Solar powered connected bus stop to improve the accessibility of bus travel for visually impaired people

Peter A. Hayton
Open Lab, School of Computing
Newcastle University
Newcastle Upon Tyne, UK
p.a.hayton@newcastle.ac.uk

Abstract— This paper explores the development of a prototype for a digital connected service to be embedded into UK bus stops, powered by solar energy and a Raspberry Pi to provide live sound-based real time bus departure information to improve the accessibility of bus stops for visually impaired people (VIP). In keeping with the principles of disability justice, the prototype is designed in such a way as to avoid the practice of "othering" by treating VIP as different and therefore will contain elements such as an LED floodlight and dot matrix display that will make the prototype usable for more groups and avoid being exclusionary to people with other disabilities such as the deaf or hard of hearing.

I. Introduction / Background

For visually impaired people (VIP), the process of finding a bus stop, waiting for and stopping the correct bus is a non-trivial task, with many VIP frequently requiring additional problem-solving skills to ask the right people for assistance and to know how to interact with bus drivers [1]. To address this challenge HCI scholars have explored solutions that enable VIP to more confidently access buses, by using an app on their smartphone [2-5]. However, smartphone-based systems are imperfect and can frequently exclude those with limited funds to purchase a smartphone [6] or can be at the detriment of older adults, who may need to learn to use this technology later in life [7]. Local authorities in the UK are experimenting with non-technical solutions to this problem, such as through initiatives like Bus Hailers [8], but these still require VIP to carry additional objects with them and is focused on VIP adapting to fit an inaccessible world, which is in opposition to the disability justice centric view, where the world should be made more accessible to people with disabilities [9, 10].For visually impaired people (VIP), the process of finding a bus stop, waiting for and stopping the correct bus is a non-trivial task, with many VIP frequently requiring additional problem-solving skills to ask the right people for assistance and to know how to interact with bus drivers [1]. To address this challenge HCI scholars have explored solutions that enable VIP to more confidently access buses, by using an app on their smartphone . However, smartphone-based systems are imperfect and can frequently exclude those with limited funds to purchase a smartphone [2] or can be at the detriment of older adults, who may need to learn to use this technology later in life [3]. Local authorities in the UK are experimenting with non-technical solutions to this problem, such as through initiatives like Bus Hailers [4], but these still require VIP to carry additional objects with them and is focused on VIP adapting to fit an inaccessible world, which is in opposition to the disability justice centric view, where the world should be made more accessible to people with disabilities [5, 6].

Aligned with the principles of disability justice [11], this research project is developing a prototype for an intelligent system, that can be embedded into a physical bus stop and powered by renewable energy sources such as solar. By embedding technology directly into the bus stop, this research aims to create more accessible bus journey experiences for people with disabilities, as it will provide additional information in an accessible format, but will not require the user to have a smartphone to use the service. For evaluation purposes, the prototype will adopt a Wizard of Oz (WoZ) design methodology [12] to explore how the features work in practice when used by people with disabilities, without investing in development while the feature set is being finalised.Aligned with the principles of disability justice [7], this research project is developing a prototype for an intelligent system, that can be embedded into a physical bus stop and powered by renewable energy sources such as solar. By embedding technology directly into the bus stop, this research aims to create more accessible bus journey experiences for people with disabilities, as it will provide additional information in an accessible format, but will not require the user to have a smartphone to use the service. For evaluation purposes, the prototype will adopt a Wizard of Oz (WoZ) design methodology [8] to explore how the features work in practice when used by people with disabilities, without investing in development while the feature set is being finalised.

This project is contextualised as part of a larger PhD research case study, which is exploring the role of data governance and stewardship in the development of intelligent systems that place improved accessibility to transportation as a primary driver to justify the rationale for their existence. The project involves collaboration with external organisations including the North East Combined Authority (NECA), who are interested in the potential of such services at addressing the challenges faced by disabled people in accessing bus services in the North East England region. This study begins with a co-creation stage, to include people with disabilities at all stages of developing the requirements, producing a WoZ prototype and, at later stages, is concerned with how such a system, after it has been evaluated by users with disabilities could be scaled up and deployed at scale across a dispersed region such as the North East.

