Gaps in the Maps? Determining if Tactile Maps Strengthen Wayfinding Accessibility at the MBTA

A focused study on low vision and blind subway riders.

A thesis submitted by

Diya Wheeler

in partial fulfillment for the requirements of the degree of

Master of Science

in

Environmental Policy and Planning

Tufts University, August 2024

Advisor: Sumeeta Srinivasan

Reader: Mary Davis

Abstract

With 1 in 4 Americans reporting a disability and about 5% of Massachusetts residents experiencing vision loss, the need for inclusive planning in the state is urgent (CDC, 2024). Resources for visual impairments are primarily focused in the Greater Boston area, drawing individuals with low vision or blind conditions towards the city. Best practices in equitable transportation planning emphasize that systems should promote autonomous travel for riders by providing consistent fixed-route options, such as the subway. Therefore, it is crucial for transit agencies to ensure access to these options for all riders when remembering that typically, individuals with visual impairments do not drive.

When it comes to the subway, *wayfinding* (navigation) within station terminals is listed in the literature as a priority concern for transit users who are low vision or blind. At the Massachusetts Bay Transportation Authority (MBTA), a common rider complaint is that the stations are difficult to navigate. Station layout maps don't exist at the MBTA. Expert consultants in the field of low vision cite the development of map skills as crucial for developing independence in populations with visual impairments.

This thesis investigates the accessibility of navigating the MBTA subway system for low vision and blind riders, with a focus on supporting signage improvements and rider autonomy through tactile mapping initiatives. A qualitative five-methods analysis aimed to assess the existing accessibility measures at the agency, identify shortcomings, and propose policy recommendations. It was concluded that a holistic approach to accessible planning is most effective. The inclusion of tactile maps as wayfinding guidance at the MBTA provides all riders, not just those with low vision or blind conditions, with a resource strengthened by sensory connections to practice orientation and navigation in subway station terminals.

Acknowledgements

This research would not have been possible without the strength of my community, both within and beyond Tufts UEP. I have a few people I'd like to appreciate for their support in this journey.

First, Sumeeta. You've been such a supporter in my academic endeavors, allowing me the freedom to explore assignments through projects of my own design, this thesis being a prime example. Thank you so much for all your advice and reason, for keeping the research on track with requirements, for providing me with a major source of encouragement, and for trusting me. Your flexibility in accommodating students is a sign of your dedication as an educator, and not a trait I take for granted. This thesis was a significant test of responsibility. I'm proud to have completed it and truly grateful for your advising and mentorship throughout the process.

Mary, you have been nothing but a hype man for this project. Thank you! Your passion for this thesis dispelled imposter syndrome at every turn, providing me with some much-needed pep in my step when things got slow. Your support, whether helping me outline next steps or linking me to necessary resources, is so appreciated. This thesis holds legitimacy because of you and Sumeeta's guidance.

Sela, Allyson, Niels, Eric, Laura, and Jennifer—your time and expertise were invaluable. Thank you for your patience, and for such great conversations. Laura and Jennifer, your excitement for the project was such an encouragement. Niels, sharing the tactile OSM package has been a huge resource. And to Eric: I still can't believe you printed those maps for me. You ROCK!! I would like to extend my gratitude to my mentors Jeff and Katie, who allowed for flexibility in my internship to prioritize this thesis. Katie, thank you again for connecting me to Esri Nederland. That was a turning point in the research that completely reshaped the outcome of this project.

To my friends: It's been a privilege to have learned alongside and from you these past two years. You motivate me to do better. Thank you for your wisdom, for sharing resources, for sharing food, for listening to me complain (and for joining in), for all your encouragement, your curiosity, our laughter, the basketball games, the endless pomodoro sessions, and for all of the daylists. Couldn't have done it without you guys!

And to my family…your belief in me has built a foundation of confidence in my life. I want to thank my mom and dad for their endless support, unconditional love, and for being there for me in times of peace and always through those moments more unstable. I love you! From my achievements to my day-to-day outlook on life, everything reflects the values and teachings you've instilled in me. Words can't capture it. I am sincerely thankful.

Table of Contents

Glossary

Accessibility: ***(****In the context of transportation planning****)*** the availability and ease of access to mobile or transit opportunities

Accessible: Designed or adapted to be usable by people with various disabilities

Americans with Disabilities Act (ADA): A civil rights law in the United States prohibiting discrimination against individuals with disabilities in many public and private spheres, such as transportation

Blind: ***(****The legal definition in Massachusetts****)*** vision with a correction of 20/200 or less in the better eye or a peripheral field of ten degrees or less, regardless of vision clarity

Braille: A tactile writing system for those with visual impairments

Detectable Warnings: A distinctive domed surface pattern designed to be sensed by cane or by foot to alert those with visual impairments of hazards or drop-offs

Disability: ***(****The legal definition of disability in the ADA****)*** a physical or mental impairment that limits one or more major life activity

Fixed-Route Transportation System: A public transit network defined by predefined routes, scheduled times, and designated stops

Geographic Information Systems (GIS): Mapping software designed to capture, analyze, and display spatial data

Greater Boston: The metropolitan area of the city of Boston, Massachusetts, extending from Rhode Island through Massachusetts and into southern New Hampshire

Low Vision: A permanent visual impairment that cannot be corrected by glasses, contact lenses, surgery, or other standard treatments

Map Skills: The ability to read and interpret maps to navigate and find information

MBTA: The Massachusetts Bay Transportation Authority is the regional transit planning agency for the Greater Boston area

O&M: Orientation and mobility is a set of navigation skills that allow for safe and independent travel for populations who are blind or with low vision

Route Navigation: The process of planning a route and following it to an end destination

Tactile/Tactual: Connected to the sense of touch; at times, designed to be perceived by touch

Tactile-Braille Signage: A type of signage that uses Braille and other tactile elements to convey information by touch to low vision and blind readers

Wayfinding: The process of orienting oneself in an environment using personal skills and purposefully navigating through to a specific destination

White Cane: A navigation aid specifically designed to assist low vision and blind populations

List of Tables

List of Figures

Chapter 1. Introduction and Research Questions

More than 61 million Americans have some type of disability: 1 in 4 people (CDC, 2024). These numbers increase in populations below the federal poverty line, women, and people over 65 years of age (CDC, 2024). By 2030, the number of Americans in that age bracket will rise, nearing a quarter of the population (Mather, et al., 2016).

In the field of planning, prioritizing our most vulnerable populations is key for the sustained safety, convenience, and long-term use of our built environment (DiPetrillo, 2016). The U.S. Department of Transportation identifies disability across three interpretations: people with mobility impairments, people with sensory disabilities (such as hearing or vision loss), and those with cognitive disabilities (USDOT, 2021). As of 2022, an estimated 46 million Americans over the age of 18 experienced vision loss (American Foundation for the Blind, 2024). In Massachusetts, where about 26% of the population has a disability, 5% report having a visual impairment (CDC, 2024). That's over 350,000 residents. Despite these high numbers, the infrastructure of the state has yet to fully reflect the necessary accommodations for populations who are blind or have low vision.

The Massachusetts Bay Transportation Authority, or MBTA, is the regional transportation agency for the Greater Boston area with a goal to promote complete travel, autonomous and assistive, for riders of all abilities. Many of the low vision and blind resources in Massachusetts are concentrated in the area, such as the New England College of Optometry, the Carroll Center for the Blind, and the Bay State Council of the Blind, drawing people with visual impairments into the city from neighboring regions. When thinking about current accessibility initiatives at the agency, improvements at key subway terminals include but are not limited to: providing elevator access, accessible entrances, detectable warnings, closing the platform gaps, and restroom upgrades (Brelsford et al., 2023). Station navigation, or wayfinding, is recognized as a priority need and the agency is currently testing pilot projects to promote accessible navigation (Brelsford et al., 2023).

Wayfinding in transportation terminals is one of the biggest barriers faced by populations with visual impairments when using public transit (Mass Transit, 1991; Rowell and Ungar, 2005). Common accessibility measures employed to mitigate this issue include signage in Braille and with raised characters, auditory assistance, and tactile or detectable considerations such as detectable platform warnings, textured tiles for guidance, and other architectural or design cues (DiPetrillo, 2016). Tactile maps are an assistive device not commonly used that conveys spatial data through touch and can assist in closing the gap in wayfinding accessibility for low vision and blind populations.

