcing real-time information for public transportation. In *2014 IEEE 15th international conference on mobile data management*, volume 2, pages 67–72. IEEE, 2014.

[139] Saideep Nannapaneni and Abhishek Dubey. Towards demand-oriented flexible rerouting of public transit under uncertainty. In *Proceedings of the Fourth Workshop on International Science of Smart City Operations and Platforms Engineering*, SCOPE ’19, page 35–40, New York, NY, USA, 2019. Association for Computing Machinery. ISBN 9781450367035. doi: 10.1145/3313237.3313302. URL https://doi.org/10.1145/3313237.3313302.

[140] United Nations. Sustainable transport must answer needs of ‘those who have the least’, says secretary-general as global conference opens in turkmenistan, 11 2016. URL https://www.un.org/press/en/2016/envdev1758.doc.htm.

[141] Zahrah Nesbitt-Ahmed and Erika Fraser. Preliminary impact study. the use of safe boda for women’s improved mobility and empowerment in kampala. Technical report, The Shell Foundation, 2017.

[142] Racheal Ninsiima. 3d prosthetic limbs come to uganda, January 2015. URL https://www.observer.ug/news-headlines/36130-3d-prosthetic-limbs-come-to-uganda.

[143] Renee Noortman, Britta F. Schulte, Paul Marshall, Saskia Bakker, and Anna L. Cox. Hawkeye - deploying a design fiction probe. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, CHI ’19, page 1–14, New York, NY, USA, 2019. Association

for Computing Machinery. ISBN 9781450359702. doi: 10.1145/3290605.3300652. URL https://doi.org/10.1145/3290605.3300652.

[144] Martha C Nussbaum. Creating capabilities: The human development approach. *Creating capabilities. Cambridge, MA: Belknap Press of Harvard*, 2011.

[145] Ministry of Health. Uganda national ehealth strategy: 2017 - 2021, 2017. URL https://health.go.ug/sites/default/files/National%20e_Health%20Strategy_0.pdf.

[146] City of Kigali. Kigali city evolution, 2015. URL http://www.kigalicity.gov.rw/fileadmin/Template/Documents/Statistics/KIGALI_CITY_POPULATION_EVOLUTION.pdf.

[147] Uganda Bureau of Statistics and The DHS Program. *Uganda Demographic and Health Survey, 2016*. Uganda Bureau of Statistics, 2018.

[148] National Institute of Statistics of Rwanda. *The Fifth Integrated Household Living Conditions Survey EICV5, 2016/17*. National Institute of Statistics of Rwanda, 2018.

[149] US Department of Transportation. Table 13. percent of disabled and nondisabled who used type of transportation in past month for local travel, Nov 2011. URL https://www.bts.gov/archive/publications/freedom_to_travel/table_13.

[150] Isaiah Oluranti Ogunrinola. Informal self-employment and poverty alleviation: empirical evidence from motorcycle taxi riders in nigeria. *International journal of economics and finance*, 3(2), 2011. doi: 10.5539/ijef.v3n2p176.

[151] Lourdes Diaz Olvera, Assogba Guézéré, Didier Plat, and Pascal Pochet. Earning a living, but at what price? being a motorcycle taxi driver in a sub-saharan african city. *Journal of Transport Geography*, 55:165 – 174, 2016. ISSN 0966-6923. doi: https://doi.org/10.1016/j.jtrangeo.2015.11.010. URL http://www.sciencedirect.com/science/article/pii/S0966692315002203.

[152] National Council on Disability. *Transportation Update: Where We've Gone and What We've Learned*. National Council on Disability, 2015. URL https://ncd.gov/publications/2015/05042015/.

[153] Joyojeet Pal and Meera Lakshmanan. Assistive technology and the employment of people with vision impairments in india. In *Proceedings of the Fifth International Conference on Information and Communication Technologies and Development*, ICTD '12, page 307–317, New York, NY, USA, 2012. Association for Computing Machinery. ISBN 9781450310451. doi: 10.1145/2160673.2160711. URL https://doi.org/10.1145/2160673.2160711.

[154] Joyojeet Pal, Tawfiq Ammari, Ramaswami Mahalingam, Ana Maria Huaita Alfaro, and Meera Lakshmanan. Marginality, aspiration and accessibility in ictd. In *Proceedings of the Sixth International Conference on Information and Communication Technologies and Development: Full Papers - Volume 1*, ICTD '13, page 68–78, New York, NY, USA, 2013. Association for Computing Machinery. ISBN 9781450319065. doi: 10.1145/2516604.2516623. URL https://doi.org/10.1145/2516604.2516623.