This paper will explore the latter stages of this project, which seek to explore how the WoZ prototype can be developed into a functional system that could be deployed cost-effectively and at scale in bus stops across the North East England region. In so doing, outputs from this summer school will assist in generating measurable impact from this research study and provide a more accessible travel experience for bus passengers with disabilities.

II. Related work

Research has identified that urban spaces pose challenges for people with disabilities, where historically the very design of modern western cities such as London or Paris has been biased towards able-bodied people and presents access barriers for anyone with a disability [13]. Today, such ableist urban design practices have yet to be eradicated with more recent developments such as shared spaces and floating bus stops presenting access barriers, particularly for the visually impaired [14, 15]. HCi scholars have also observed how the built environment poses challenges, even when steps are taken to make it accessible for one group of disabled people [16] while other crowdsourcing projects such as Project Sidewalk have sought to use the assistance of a network of volunteers to identify obstacles [17] or verify the location of bus stops within a city [3].Research has identified that urban spaces pose challenges for people with disabilities, where historically the very design of modern western cities such as London or Paris has been biased towards able-bodied people and presents access barriers for anyone with a disability [9]. Today, such ableist urban design practices have yet to be eradicated with more recent developments such as shared spaces and floating bus stops presenting access barriers, particularly for the visually impaired [10, 11]. HCi scholars have also observed how the built environment poses challenges, even when steps are taken to make it accessible for one group of disabled people [12] while other crowdsourcing projects such as Project Sidewalk have sought to use the assistance of a network of volunteers to identify obstacles [13] or verify the location of bus stops within a city [14].

To address the immediate challenges of independent navigation for VIP, HCI scholars frequently resorted to the affordances of the smartphone to present solutionist approaches for VIP, that view the smartphone as an enabler for independent navigation. Broadly this includes challenges such as indoor navigation, where a smartphone's sensors can provide turn-by-turn directions [18], with private companies developing commercially available systems that use a similar underpinning of the smartphone being central to the navigation experience [19, 20]. With respect to public transportation and bus travel, the smartphone too has been adopted to provide VIP with confidence when traversing urban spaces, such as in the development and subsequent enhancement of the OneBusAway system [21], that uses smartphones to provide live bus departure times to VI passengers [22].To address the immediate challenges of independent navigation for VIP, HCI scholars frequently resorted to the affordances of the smartphone to present solutionist approaches for VIP, that view the smartphone as an enabler for independent navigation. Broadly this includes challenges such as indoor navigation, where a smartphone's sensors can provide turn-by-turn directions [15], with private companies developing commercially available systems that use a similar underpinning of the smartphone being central to the navigation experience [16, 17]. With respect to public transportation and bus travel, the smartphone too has been adopted to provide VIP with confidence when traversing urban spaces, such as in the development and subsequent enhancement of the OneBusAway system [18], that uses smartphones to provide live bus departure times to VI passengers [19].

While some works have explored the use of embedded technologies into bus stops, research projects such as BusMyFriend still require that the technology connects to a smartphone to initiate the interaction between the bus stop and the approaching vehicle [23]. Other physical prototype systems involving VIP have involved the use of virtual reality (VR) to simulate urban environments [24]. However, In keeping with the principles of disability justice [11], this research seeks to build on a real-world WoZ prototype, that has been tested by VIP and explore avenues whereby this prototype could be realised into a deployable product that could be rolled out in collaboration with relevant organisations or local authorities.While some works have explored the use of embedded technologies into bus stops, research projects such as BusMyFriend still require that the technology connects to a smartphone to initiate the interaction between the bus stop and the approaching vehicle [20]. Other physical prototype systems involving VIP have involved the use of virtual reality (VR) to simulate urban environments [21]. However, In keeping with the principles of disability justice [7], this research seeks to build on a real-world WoZ prototype, that has been tested by VIP and explore avenues whereby this prototype could be realised into a deployable product that could be rolled out in collaboration with relevant organisations or local authorities.