This thesis aims to explore if tactile maps are a solution in strengthening wayfinding accessibility at the MBTA, with a focus on low vision and blind subway ridership. The research questions in this thesis are as follows:

"At the MBTA…

1) *…how are the needs of blind and low vision subway riders met, and where are they unfulfilled?"*
2) *…what future actions regarding blind and low vision rider accessibility are being considered, and which aspects are not being addressed?"*
3) *…how can a tactile map meet the needs of low vision riders?"*

Chapter 2. Literature Review

This literature review includes eight sections. Beginning with definitions of accessibility and mobility in modern transportation planning, the review continues to outline selected best practices relevant to the MBTA's efforts with regards to low vision and blind subway terminal accessibility. Existing conditions at the agency are then discussed, with solutions such as a tactile map wrapping up the conversation to set up for the discussion.

Introduction

When it comes to transportation planning, prioritizing our most vulnerable populations ensures infrastructure accessibility for all riders, improving the health and livelihood of the community (Frye, 2019; DiPetrillo et al., 2016). A key perspective for planners to maintain is the understanding that disability is more than just a single perspective, but an "an everyday reality" for riders (Jacobs, 2009). As there is not a one-size-fits-all methodology to inclusive transit planning due to the variety of and specificity of rider conditions, a holistic approach to policy and initiatives must be adopted to ensure successful accessibility (Jacobs, 2009; DiPetrillo et al., 2016).

In transportation planning and policy, there is a bit of a gray area when it comes to definitions of *accessibility*. Often used in place of *mobility*, which is the physical movement of riders measured by trip number, distance, and speed, *accessibility* can be defined as the ease of access of which mobile opportunities exist (Litman, 2007). Currently in the field, system evaluation metrics are shifting from mobility-oriented performance measures, such as travel speed and vehicle operating costs, to an accessibility-oriented model which considers the time, ability, and money necessary for opportunity access (Litman, 2007). Measuring accessibility can be difficult when considering the scale of inclusivity, and the fact that different methods can reflect a variety of results and impacts, such as walkability scores in comparison to a road network analysis (Litman, 2007).

Ideally, a region's accessible transportation system will support complete trip travel, both autonomous and assistive, for all riders regardless of ability (DiPetrillo et al., 2016; NADTC, n.d.; USDOT, 2021). The concept of the complete trip focuses on point-to-point accessibility for a rider and considers the barriers to mobility not only when traveling within a station, but also those encountered on the journey such as poorly maintained sidewalks, complicated traffic intersections, and steep grades in slope (DiPetrillo et al., 2016; USDOT, 2021). Assistive travel comes in the form of paratransit: individual or group-based transportation services that offer more private and flexible door-to-door travel options. The increase of driver responsibility to accommodate a diverse set of individual needs and the traffic unpredictability that comes with paratransit travel causes the choice to be one filled with uncertainty.

In comparison, autonomous travel within a system is most effective when a rider has access to fixed-route systems, such as the bus, rail, subway, or ferry. (DiPetrillo et al., 2016). Cost-effective, sustainable, and with less liability than paratransit, accessible fixed routes help to dismantle barriers to independent travel, such as fear, anxiety, and traffic unpredictability, and should invite riders of all abilities to participate (DiPetrillo et al., 2016). As follows, the increased use of public transportation services by those with disabilities leads to increased integration in society. Transportation access is a means for people to learn from each other and their community, and to travel between work, play, and school (DiPetrillo et al., 2016). A lack of access to transportation can keep populations in poverty and in poor health (Frye, 2019). It prevents society from mingling and upholds stigma around disability by isolating community members: taking away their autonomy, keeping them distanced from work, and preventing them from contributing to society and the local economy (Frye, 2019; DiPetrillo et al., 2016).

What follows is a consolidated review of selected best practices for prioritizing accessibility in transit developments.

Communication Builds Trust

When designing and implementing new transit infrastructure, information regarding the project must be easily and consistently available for public access through every step of the process to establish and maintain trust with the local community (NADTC, 2021). Without intentional communication, awareness around transit development falls, fostering a disconnect between the project and its target populations and potentially leaving people feeling uninterested, anxious, or fearful of the new change (Litman, 2007). This lack of trust is a barrier to communication and overall project success as it prevents people with disabilities from being able to communicate their specific needs (NADTC, 2021).

Trust Creates a Space

Agencies should never make assumptions about needs and must consult with vulnerable populations as part of protocol when considering developments for people with disabilities (Frye, 2019). Engaging partner organizations and community groups that serve the target population(s) is necessary to ensure that the development is in line with the community by providing a space for collaboration and accurately identifying needs (DiPetrillo et al., 2016; NADTC, 2021; USDOT, 2021).

Along with positive stakeholder relationships, there can be strained relations to maintain. Opposition to new developments will occur, so being proactive and establishing a relationship with stakeholder groups that may be predicted to oppose transit development assists in keeping an agency ahead of negative feedback (DiPetrillo et al., 2016).

Consistency Upholds Trust

Coordination

A coordinator, or coordinators, can be established to maintain clear communication and to consolidate feedback (Jacobs, 2009). The familiar face of a coordinator also works to build trust between target populations and the agency, as people may be more willing to speak to a person or entity that they know and trust (Jacobs, 2009; NADTC, 2021).

Outside of the agency's scope of work, coordination with other local transit and municipal authorities that maintain the built environment, such as sidewalks, roads, and icy conditions, are essential to successful implementation and to promote complete trip travel for riders (DiPetrillo et al., 2016).

Self-Checks

Self-assessments and evaluations throughout the process of implementing a new development keeps the agency on track with the goals of the project (DiPetrillo et al., 2016). Self-evaluation measures can be created in collaboration with partner organizations, or internally; creating a system to collect grievances and revisiting these comments is one way to keep community and target population needs as a priority (Jacobs, 2009). An initial evaluation establishes a baseline of performance measures (DiPetrillo et. al, 2016).

Universal Design and Complete Trip Travel

Universal Design is a concept in transportation planning that prioritizes meeting all rider needs and is defined by "easy and intuitive use, without causing confusion or anxiety…minimal physical effort…[and] sufficient space for all," (Frye, 2019). A rider's journey begins not at a transportation station, but the minute they step foot outside their front door. As discussed, maintaining elements of the complete trip may fall outside of a transportation agency's jurisdiction, but these conditions (poor roads, uneven surfaces, quality of sidewalks) present as barriers to mobility if not addressed (Frye, 2019). Creative solutions and the pursuit of innovation outside of traditional schemas is crucial to accessible change (USDOT, 2021).