[155] Joyojeet Pal, Maura Youngman, Terence O'Neill, Priyank Chandra, and Cyprien Semushi. Gender and accessibility in rwanda and malawi. In *Proceedings of the Seventh International Conference on Information and Communication Technologies and Development*, ICTD '15, New York, NY, USA, 2015. Association for Computing Machinery. ISBN 9781450331630. doi: 10.1145/2737856.2738020. URL https://doi.org/10.1145/2737856.2738020.

[156] Akshat Pandey and Aylin Caliskan. *Disparate Impact of Artificial Intelligence Bias in Ridehailing Economy's Price Discrimination Algorithms*, page 822–833. Association for Computing Machinery, New York, NY, USA, 2021. ISBN 9781450384735. URL https://doi.org/10.1145/3461702.3462561.

[157] Konstantinos Papangelis, Somayajulu Sripada, David Corsar, Nagendra Velaga, Peter Edwards, and John D. Nelson. Developing a real time passenger information system for rural areas. In Sakae Yamamoto, editor, *Human Interface and the Management of Information. Information and Interaction for Health, Safety, Mobility and Complex Environments*, pages 153–162, Berlin, Heidelberg, 2013. Springer Berlin Heidelberg. ISBN 978-3-642-39215-3.

[158] Eric Paulos and Elizabeth Goodman. The familiar stranger: Anxiety, comfort, and play in public places. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '04, pages 223–230, New York, NY, USA, 2004. ACM. ISBN 1-58113-702-8. doi: 10.1145/985692.985721. URL http://doi.acm.org/10.1145/985692.985721.

[159] Rafael HM Pereira, Tim Schwanen, and David Banister. Distributive justice and equity in transportation. *Transport reviews*, 37(2):170–191, 2017.

[160] Dan Pescaru and Daniel-Ioan Curiac. Ensemble based traffic light control for city zones using a reduced number of sensors. *Transportation Research Part C: Emerging Technologies*, 46:261–273, 2014. ISSN 0968-090X. doi: https://doi.org/10.1016/j.trc.2014.06.006. URL https://www.sciencedirect.com/science/article/pii/S0968090X14001855.

[161] Dorian Peters, Susan Hansen, Jenny McMullan, Theresa Ardler, Janet Mooney, and Rafael A. Calvo. "participation is not enough": Towards indigenous-led co-design. In *Proceedings of the 30th Australian Conference on Computer-Human Interaction*, OzCHI '18, page 97–101, New York, NY, USA, 2018. Association for Computing Machinery. ISBN 9781450361880. doi: 10.1145/3292147.3292204. URL https://doi.org/10.1145/3292147.3292204.

[162] Ehsan Rahimi, Ali Shamshiripour, Ramin Shabanpour, Abolfazl Mohammadian, and Joshua Auld. Analysis of transit users' response behavior in case of unplanned service disruptions. *Transportation Research Record*, 2674(3):258–271, 2020.

[163] B.S.Y. Rao and P. Varaiya. Roadside intelligence for flow control in an intelligent vehicle and highway system. *Transportation Research Part C: Emerging Technologies*, 2(1):49–72, 1994. ISSN 0968-090X. doi: https://doi.org/10.1016/0968-090X(94)90019-1. URL https://www.sciencedirect.com/science/article/pii/0968090X94900191.

[164] Nicolas J Raynor and Tolib Mirzoev. Understanding road safety in kenya: views of matatu drivers. *International health*, 6(3):242–248, 2014. doi: 10.1093/inthealth/ihu034.

[165] Brigitte Rohwerder. Assistive technologies in developing countries. K4d helpdesk report, Institute of Development Studies, Brighton, UK, 2018.

[166] Maria Rosala. How many participants for a ux interview? URL https://www.nngroup.com/articles/interview-sample-size/.

[167] William S Kisaalita and Josephat Sentongo-Kibalama. Delivery of urban transport in developing countries: the case for the motorcycle taxi service (boda-boda) operators of kampala. *Development Southern Africa*, 24(2):345–357, 2007. doi: 10.1080/03768350701327319. URL https://doi.org/10.1080/03768350701327319.