III. Connected bus stop prototype

Given the current stage of the project, requirements are still being determined through the co-creation process at the time of writing, but what follows is a representation of technologies that could be adopted to create a similar prototype, to improve the accessibility of bus stops for VIP using assumptions of the technologies and designs that might be adopted in the final prototype.

While the eventual prototype may harness a camera and the use of AI models for shape recognition etc. This prototype avoids using AI at this stage, steering away from complex ethical questions that will be explored elsewhere in this research and will instead focus on proving what is possible using non-AI powered technologies. To do this, a Raspberry

Pi will provide the processing backhaul and will be connected to the following components:

- Motion sensor
- Weatherproof speaker
- Dot matrix display used to provide real time information (RTI).
- An LED floodlight, to provide illumination to the bus stop for all passengers which will be triggered based on activity detected by the motion sensor.
- An LTE/5G antenna to connect to online live departure services.
- A separate button located within the bus stop, to be used to request that an approaching bus will stop at the bus stop. This will communicate a message to vehicles on the bus route, indicating that they are requested to stop at this bus stop.

It is also important to note that while the motion sensor only explicitly describes its functionality in relation to the LED floodlight, the motion sensor will also be used to trigger the dot matrix display and audio from the speaker, ensuring these components function only when there is a presence detected inside the bus stop's waiting area, thus reducing unnecessary energy usage which is important given the solar powered elements of this prototype.

The current early stage of the project means that a physical prototype has yet to be developed, but the following sketch outlines how this system may look, if built using off-the-shelf components available from retailers such as the Pi Hut. This will illustrate how this system may be attached to existing bus stops, though it is hoped more intricate aspects of this design process could be refined and developed during the summer school.

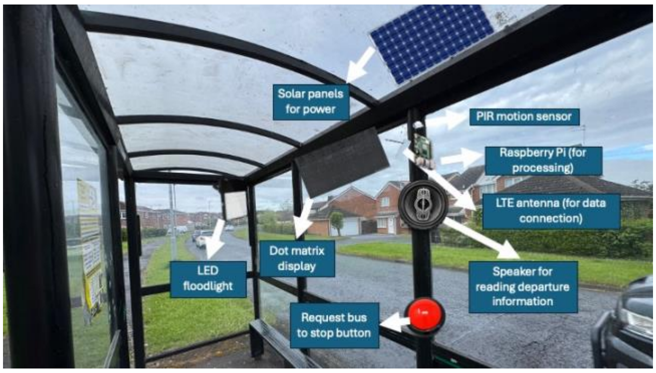

Fig. 1. A detailed diagram of all proposed components of the smart bus stop.

A. *Encasing the design*

Earlier research in this project identified from participants that vandalism is a key concern in the deployment of technology to improve the accessibility of public transport and the risk of vandalism impacted on their willingness to trust and use such systems. Therefore, it is important to ensure the casing around such a device is secured to protect against anti-social behaviour and is fully weatherproof, as many bus stops are exposed to the elements. Additionally, while the final components have yet to be decided, for the purposes of this prototype, using cost-effective components such as a Raspberry Pi provides a level of scalability for the system to prove that these systems can be deployed at scale across a wider bus network. Critically, they do so while maintaining a small physical footprint and avoid making accessibility a bespoke feature, that is required if this system is to embody the disability justice values it is built upon.

The following figure illustrates how components of the prototype will be encased to ensure their effective usage on a public bus stop. This will include the encasement of all key components, leaving exposed only the dot matrix display, stop request button and solar panels to provide power.

Fig. 2. A mock-up of the smart bus stop system, when delicate components have been covered by weatherproof materials.

IV. Responsible Innovation

This prototype will make use of solar power to provide all power to the system. In so doing, the system will build on suggestions from earlier work within this research project, where participants identified that accessibility should not come at the expense of environmental consideration. Additionally, the inclusion of solar power for this system means that traditional bus stop infrastructure, such as lights and real time departure boards, that previous discussions with relevant professionals have shown are usually powered from the National Grid will now migrate to solar power, thus enabling bus stops to simultaneously become more accessible and more environmentally friendly.