Existing Conditions at the MBTA

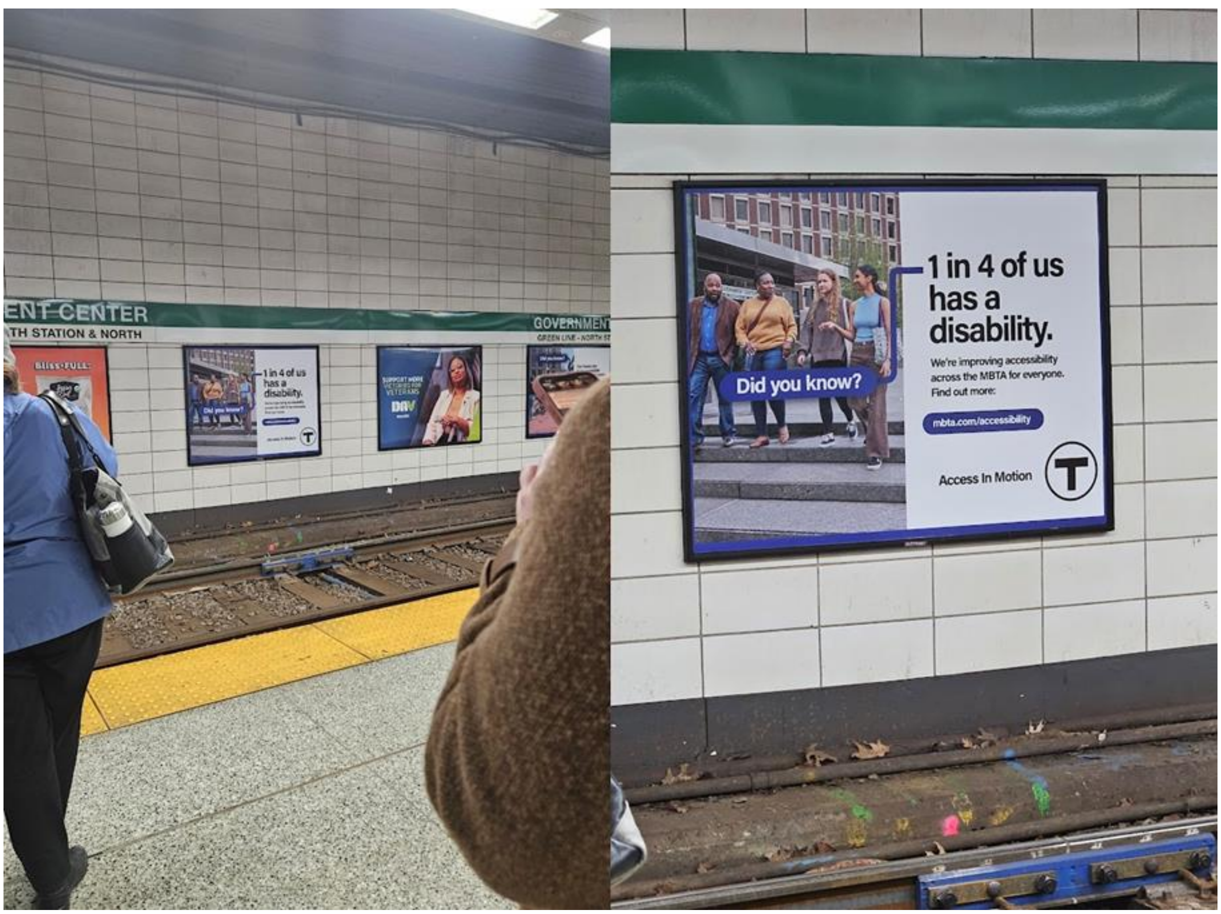

Figure 2.1: Signage from the MBTA's Access in Motion campaign, February 2024

When considering the transit system, the MBTA is in the process of developing and launching initiatives outlined in their System-Wide Accessibility (SWA) campaign. General accessibility efforts regarding automatic doors, elevator access, raised and tactile platforms, hands-free tap-ins, urine detection, and wayfinding communications are a priority (Brelsford et al., 2023). As part of the SWA, the agency has launched an Access in Motion campaign (Figure 2.1) which aims to bring awareness to new accessibility initiatives and disability at the MBTA (Brelsford et. al, 2023). Other accessibility considerations employed by the agency are an integrated Mobility Center downtown (which offers individual and group travel training) and the Riders Transportation Access Group (RTAG), an autonomous feedback group with a focus on disability that meets regularly with MBTA representatives. This information is available to the public through the MBTA website. The author sat in on the December 2023 RTAG meeting to learn the current issues cited to be the top accessibility concerns by riders at the MBTA (below).

1) *A lack of safe and reliable access to bus stops and shelters (illegally parked vehicles, snow and ice, bicycle lanes)*
2) *Platform gaps on the Orange Line*
3) *Accessibility during diversions (route closures, delays, third-party drivers and shuttle issues)*
4) *Lack of accessible real-time information on vehicles*

Wayfinding specifically was reported in the November 2023 SWA report to be currently non-compliant with internal regulations, as well as those outlined in the 2010 ADA Standards for Accessible Design and the MAAB 521 CMR. The Wayfinding and Station Improvements project is working on replacing signage at the top ten stations in the MBTA rapid transit system: Park Street, Downtown Crossing, North Station, State, Haymarket, Chinatown, South Station, Back

Bay, Malden, and Harvard. Digital displays are part of this improvement, and the MBTA worked with design firm BIA.studio to develop unified signage across all stations that includes Braille (Bertaux + Iwicks, 2015).

When it comes to low vision and blind ridership, direct initiatives include Braille and auditory assistance (Brelsford et al., 2023). These two accommodations can still fall short when it comes to orientation and mobility (O&M), specifically in regard to their usefulness in conveying spatial information. Low vision populations have found the combination of Braille, auditory, and tactile resources to work best together when it comes to wayfinding (Papadopoulos et al., 2014). Tactile maps are physical maps that display spatial information to a user; a variety of methods can be employed, including but not limited to printing on swell paper, thermoforming, embossing, or using a 3D printer. Other initiatives to strengthen wayfinding include architectural cues such as landmarks, specific choices in built design, and color.

Tactile Maps as a Solution

Tactile maps are not commonly employed because of the effort, resources, and money required for production (Baldwin and Higgins, 2022). Additionally, user needs vary on an individual level due to the wide scope of vision loss; for example, some may have been born with eye conditions, while others face macular degeneration in older age (Erin, 2009). Therefore, individuals have differing experiences with both assistive devices and the development of map skills (Erin, 2009). These specific needs have also led to a lack of a unified methodology when creating tactile maps, though best practice is to follow the logic of traditional cartography (Luxton et al., 1994; Lobben, 2015). However, older populations with low vision cite that the development of map skills from an early age as a key step in creating and maintaining autonomy for disability related to vision, especially when considering that mental mapping takes longer when using a cane or guide dog over tactile devices (Erin, 2009; Feucht and Holmgren, 2018).

Map portability is cited in the literature as an important characteristic when designing a tactile map, so that users may understand the map without the pressure of time constraints. Additionally, practicing at home or along route navigation with a handheld assistive device as a reference can ease some of the anxiety present when wayfinding with low vision (Rowell and Ungar, 2005). A study exploring the relationship between tactile mapping and natural hazards found that a map series that overlays flood zones provided users with a greater understanding of map-oriented risk assessment (Cole and Robinson, 2023). Outside of disability, tactile resources help everyone. Sensory connections stimulate the brain and improve memory, adding a “physical dimension to the cognitive process,” and bridging the gap between theory and a tangible experience (Main, 2024).

Chapter 3. Methods

This thesis drew on four main methods: a literature review, a policy analysis, observational studies, and interviews. This mixed-methods approach worked together to answer the research questions and understand how the MBTA currently services riders with disabilities related to vision, as outlined in Table 3.1. A tactile map was developed as a proof-of-concept for the Medford/Tufts station in support of the argument that more initiatives aimed at the low vision or blind rider experience be incorporated into ongoing accessibility efforts at the agency. The process of creating these tactile maps provided insight into the effort required to develop such tools.

Method	Data	Research Question(s) MBTA: Low Vision and Blind Subway Riders
Literature Review	• Best practices in accessible transportation planning • Existing conditions for low vision and blind riders at the MBTA • The argument for tactile map	• How are needs met and where are they unfulfilled? • How can a tactile map meet those needs?
Policy Analysis	• Policy definitions of disability in Massachusetts • Counts of considerations specifically and generally relevant to low vision and blind subway wayfinding	• How are needs met and where are they unfulfilled?

Observational Studies	• Perceived use of assistive devices at the Charles/MGH station	• How are needs met and where are they unfulfilled?
Interviews	• Insights into MBTA accessibility efforts not available on public records • Expert advice from O&M instructors in the field of blind and low vision • Expert advice from tactile map developers • Discussions about the MBTA signage unification project	• How are needs met and where are they unfulfilled? • What future accessible actions are and are not being considered by the agency? • How can a tactile map meet those needs?
Tactile Maps	• Firsthand experience in creating tactile maps, from conception to development (time, effort, resources) • Methodology draws from the literature review and interviewee comments	• How can a tactile map meet those needs?

Table 3.1: Justification of methods

Literature Review

The literature review began with an introduction to the concept of accessibility in the field of transportation planning. Selected best practices compiled from multiple sources were synthesized and presented as a framework for the Massachusetts Bay Transportation Authority

(MBTA) in the context of subway terminal wayfinding. Existing conditions at the MBTA are reviewed, with a specific look at low vision and blind ridership. Ongoing initiatives and other solutions, such as a tactile map, were brought into the conversation to set up for the discussion and conclusion.

The literature review used academic databases such as Academic Search Premier, Google Scholar, and internal Tufts resources through the Tisch library to source peer-reviewed content.

Policy Review and Content Analysis

The following two policies were reviewed and coded to understand how much of a priority vision loss is in the context of transit planning in the state of Massachusetts.

1) The 2010 Americans with Disabilities Act (ADA) Standards for Accessible Design

2) The Massachusetts Architectural Access Board Code of Massachusetts Regulations Title 521 (MAAB 521 CMR)

Chapters and sections of the policies will be coded using the schema described in Figure 3.1.

Figure 3.1: Coding schema for policy analysis

Observational Study

The author conducted two observational studies at the Charles/MGH station to see if riders needing assistance frequent the station, and if those riders were perceived to have low vision. Identifying these riders was a subjective process. Low vision ridership was determined *specifically* by the use of white canes (canes designed to guide those with low vision), with *general* assisted ridership identified by walking canes, wheelchairs, walkers, crutches, braces, guide dogs, or having assistance from another party.