[168] Simon Saddier and Alex Johnson. Understanding the operational characteristics of paratransit services in accra, ghana: A case study. Technical report, Transportation Research Board 97th Annual Meeting, 2018.

[169] Simon Saddier, Zachary Patterson, Alex Johnson, and Natalie Wiseman. Fickle or flexible? assessing paratransit reliability with smartphones in accra, ghana. *Transportation Research Record: Journal of the Transportation Research Board*, 2650:9–17, 2017. doi: 10.3141/2650-02. URL https://doi.org/10.3141/2650-02.

[170] Manaswi Saha, Alexander J. Fiannaca, Melanie Kneisel, Edward Cutrell, and Meredith Ringel Morris. Closing the gap: Designing for the last-few-meters wayfinding problem for people with visual impairments. In *The 21st International ACM SIGACCESS Conference on Computers and Accessibility*, ASSETS '19, page 222–235, New York, NY, USA, 2019. Association for Computing Machinery. ISBN 9781450366762. doi: 10.1145/3308561.3353776. URL https://doi.org/10.1145/3308561.3353776.

[171] Manaswi Saha, Michael Saugstad, Hanuma Teja Maddali, Aileen Zeng, Ryan Holland, Steven Bower, Aditya Dash, Sage Chen, Anthony Li, Kotaro Hara, and Jon Froehlich. Project sidewalk: A web-based crowdsourcing tool for collecting sidewalk accessibility data at scale. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, CHI '19, page 1–14, New York, NY, USA, 2019. Association for Computing Machinery. ISBN 9781450359702. doi: 10.1145/3290605.3300292. URL https://doi.org/10.1145/3290605.3300292.

[172] Nithya Sambasivan, Nibha Jain, Garen Checkley, Asif Baki, and Taylor Herr. A framework for technology design for emerging markets. *Interactions*, 24(3):70–73, April 2017. ISSN 1072-5520. doi: 10.1145/3058496. URL https://doi.org/10.1145/3058496.

[173] Jeff Sauro and James Lewis. Correlations among prototypical usability metrics: Evidence for the construct of usability. pages 1609–1618, 04 2009. doi: 10.1145/1518701.1518947.

[174] Herrie Schalekamp. Lessons from building paratransit operators' capacity to be partners in cape town's public transport reform process. *Transportation Research Part A: Policy and Practice*, 104:58 – 66, 2017. ISSN 0965-8564. URL http://www.sciencedirect.com/science/article/pii/S0965856415302445.

[175] Herrie Schalekamp and Roger Behrens. Engaging the paratransit sector in cape town on public transport reform: Progress, process and risks. *Research in Transportation Economics*, 39(1): 185–190, 2013. doi: 10.1016/j.retrec.2012.06.012. URL https://doi.org/10.1016/j.retrec.2012.06.012.

[176] Matthias Schneider-Hufschmidt, Uwe Malinowski, and Thomas Kuhme. *Adaptive user interfaces: Principles and practice*. Elsevier Science Inc., 1993.

[177] Amartya Sen. The idea of justice. *Journal of human development*, 9(3):331–342, 2008.

[178] Ather Sharif, Aedan Liam McCall, and Kianna Roces Bolante. Should i say "disabled people" or "people with disabilities"? language preferences of disabled people between identity-and person-first language. In *Proceedings of the 24th International ACM SIGACCESS Conference on Computers and Accessibility*, pages 1–18, 2022.

[179] Spin. Bringing mobility-as-a-service and universal basic mobility to pittsburgh, 07 2021.

[180] Jennifer Stark and Nicholas Diakopoulos. Uber seems to offer better service in areas with more white people. that raises some tough questions., 03 2016. URL https://www.washingtonpost.com/news/wonk/wp/2016/03/10/uber-seems-to-offer-better-service-in-areas-with-more-white-people-that-raises-some\-tough-questions/?utm.

[181] Aaron Steinfeld, Odest Chadwicke Jenkins, and Brian Scassellati. The oz of wizard: Simulating the human for interaction research. In *Proceedings of the 4th ACM/IEEE International Conference on Human Robot Interaction*, HRI '09, page 101–108, New York, NY, USA, 2009. Association for Computing Machinery. ISBN 9781605584041. doi: 10.1145/1514095.1514115. URL https://doi.org/10.1145/1514095.1514115.