V. Author Bio

Peter Hayton is a visually impaired PhD student at Open Lab, Newcastle University. He is currently in the third year of a 5-year PhD programme of study that is combined with a part-time lecturing and teaching assistant job at Newcastle University.

He has a strong interest in accessibility and disability justice. His research is focused on how the increased automation of technologies in urban spaces are impacting on the mobility of visually impaired people, seeking to identify how designers can create intelligent systems that make public transport more accessible for people with a visual impairment. Previously, this has involved providing a methodological contribution with his paper entitled "The Blind Leading the Blind" that was published at the ASSETS '25 conference and explored how co-creation workshops could be made more accessible for visually impaired facilitators using physical materials [25]. He is also interested in exploring the accessibility of human-centred design methodologies for visually impaired researchers, such as himself, illustrated through his role in projects such as the Access InContext workshop at CHI '25 [26]. Peter has a BSc in Computer Science and has worked on digital accessibility, within the UK charity sector at a national level, before returning to academia to pursue his PhD[22]. He is also interested in exploring the accessibility of human-centred design methodologies for visually impaired researchers, such as himself, illustrated through his role in projects such as the Access InContext workshop at CHI '25 [23]. Peter has a BSc in Computer Science and has worked on digital accessibility, within the UK charity sector at a national level, before returning to academia to pursue his PhD.

VI. Acknowledgements

I would like to extend my thanks to my project supervisors Clara Crivellaro and Alexander Wilson at Open Lab, Newcastle University who have provided me with extensive guidance and support in shaping this research project. I would also like to thank the North East Combined Authority for their continued time and support getting involved in this research.

VII. References

[1] A. Crudden, K. Antonelli, and J. O'Mally, "Transportation Self-Efficacy and Social Problem-Solving of Persons Who Are Blind or Visually Impaired," *Journal of Social Work in Disability & Rehabilitation,* vol. 15, no. 1, pp. 52-61, 2016/01/02, 2016.

[2] J. Kostiainen, C. Erkut, and F. B. Piella, "Design of an audio-based mobile journey planner application," in Proceedings of the 15th International Academic MindTrek Conference: Envisioning Future Media Environments, Tampere, Finland, 2011, pp. 107–113.

[3] K. Hara, S. Azenkot, M. Campbell, C. L. Bennett, V. Le, S. Pannella, R. Moore, K. Minckler, R. H. Ng, and J. 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.,* vol. 6, no. 2, pp. Article 5, 2015.

[4] N. Aziz, T. Stockman, and R. Stewart, "Planning Your Journey in Audio: Design and Evaluation of Auditory Route Overviews," *ACM Trans. Access. Comput.,* vol. 15, no. 4, pp. Article 28, 2022.

[5] M. Campbell, C. Bennett, C. Bonnar, and A. 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, Rochester, New York, USA, 2014, pp. 11–18.

[6] S. M. Khan, M. S. Salek, V. Harris, G. Comert, E. Morris, and M. Chowdhury, "Autonomous Vehicles for All?," *ACM J. Auton. Transport. Syst.*, 2023.

[7] I. Figueira, Y. Cha, J. Zhu, and S. M. Branham, "Smartphone Stories: Experiences of Blind and Low Vision Older Adults in Acquiring a Smartphone," in Companion Publication of the 2023 ACM Designing Interactive Systems Conference, Pittsburgh, PA, USA, 2023, pp. 156–159.

[8] Henshaws. "The bus hailer: Making bus travel easier," 12 May, 2026; https://www.henshaws.org.uk/hints-and-tips/the-bus-hailer-making-bus-travel-easier/.

[9] N. Kane, R. Liebeskind, T. Hunt, Victoria, and h. i. Albert Museum, *Design and disability : 10 tales of accessible design*, London: V&A Publishing, 2025.

[10] L. Jackson., A. Haagaard., and R. Williams. "Disability Dongle," 23 May 2025, 2025; https://blog.castac.org/2022/04/disability-dongle/.

[11] P. Berne, A. L. Morales, and D. Langstaff, "Ten Principles of Disability Justice," *Women's studies quarterly,* vol. 46, no. 1/2, pp. 227-230, 2018.