> **Visible assistive devices to identify: white canes, walking canes, walkers, wheelchairs, crutches and braces, guide dogs, in-person assistance.**

The author visited the station twice during the middle of the day for two-hour periods and in addition, made note of observed riders using assistance outside of the official observational studies.

Interviews

Interviews with MBTA representatives provided context of both existing and future initiatives from the agency regarding accessibility, with a discussion on specific efforts related to vision. Expert consultants in the field of orientation & mobility (O&M) were interviewed from the Massachusetts Commission for the Blind (MCB) and the Perkins School for the Blind (Perkins), both of whom work with low vision and blind populations. These conversations gave insight into the transit habits and needs of these populations, and if those needs are currently met at the MBTA. Guidance on tactile signage and the development of the tactile maps were gained through interviews with representatives from Esri Nederland and BIA.studio. The studio also developed a unified signage system for the MBTA. See Table 3.2 for justification of organizations interviewed.

The comments from all five interviews were codified, organized thematically, and developed into a narrative to answer the research questions. Specific interview questions are included in the Appendix. Interviews were conducted in-person and using Zoom.

Organization	Who?	Why?	Topic
Massachusetts Bay Transit Authority (MBTA)	Laura Brelsford, Assistant General Manager of the Department of System-Wide Accessibility (SWA) at the MBTA. Jennifer Ross, Deputy Director of Customer Engagement at the MBTA.	Have insight into existing and future MBTA efforts, and how a tactile map could be integrated into the MBTA system.	MBTA
Perkins School for the Blind	Eric Jerman, Orientation and Mobility (O&M) Instructor at Perkins School for the Blind.	Insights into tactile map usage and transit habits of local low-vision and blind populations.	Expert Consultant
Massachusetts Commission for the Blind	Allyson Bull, Director of Orientation and Mobility at the Massachusetts Commission for the Blind.	May offer commentary on popularity/use of tactile maps. Might have insight into what other assistive devices/combinations of assistance work best for low vision populations. Transit habits of local low vision and blind populations.	Expert Consultant
Esri Nederland	Niels van der Vaart,	Can speak to the	Tactile Maps

	Manager of Product Management and Innovation at Esri Nederland.	company's process of developing tactile maps.	
BIA.studio	Sela Bailey, principal architect at BIA.studio who worked on the MBTA signage unification project.	Can speak to the necessary elements of the station layout to be included in the tactile map. Details regarding the MBTA signage unification project.	Tactile Maps, MBTA

Table 3.2: Organizations interviewed

Tactile Map

As a supplement to the research, tactile map prototypes for the Medford/Tufts station were developed as proof-of-concepts. Legitimate tactile maps must be developed in tandem with feedback from low vision focus groups. However, the timeline of this thesis did not allow for the author to establish trust and facilitate an intentional environment for feedback with a focus group. This limitation is discussed in Chapter 8.

The purpose of developing these tactile map prototypes was to understand the process behind creating a functional tactile assistive device for public use. Creating these prototypes provided the author with experience and familiarity with the production of tactile maps.

A set of route navigation maps were created using the tool TinkerCAD and 3D printed. Prusa 3D printers were available at the Tufts Nolop makerspace in Tufts University's Medford campus and at the Cambridge HIVE makerspace found at the Cambridge Public Library's Main

Branch location. A series of neighborhood orientation maps were created using ArcGIS Pro software and a tactile open street map (OSM) symbology package shared by the interviewee from Esri Nederland. These maps were printed using a Picture in a Flash (PiaF) thermoform printer available at the Perkins School for the Blind.

Chapter 4. Policy Analysis

Purpose

The 2010 ADA Standards for Accessible Design, the federal code, and the Massachusetts Architectural Access Board Code of Massachusetts Regulations Title 521, the local code, were both analyzed to find the section count and percentage of the policy relevant to low vision and blind wayfinding in subway terminals. After an initial review, *relevancy* was first defined in policy sections by the presence of the following terms or concepts: tactile, tactual, detectable, low vision, Braille, reach clearances (when thinking about touch), knee and toe clearances (when thinking about assistive devices, such as a cane), and handrails (which offer support and route guidance).

Relevancy was then determined to be across two categories: general relevancy, or general accessibility considerations related to *wayfinding* in subway terminals, and specific relevancy, sections specific to the *low vision and blind rider experience* in subway terminals.

> Relevant key concepts: tactile, tactual, detectable, low vision, Braille, reach clearances, knee and toe clearances, handrails.

ADA

The 2010 ADA Standards of Accessible Design's ten chapters span a total of 471 sections, ~11% of which generally relate to accessible subway terminal wayfinding and about ~5% relating to the low vision and blind rider experience specifically. Figure 4.1 describes the percentage and section count of the policy across *not applicable*, *general*, and *specific* designations. Disability was not given a formal definition in these standards but was clarified to mean the inclusion of wheelchair accessibility standards, hearing loss, or vision loss.

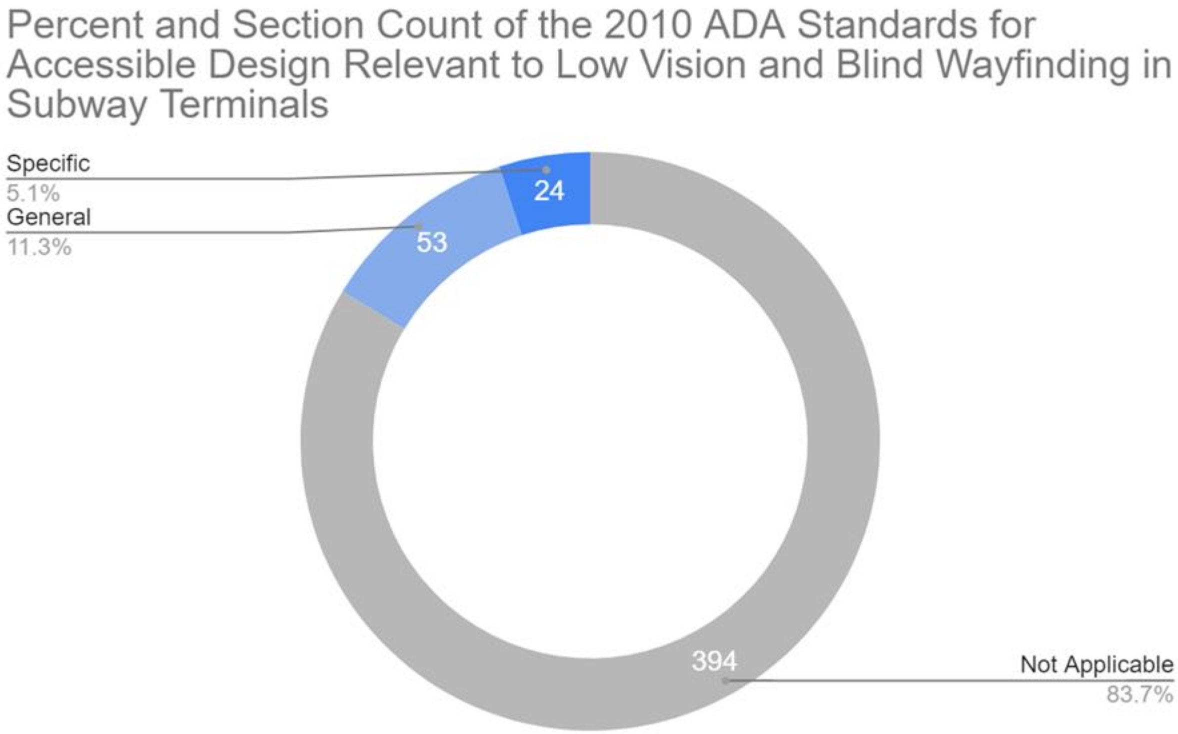

Figure 4.1: Percentage breakdown of the 2010 ADA Standards for Accessible Design in relation to the low vision and blind subway terminal wayfinding experience

MAAB 521 CMR

The MAAB 521 CMR contains 47 chapters. Chapters 42 through 47, covering Group 1 and Group 2 bathrooms, kitchens, and bedrooms, were not included in this analysis as they were designated *not applicable* to subway terminal wayfinding. The remaining 41 chapters contain a total of 415 sections; almost 25% of these were designated as *general* and ~10% were identified to be *specific*. This distribution is illustrated in Figure 3.2. Disability was not formally defined in this policy. Accessible was defined as to be both physically and communicatively accessible, unless otherwise noted.