[182] Aaron Steinfeld, Shree Lakshmi Rao, Allison Tran, John Zimmerman, Anthony Tomasic, et al. Co-producing value through public transit information services. *Advances in the Human Side of Service Engineering*, pages 231–40, 2013.

[183] Aaron Steinfeld, Leslie Bloomfield, Sarah Amick, Yun Huang, Will Odom, Qian Yang, and John Zimmerman. Increasing access to transit: Localized mobile information. *Journal of Urban Technology*, 26(3):45–64, 2019. doi: 10.1080/10630732.2019.1614896. URL https://doi.org/10.1080/10630732.2019.1614896.

[184] Edward Steinfeld and Jordana Maisel. *Universal Design: Creating Inclusive Environments*. John Wiley & Sons, Inc., Hoboken, NJ, USA, 2012. ISBN 9780470399132.

[185] Jonathan Stempel. Uber must face lawsuit claiming bias against blind riders, 04 2015. URL https://www.reuters.com/article/us-uber-blind-lawsuit/uber-must-face-lawsuit-claiming-bias-against-blind-riders-idUSKBN0NB1W020150420.

[186] Veda C. Storey, Roman Lukyanenko, Wolfgang Maass, and Jeffrey Parsons. Explainable ai. *Commun. ACM*, 65(4):27–29, mar 2022. ISSN 0001-0782. doi: 10.1145/3490699. URL https://doi.org/10.1145/3490699.

[187] Samina T Syed, Ben S Gerber, and Lisa K Sharp. Traveling towards disease: transportation barriers to health care access. *Journal of community health*, 38(5):976–993, 2013.

[188] Mohammadamin Tajgardoon and Hassan A Karimi. Simulating and visualizing sidewalk accessibility for wayfinding of people with disabilities. *International Journal of Cartography*, 1(1):79–93, 2015.

[189] Jacob Thebault-Spieker, Loren G. Terveen, and Brent Hecht. Avoiding the south side and the suburbs: The geography of mobile crowdsourcing markets. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing*, CSCW '15, page 265–275, New York, NY, USA, 2015. Association for Computing Machinery. ISBN 9781450329224. doi: 10.1145/2675133.2675278. URL https://doi.org/10.1145/2675133.2675278.

[190] Kentaro Toyama. From needs to aspirations in information technology for development. *Information Technology for Development*, 24(1):15–36, 2018. doi: 10.1080/02681102.2017.1310713. URL https://doi.org/10.1080/02681102.2017.1310713.

[191] Elizabeth J Traut and Aaron Steinfeld. Identifying commonly used and potentially unsafe transit transfers with crowdsourcing. *Transportation research part A: policy and practice*, 122: 99–111, 2019. URL https://doi.org/10.1016/j.tra.2019.02.005.

[192] Shari Trewin, Sara Basson, Michael Muller, Stacy Branham, Jutta Treviranus, Daniel Gruen, Daniel Hebert, Natalia Lyckowski, and Erich Manser. Considerations for ai fairness for people with disabilities. *AI Matters*, 5(3):40–63, dec 2019. doi: 10.1145/3362077.3362086. URL https://doi.org/10.1145/3362077.3362086.

[193] Judy van Biljon. Human-computer interaction for development: A knowledge mobilisation framework. *GlobDev*, 2018. URL https://aisel.aisnet.org/globdev2018/4.

[194] Manon ML Verdonschot, LP De Witte, E Reichrath, WHE Buntinx, and LMG Curfs. Impact of environmental factors on community participation of persons with an intellectual disability: a systematic review. *Journal of intellectual disability research*, 53(1):54–64, 2009.

[195] Arun Vishwanath, Heng-Soon Gan, Shivkumar Kalyanaraman, Stephan Winter, and Iven Mareels. Personalized public transportation: A mobility model and its application to melbourne. *IEEE Intelligent Transportation Systems Magazine*, 7(4):37–48, 2015. doi: 10.1109/MITS.2015.2474975.

[196] Greg Walsh. Towards equity and equality in american co-design: A case study. In *Proceedings of the 17th ACM Conference on Interaction Design and Children*, IDC '18, page 434–440, New York, NY, USA, 2018. Association for Computing Machinery. ISBN 9781450351522. doi: 10.1145/3202185.3202768. URL https://doi.org/10.1145/3202185.3202768.