[12] N. Dahlbäck, A. Jönsson, and L. Ahrenberg, "Wizard of Oz studies: why and how," in Proceedings of the 1st international conference on Intelligent user interfaces, Orlando, Florida, USA, 1993, pp. 193–200.

[13] D. Gissen, "THE URBANIZATION OF DISABILITY," *The Architecture of Disability*, Buildings, Cities, and Landscapes beyond Access, pp. 45-72: University of Minnesota Press, 2022.

[14] RNIB, All aboard? Navigating bus travel with sight loss, London, England, 2025.

[15] L. Cushley, N. Galway, and T. Peto, "The unseen barriers of the built environment: navigation for people with visual impairment," *Town Planning Review,* vol. 94, no. 1, pp. 11-35, 2023.

[16] S. Rodger, D. Jackson, J. Vines, J. McLaughlin, and P. Wright, "JourneyCam: Exploring Experiences of Accessibility and Mobility among Powered Wheelchair Users through Video and Data," in Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems, Glasgow, Scotland Uk, 2019, pp. Paper 630.

[17] M. Saha, M. Saugstad, H. T. Maddali, A. Zeng, R. Holland, S. Bower, A. Dash, S. Chen, A. Li, K. Hara, and J. 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, Glasgow, Scotland Uk, 2019, pp. Paper 62.

[18] D. Ahmetovic, C. Gleason, C. Ruan, K. Kitani, H. Takagi, and C. Asakawa, "NavCog: a navigational cognitive assistant for the blind," in Proceedings of the 18th International Conference on Human-Computer Interaction with Mobile Devices and Services, Florence, Italy, 2016, pp. 90–99.

[19] Goodmaps. "Mapping the Future with Indoor Navigation," 24 June 2025, 2025; https://goodmaps.com.

[20] NaviLens. "Discover NaviLens," 24 June 2025, 2025; https://www.navilens.com/en/#main-section.

[21] B. Ferris, K. Watkins, and A. Borning, "OneBusAway: results from providing real-time arrival information for public transit," in Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Atlanta, Georgia, USA, 2010, pp. 1807–1816.

[22] S. Azenkot, and E. Fortuna, "Improving public transit usability for blind and deaf-blind people by connecting a braille display to a smartphone," in Proceedings of the 12th international ACM SIGACCESS conference on Computers and accessibility, Orlando, Florida, USA, 2010, pp. 317–318.

[23] C. Yu, Y. Li, T.-Y. Huang, W.-A. Hsieh, S.-Y. Lee, I.-H. Yeh, G. K. Lin, N.-H. Yu, H.-H. Tang, and Y.-J. Chang, "BusMyFriend: Designing a Bus Reservation Service for People with Visual Impairments in Taipei," in Companion Publication of the 2020 ACM Designing Interactive Systems Conference, Eindhoven, Netherlands, 2020, pp. 91–96.

[24] Y. Zhao, C. L. Bennett, H. Benko, E. Cutrell, C. Holz, M. R. Morris, and M. Sinclair, "Enabling People with Visual Impairments to Navigate Virtual Reality with a Haptic and Auditory Cane Simulation," in Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems, Montreal QC, Canada, 2018, pp. Paper 116.

[25] P. A. Hayton, A. Wilson, B. Morris, J. Dent, and C. Crivellaro, "The Blind Leading the Blind: Designing a Co-Creation Workshop for Visually Impaired and Sighted Participants by a Visually Impaired Researcher," in Proceedings of the 27th International ACM SIGACCESS Conference on Computers and Accessibility, 2025, pp. Article 61.

[26] P. Piedade, P. A. Hayton, C. L. Bennett, A. R. L. Carter, C. Crivellaro, A. Dix, J. McGowan, K. Spiel, M. Sturdee, G. W. Tigwell, and H. Nicolau, "Access InContext: Futuring Accessible Prototyping Tools and Methods," in Proceedings of the Extended Abstracts of the CHI Conference on Human Factors in Computing Systems, 2025, pp. Article 766