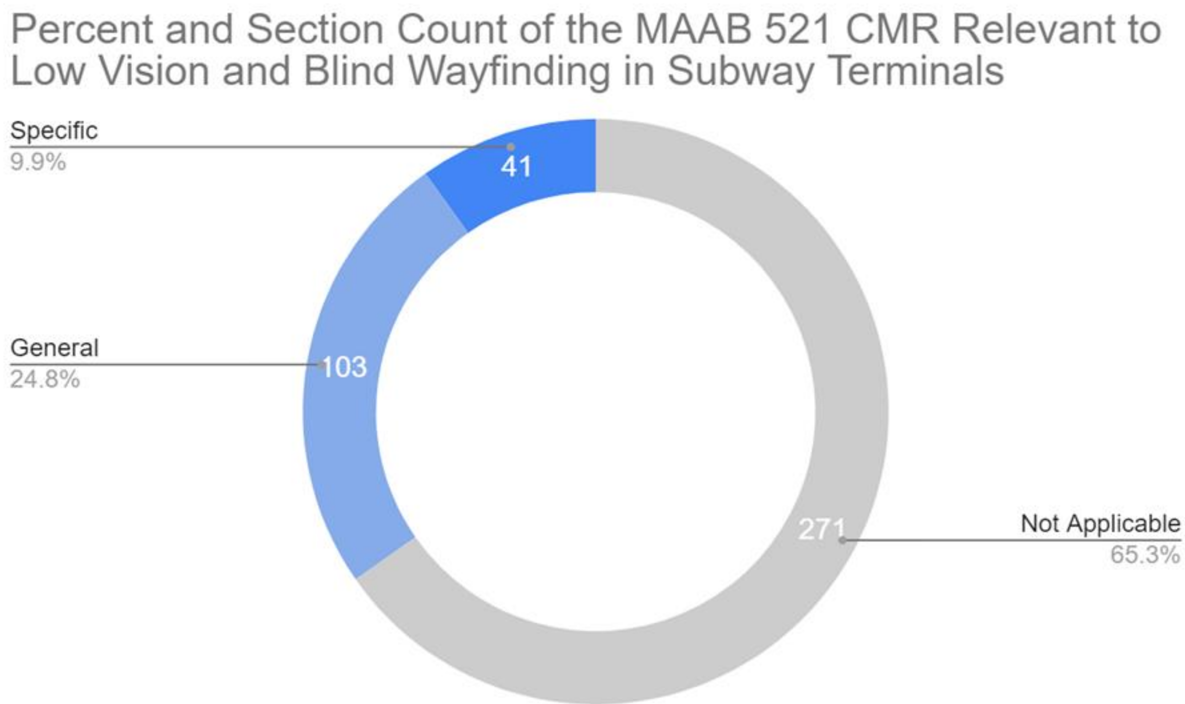

Figure 4.2: Percentage breakdown of the MAAB 521 CMR in relation to the low vision and blind subway terminal wayfinding experience

Results

As described in Chapter 2, shifting definitions around disability and accessibility persist in the policy. Standard considerations specific to visual impairments are included (Braille, auditory assistance, detectable warnings) but do not consider more nuanced approaches to the low vision experience with wayfinding, such as other architectural cues or mapping resources.

Figure 5.1: Riders exit at Charles/MGH

Chapter 5. Observational Studies

Purpose and Limitations

Two observational studies were conducted at the Charles/MGH station (Figure 5.1) to understand the usage patterns of MBTA riders who use the subway system with assistance. The station was chosen for its proximity to Mass Eye & Ear, a teaching hospital part of Harvard Medical school dedicated to, among other considerations, eye care. The date and time frame were chosen to be during the week to see if riders, potentially with appointments at Mass Eye & Ear, would use the station.

The observations are subjective and do not consider the range of how disability presents, focusing on *visible* disability as opposed to identifying cognitive and hidden disabilities (both of which can cross over with low vision and blind conditions). The use of visible assistive devices was set as the objective standard in determining riders with assistance. As outlined in Chapter 3, these visible devices were defined as: white canes, walking canes, wheelchairs, walkers, crutches, braces, guide dogs, and assistance from another party.

Context

Figure 5.2: The Charles/MGH station

Charles/MGH consists of two platforms, inbound and outbound, with one point-of-entry each. The station is largely outdoors (Figure 5.2), with the station entrance, exit, elevator, stairs, escalators, and ticket kiosks located indoors. To cross between the inbound and outbound platform a rider must pass through the indoor section (Figure 5.3).

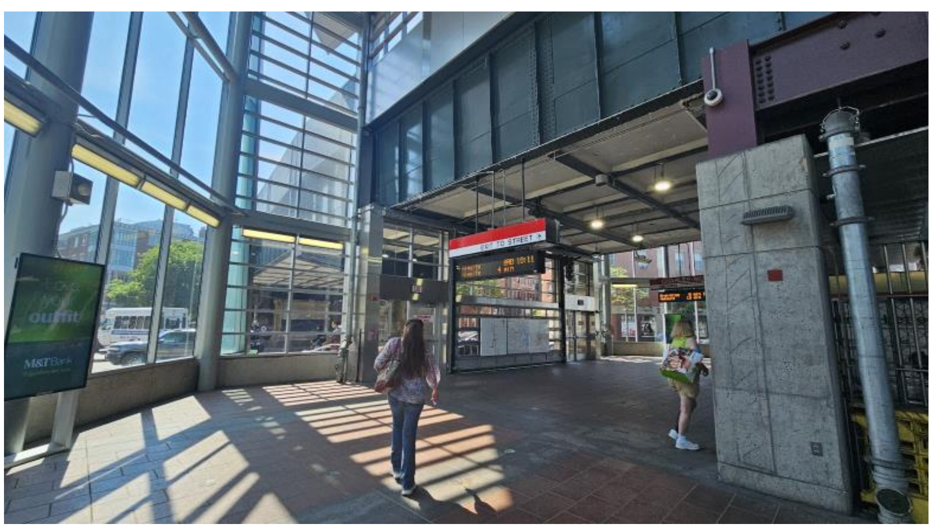

Figure 5.3: A rider inside Charles/MGH

Figure 5.4: Signage at the Charles/MGH station

Figure 5.5: MBTA Bridge plate

Signage at the station indicates the direction for Mass Eye & Ear and for the Mass General Infirmary (Figure 5.4). There are signs for the bridge plate, a device that spans the gap between the subway platform and car, using the universal wheelchair symbol of accessibility (Figure 5.5) Additionally, there are two passenger assistance stations per platform, with both station buttons providing tactile-Braille translations (Figure 5.6). In total one MBTA ambassador was observed at the station, during the second observation.

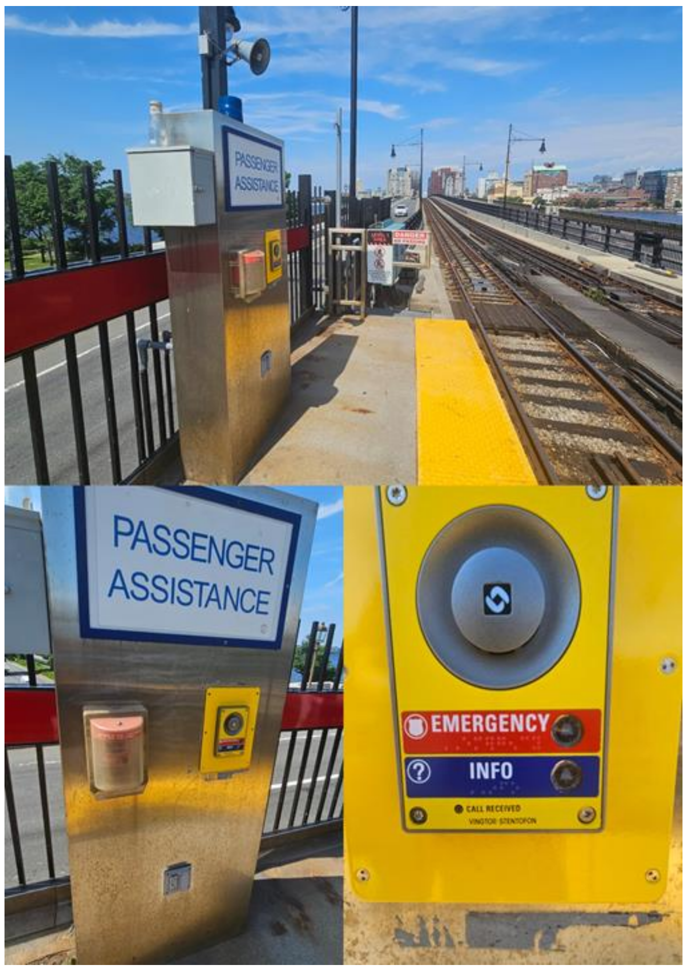

Figure 5.6: Passenger assistance station at Charles/MGH

Observations

In March 2024, at the Davis Square station between 7:30 a.m. and 8:30 a.m., one person was observed by the author using a white cane while boarding the inbound car. On Friday, June 14th, 2024, at about 9:57 a.m., the author observed a rider at North Station using a walking cane.