[197] Jacob O. Wobbrock, Shaun K. Kane, Krzysztof Z. Gajos, Susumu Harada, and Jon Froehlich. Ability-based design: Concept, principles and examples. *ACM Trans. Access. Comput.*, 3(3), April 2011. ISSN 1936-7228. doi: 10.1145/1952383.1952384. URL https://doi.org/10.1145/1952383.1952384.

[198] Jacob O Wobbrock, Krzysztof Z Gajos, Shaun K Kane, and Gregg C Vanderheiden. Ability-based design. *Communications of the ACM*, 61(6):62–71, 2018.

[199] Christine T. Wolf and Kathryn E. Ringland. Designing accessible, explainable ai (xai) experiences. *SIGACCESS Access. Comput.*, 125, mar 2020. ISSN 1558-2337. doi: 10.1145/3386296.3386302. URL https://doi.org/10.1145/3386296.3386302.

[200] Beatrice A Wright. Developing constructive views of life with a disability. 1983.

[201] Qian Yang, John Zimmerman, Aaron Steinfeld, and Anthony Tomasic. Planning adaptive mobile experiences when wireframing. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems*, DIS '16, page 565–576, New York, NY, USA, 2016. Association for Computing Machinery. ISBN 9781450340311. doi: 10.1145/2901790.2901858. URL https://doi.org/10.1145/2901790.2901858.

[202] Qian Yang, Aaron Steinfeld, and John Zimmerman. Unremarkable ai: Fitting intelligent decision support into critical, clinical decision-making processes. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, CHI '19, page 1–11, New York, NY, USA, 2019. Association for Computing Machinery. ISBN 9781450359702. doi: 10.1145/3290605.3300468. URL https://doi.org/10.1145/3290605.3300468.

[203] Daisy Yoo. Stakeholder tokens: A constructive method for value sensitive design stakeholder analysis. In *Proceedings of the 2017 ACM Conference Companion Publication on Designing Interactive Systems*, pages 280–284, New York, NY, 2017. ACM Press. URL https://doi.org/10.1145/3064857.3079161.

[204] Daisy Yoo, John Zimmerman, Aaron Steinfeld, and Anthony Tomasic. Understanding the space for co-design in riders' interactions with a transit service. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '10, page 1797–1806, New York, NY, USA, 2010. Association for Computing Machinery. ISBN 9781605589299. doi: 10.1145/1753326.1753596. URL https://doi.org/10.1145/1753326.1753596.

[205] Daisy Yoo, John Zimmerman, and Tad Hirsch. Probing bus stop for insights on transit co-design. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '13, page 409–418, New York, NY, USA, 2013. Association for Computing Machinery. ISBN 9781450318990. doi: 10.1145/2470654.2470714. URL https://doi.org/10.1145/2470654.2470714.

[206] AK Yousafzai, K Edwards, C D'Allesandro, and L Lindström. Hiv/aids information and services: The situation experienced by adolescents with disabilities in rwanda and uganda. *Disability and rehabilitation*, 27:1357–63, 12 2005. doi: 10.1080/09638280500164297.

[207] Pengfei Zhou, Yuanqing Zheng, and Mo Li. How long to wait? predicting bus arrival time with mobile phone based participatory sensing. In *Proceedings of the 10th international conference on Mobile systems, applications, and services*, pages 379–392, 2012.

[208] John Zimmerman, Anthony Tomasic, Charles Garrod, Daisy Yoo, Chaya Hiruncharoenvate, Rafae Aziz, Nikhil Ravi Thiruvengadam, Yun Huang, and Aaron Steinfeld. Field trial of tiramisu: Crowd-sourcing bus arrival times to spur co-design. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '11, page 1677–1686, New York, NY, USA, 2011. Association for Computing Machinery. ISBN 9781450302289. doi: 10.1145/1978942.1979187. URL https://doi.org/10.1145/1978942.1979187.

[209] John Zimmerman, Changhoon Oh, Nur Yildirim, Alex Kass, Teresa Tung, and Jodi Forlizzi. Ux designers pushing ai in the enterprise: A case for adaptive uis. *Interactions*, 28(1):72–77, dec 2020. ISSN 1072-5520. doi: 10.1145/3436954. URL https://doi.org/10.1145/3436954.