On Wednesday, June 12th, 2024, during the first official observational study of the Charles/MGH station on the inbound platform from 11:28 a.m. until 1:00 p.m., 14 riders using assisted devices were observed (Figure 5.7).

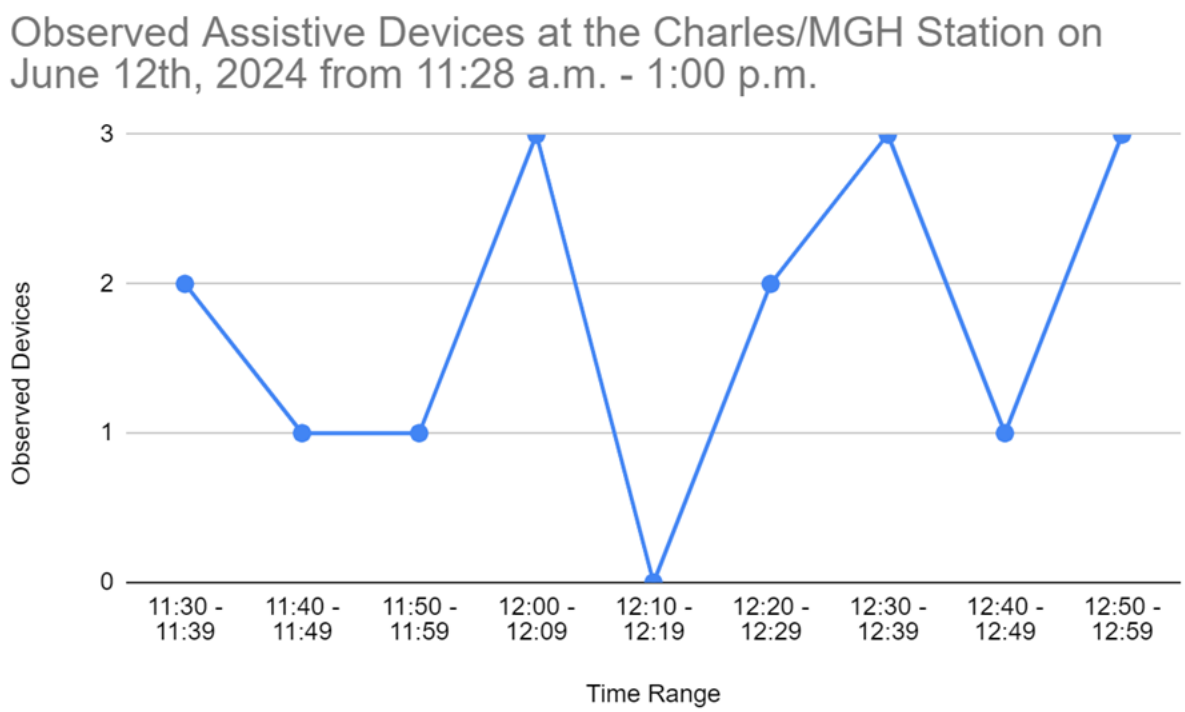

Figure 5.7: Observed assistive devices during the 06/12/2024 observational study

On Friday, June 14th, 2024, the author conducted a second observational study of the Charles/MGH station on the outbound platform from 10:12 a.m. until 12:02 p.m. 10 riders needing assistive devices were observed (Figure 5.8).

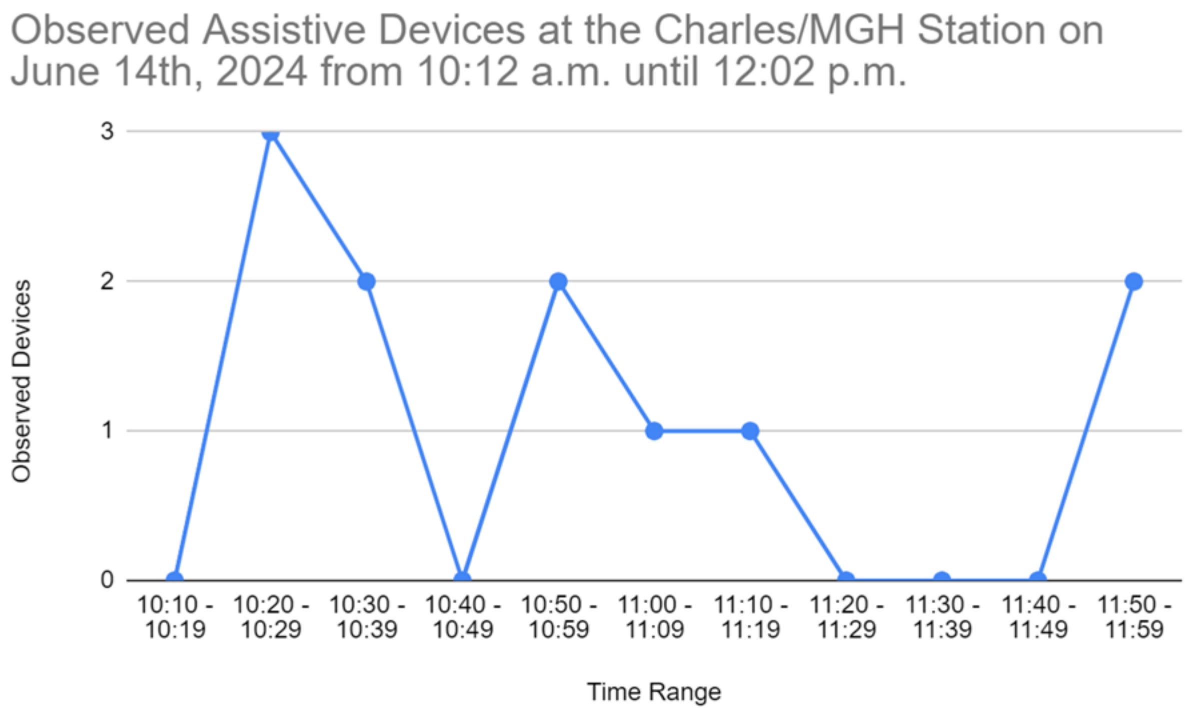

Figure 5.8: Observed assistive devices during the 06/14/2024 observational study

Results

The Charles/MGH station was observed for a total of three hours and 22 minutes over the course of two weekdays in June 2024. During this time, a total of 27 riders were observed using assistive devices, with device frequency observed as up to three during any ten-minute interval. 22 out of the 27 observed riders (or about 81%) were using a walking cane, with the remaining riders using a mixture of wheelchairs, walkers, crutches, and braces. One rider was wearing an eyepatch, a reminder of vision loss due to an accident. No riders during the two official observational studies utilized a white cane. Please refer to Figure 5.9 for the distribution of observed assistive devices at Charles/MGH.

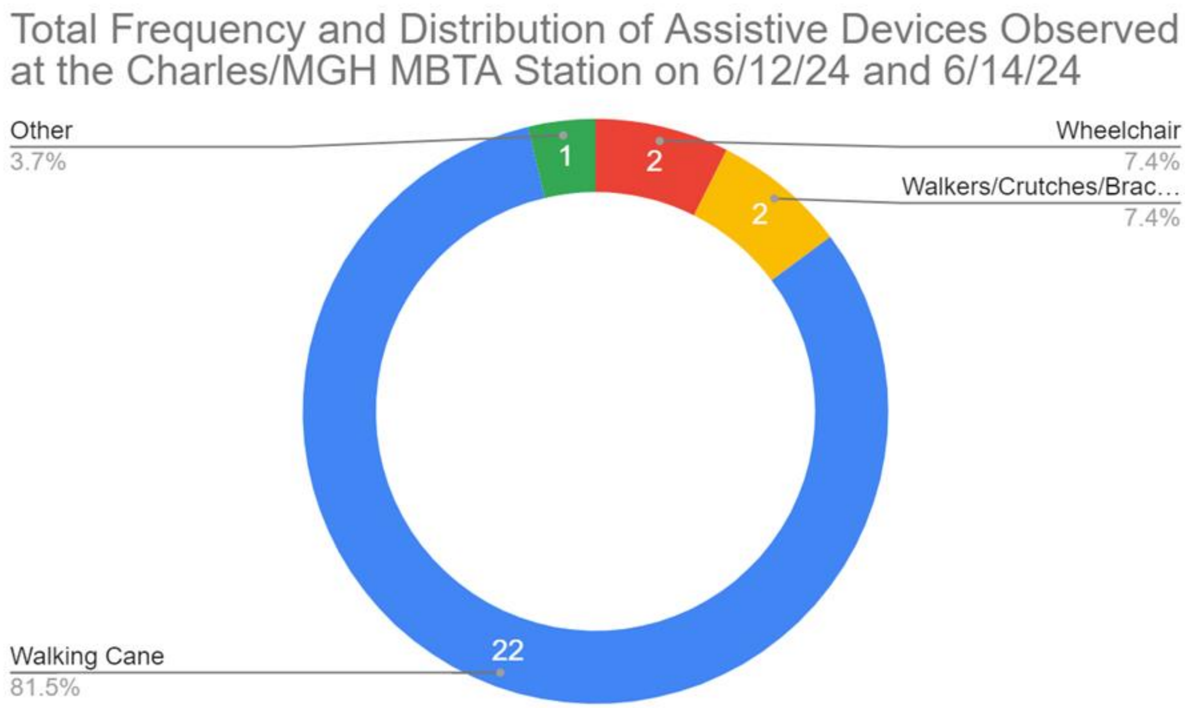

Figure 5.9: Total frequency and distribution of assistive devices at Charles/MGH

Chapter 6. Interview Results

As mentioned in Chapter 3, five interviews were carried out between January 25th, 2024, and February 22nd, 2024, with representatives from the Massachusetts Bay Transportation Authority, the Massachusetts Commission for the Blind (MCB), Perkins School for the Blind (Perkins), BIA.studio, and Esri Nederland. Interviews were either held in a Zoom meeting or conducted in-person and were between the author and the representative(s). All interviews followed a semi-structured format, guided by pre-determined interview questions. The next section includes the interview summaries and codified results, after brief introductions.

Introductions

The Nation's Oldest Transit System

The MBTA is the largest transit system in Massachusetts and the oldest public transit system in the nation. As part of the Massachusetts Department of Transportation (MassDOT), the agency services eastern Massachusetts and parts of Rhode Island with subway, bus, commuter rail, paratransit, and ferry options.

The interview with the MBTA was with two MBTA representatives: Laura Brelsford, the Assistant General Manager of the MBTA's Department of System-Wide Accessibility, and Jennifer Ross, Deputy Director of Customer Engagement. The conversation started with the history of accessibility at the MBTA, and with details about the 2006 Daniels-Feingold lawsuit. This settlement, which is the most comprehensive settlement on transit in the United States, was filed by 11 riders and the Boston Center for Independent Living on the basis that MBTA subway and bus services were not maintained to be accessible. The lawsuit has become the basis of current accessibility projects for the agency, leading to the development of the SWA campaign and RTAG, the monthly autonomous feedback group that meets about accessibility at the MBTA. Information regarding the lawsuit is publicly available, sourced from the MBTA's official website.

The representatives discussed existing conditions and current projects, ongoing and future goals of the MBTA, and policy considerations. They noted that the MBTA wants to be a leader in the national conversation around accessible transit due to the agency's status as the oldest transit system in the United States. The SWA is working on prioritizing the disability perspective in all departments of the MBTA, including across staffing and stakeholder groups. This is an effort to shift agency operations to a structure that can develop change via an ongoing conversation from within. Overall, the agency is making efforts with regard to multiple aspects of disability, and they admit that much more work remains to be done.

A Commission with a Mission

The MCB is a public state entity that offers rehabilitation and social services to legally blind persons in the state of Massachusetts quoted online as having a mission "to provide training, education, empowerment…and advocate for inclusive policies across the Commonwealth."

The second interview was with Allyson Bull, Director of O&M at the MCB. She noted the concept of orientation and mobility, as well as the interconnectedness of low vision, blindness, and other physical or cognitive disabilities. Bull also highlighted the importance of mapping skills and cardinal direction for orientation, as well as the need to understand spatial relationships for populations who are blind or with low vision. This was followed by a discussion on the relevance of tactile resources for maps. Transit options observed by the representative for the populations they work with were recorded, as well as specific comments on the MBTA, and some best practices for wayfinding for low vision and blind populations.

Figure 6.1: Perkins School for the Blind campus

Wayfinding in Watertown

On the bank of the Charles River in Watertown, Massachusetts, is Perkins School for the Blind (Figure 6.1), the first school for the blind in the United States. Founded in 1829, the school services students with visual impairments, deafblindness, CHARGE syndrome, and Cortical Visual Impairments from birth until age 22 (taken from the school website).

Eric Jerman, an O&M instructor at the school, provided examples of tactile maps at Perkins and discussed other examples of public tactile devices in the greater Boston area. He expanded upon the definition of blindness with the introduction of Cortical Visual Impairment, or CVI–a new type of blindness common in new students at Perkins. The overlap between vision and a spectrum of other cognitive disorders was discussed. The conversation covered bridging the gap between low vision and blind populations and their ability to navigate spatial relationships. Jerman described many tech and app-based examples and noted the importance of accessible planning in the built environment.

Designers Downtown

BIA.studio is a design firm in Boston that, among other topics, focuses specifically on wayfinding systems and transportation facilities. The studio was assigned to unify MBTA signage by the judge of the 2006 Daniels-Feingold class action lawsuit against the agency (Bailey, 2024).

Sela Bailey, principal architect at the studio, noted the theory and research behind the studio's signage unification project for the MBTA, specifically in relation to wayfinding and tactile developments. She highlighted the considerations around Braille and raised characters in reference to the local and federal codes that regulate accessibility in Massachusetts. She shared the final report of the signage unification project, along with project goals and the developed methodology borne out of addressing existing deficiencies in the MBTA signage system. Specifics relating to tactile map development were also discussed.

Mapmakers Across the Atlantic

Environmental Systems Research Institute, Inc., trade name Esri, is a Geographic Information System (GIS) software company, which has a branch in the Netherlands. The author first came to know about tactile maps through a tactile mapping project carried out by Esri Nederland. Neils van der Vaart is the Manager of Product Management and Innovation at Esri Nederland and works for Dutch Kadaster, the national mapping and land registry agency in the Netherlands.

Currently, his team is trying to automate the process of printing tactile maps at the neighborhood scale as a low-cost way to bring spatial awareness to low vision and blind populations. While this project is still a work in progress, van der Vaart shared resources and information relating to the production of such maps, along with some best practices for tactile map development.

Coded Interview Results

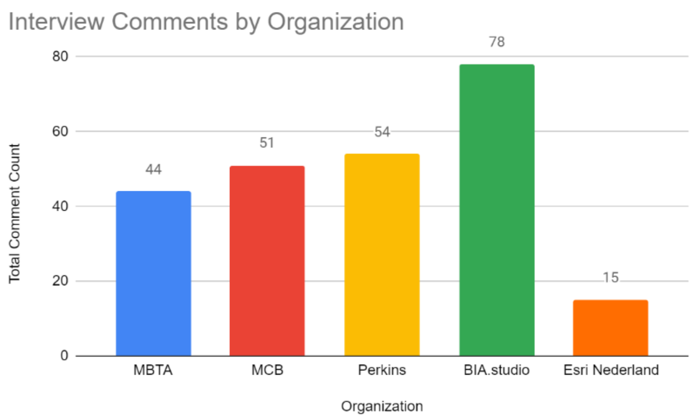

Figure 6.2: Sum of interview comments by organization

The interview transcripts were thematically coded. First, 242 comments were identified as containing information relevant to the research questions, with the following distribution: 44 from the MBTA, 51 from MCB, 54 from Perkins, 78 from BIA.studio, and 15 from Esri Nederland (Figure 6.2). These 242 comments were then coded (Table 6.1) and organized (Figure 6.3).