[210] Ting Zuo, Heng Wei, Na Chen, and Chun Zhang. First-and-last mile solution via bicycling to improving transit accessibility and advancing transportation equity. *Cities*, 99:102614, 2020. ISSN 0264-2751. doi: https://doi.org/10.1016/j.cities.2020.102614. URL https://www.sciencedirect.com/science/article/pii/S0264275119305347.

Appendix A

Human-Centered Methods: A Reflection

This section reflects on the contextual nature of the work presented in this dissertation. It details how traditional methods were adapted to suit contexts and research populations appropriately.

A.1 Adapting for Online Research & Modes of Online Compensation

The study presented in (Chapter 5) was conducted online with participants in the Global South. There is often tension concerning conducting online research, specifically with Global South populations (especially before the COVID 19 pandemic). Some of the reasons behind this are: 1) the affordability of the Internet in the Global South and 2) research with Global South populations must include onsite field studies in rural and remote areas. While some of this may hold, they need to be reevaluated for populations living in urban areas. These populations are in locations with internet connectivity and are familiar with and comfortable using the Internet. Urban populations are sometimes not considered potential participants of Global South research because they do not fit a specific narrative – even though they belong to the local context. These generalizations often limit the kinds of research that is done.

There were multiple ways of communicating with our participants during online research; we allowed our participants to choose between communicating using audio only or video. Additionally, we designed multiple alternatives for our screen share activity in the event that it was interrupted or unavailable. Our participants could print the map and verbally call out the connections they wanted to make. After which, the interviewer emailed the final map with connections to the participant and asked they to verify whether they agreed with all the connections.

Online participation also allows for diverse compensation forms – from using payment platforms like Venmo, Paypal, and/or gift cards. However, for this specific population, these payment modes were not appropriate for our participants at the time. We opted to use Mobile Money, a payment method familiar to all our participants. Many diaspora communities leverage remittance applications to send mobile money to their home communities. Therefore, we also used remittance applications to send mobile money as compensation to our participants. We used the monthly data rates from local telecommunications websites to determine the amount of compensation. Since we expected our participants to use online platforms to participate in the research, we wanted to be thoughtful and intentional about our compensation policy.

A.2 Expanding Study Design to Include Cultural Diversity & Disability

Low-effort adaptations of study methods included modifying content, e.g., swapping "waving a magic wand" for "if you had all the resources in the world." The initial phrasing may or may not have been familiar to our research population, and "magic" may have generated a debate that would have detracted from the discussion.

High-effort adaptations included critically thinking about how the traditional procedure of a specific research method may not be appropriate for specific research participants – for example, using the card sort method with blind and low-vision research participants. In this instance (Chapter 8), we designed a version of the card sort method that was accessible. We leveraged interactive buttons that played a specific audio recording when pressed. For this study, our participants included blind/low-vision participants and wheelchair users. During the study, we learned that not all the wheelchair users wanted to use the interactive buttons, so we made sure to have the printed options available to them as well.

A.3 Local & Online Recruitment

Participant recruitment, especially for diverse populations, takes commitment and intentionality. Researchers can benefit from including other stakeholders in their research – specifically collaborating with community organizations as experts. Collaborating with community organizations offers a unique opportunity for academic researchers to engage with the community and share their results with stakeholders who can leverage them. Sometimes, potential participants can be inundated with research requests in smaller communities. Therefore, it is on researchers to be aware of the demands they put on the populations.

Online recruitment services like Prolific can also be used to reach diverse populations. However, researchers need to investigate whether such services use the same definitions as researchers. For instance, when participants select vision disability, do they identify as color blind, blind/low-vision, or near-sighted? Some online recruitment services will allow researchers to reinforce specific criteria to ensure that researchers are collaborating with their intended participant audience. We added another layer of demographic questions in our study protocol. This allowed users to choose the disability category they belonged to. This data then complimented the demographic information from the online recruitment service.

Limitations of Exploratory Research

One of the main limitations of qualitative exploratory research is conversations around statistical significance. While statistical significance is not the goal of the qualitative research in this dissertation, the lack of this specific analysis should not detract from the value of the experiences shared in the qualitative interviews. As mentioned in the previous section, in some of the studies, we engaged with community organizers who self-identified as having a disability. These participants had rich insight as organizers who also experienced public transit with a disability. Later studies with larger populations reinforced findings from earlier populations with smaller sample sizes (Section 8.3.4).