	Blind and Low Vision	Tactile/Map Information	Accessibility	MBTA	Solutions	Best Practices
MBTA	2	5	4	21	8	4
MCB	12	9	5	17	6	2
Perkins	9	16	3	3	17	6
BIA.studio	5	8	8	26	14	17
Esri Nederland	1	4	2	0	3	5
Total	29	42	22	67	48	34

Table 6.1: Interview comments across theme

Six code themes naturally emerged from this process across all five interviews:

1) *Details relating to blind or low vision,* with 29 comments
2) *Information on tactile and map resources,* with 42 comments
3) *General accessibility considerations*, with 22 comments
4) *The MBTA,* with 67 comments
5) *Existing solutions for blind and low vision wayfinding and orientation,* with 48 comments
6) *Best practices,* with 34 comments

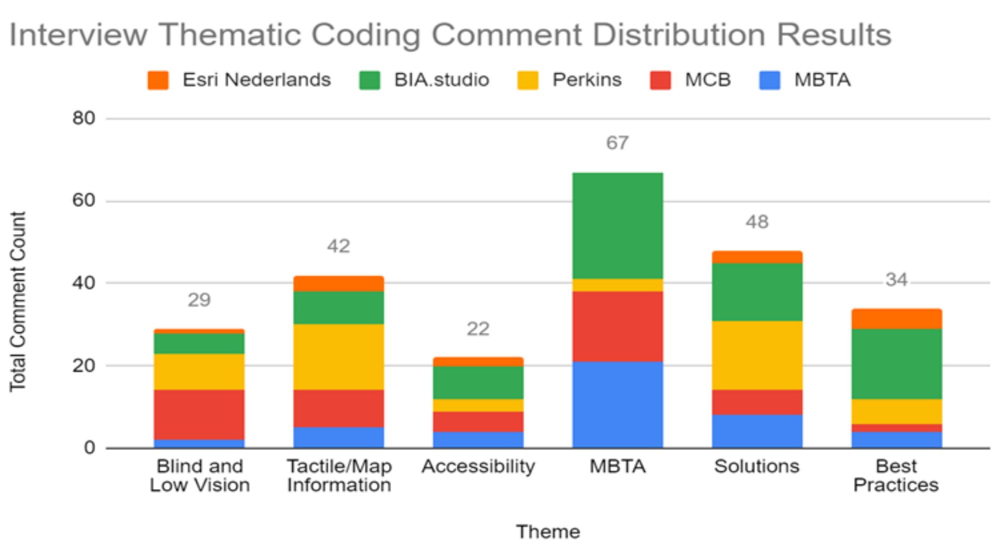

Figure 6.3: Comment distribution results from interview coding

Interview results reflect professional experience but are not meant to generalize across all experiences of people with disabilities related to vision. What follows is a condensed flowing text report on these interview results, with comments under the six major themes further organized for readability and understanding.

Theme 1: Blind and Low Vision

In Massachusetts

In Massachusetts, there are four full-time vocational rehabilitation centers across the six state regions (Bull, 2024). Blind and low vision conditions "var[y]...[with] an array of cognitive abilities." (Jerman, 2024). Like students at Perkins, many of Bull's clients at the MCB have multiple disabilities, some being "...elderly, [who] lost vision later in life." (Jerman, 2024; Bull, 2024). A vast majority of new students at Perkins come in with Cortical Visual Impairment (CVI), a new type of blindness that cannot process images due to damage to the brain (commonly at or around birth) (Jerman, 2024).

There's "a range" in qualifying for legal blindness in Massachusetts: one must have vision with a correction of 20/200 or less in the better eye, or a peripheral field of 10 degrees or less (Bull, 2024). Jerman noted that in the state, "you can go to school earlier if you have a disability—at age three instead of age five," adding that while some students at Perkins are classroom-based, working on "basic stuff," others are on an academic track and think about college. MassBay Community college was given as an example (Jerman, 2024). Those with vision impairments do not usually have a high income (Van der Vaart, 2024), with blind and low vision students having a "high college dropout rate" and a "low gainful employment rate"

(Jerman, 2024). As O&M Director of the MCB, Bull is involved with "social rehabilitation" for those not on track for gainful employment.

Transportation Habits

Transit is discussed by the MCB as one of the biggest issues for low vision and blind populations. "It's frustrating for people—when you register with the Commission, your…license is revoked [and you]...[l]ose that independence," (Bull, 2024). Many, especially those with sudden vision loss, would prefer to learn or relearn how to be a commuter, but it's intimidating. "There is a process in acceptance, and realizing [one is] able." (Bull, 2024).

Bull shares paratransit, public transportation, family or friends, and rideshare as common habits, in comparison to students at Perkins who are offered options like school buses, vehicles or carpools, walking, and other assistance (Bull, 2024; Jerman, 2024). Though it is stated that there are many low vision and blind riders at the MBTA (Brelsford and Ross, 2024), Jerman can't think of many at Perkins using the MBTA subway system post-grad. Bull feels they may be more likely to try using the subway when they feel comfortable and confident (Bull, 2024), as many "don't get out much, meaning they don't practice route navigation or orientation often." (Jerman, 2024).

Wayfinding Skills

Orientation and mobility in the environment has a "primary focus on…the visual aspect" at the MCB, where instructors focus on navigating home errands and grocery stores, and train coordination across different accessible devices (such as a white cane, walking cane, or wheelchair) (Bull, 2024). In considering signage at the MBTA, Bailey from BIA.studio stated that many with visual impairments "don't read Braille," and that "the inclusion of raised characters alongside Braille should be succinct." She affirms that experiences vary, as do the needs of customers: "some may just need to confirm details, while others, like a newcomer to the system, may need more information."

Theme 2: Tactile Maps

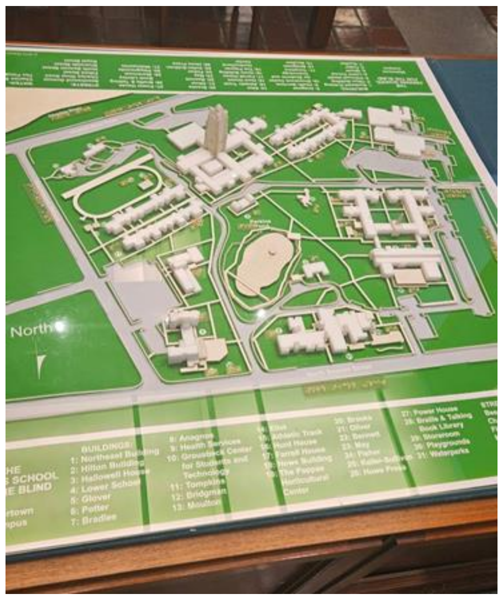

Figure 6.4: Tactile map of the Perkins campus, courtesy of Perkins School for the Blind

Available for the past 200 years, tactile mapping resources are a low-tech method to building foundational wayfinding skills such as mapping, cardinal direction, and independent orientation (Van der Vaart, 2024; Bull, 2024). They can present examples of change over time of a spatial area or offer a way for people to practice navigating their environment (Van der Vaart, 2024; Bull, 2024). At Perkins, the use of tactile resources is common; as an example, the school utilizes tactile symbols outside doorways for guidance, and would incorporate more tactile maps into programming if maps were more widely available (Jerman, 2024), as students want to understand spatial relationships (Bull, 2024). Jerman recommends that mapping resources should range from simple to complex to serve the array of abilities present across low vision, adding that older populations and those with more cognitive functions tend to not use tactile maps, though it was not elaborated as to why. Refer to Figure 6.4 for an example of a tactile resource at the Perkins campus.

Design

As it's "...tough to design a map that will help everyone" (Jerman, 2024), map design is further strained due to the lack of a uniformed methodology to the process (Bull, 2024). Simple, uncluttered tactile resources are effective, with streamlined information (Bull, 2024; Jerman, 2024). As part of the MBTA signage unification process, BIA.studio tested reducing visual clutter through a series of signage iterations backed by research on design standards and best practices before reaching a final solution (Bailey, 2024).

Van der Vaart encourages thoughtful determination of symbology in tactile maps by considering *how many* symbols and *what information* to present. BIA.studio provides the example of a "decision point", a symbology developed while mapping MBTA ambulatory and assistive routes through a station. These points are placed at transitions such as doorways or between different levels (Bailey, 2024).

For outdoor tactile maps, Bailey suggests considering wear and tear on the signage due to weather. A durable material with high contrast (such as zinc or aluminum) and plating with different metals were presented by Bailey as solutions to map creation. Since polymer and plastic are easy to carve, the MBTA mitigated vandalization by standardizing signage to be porcelain and enamel for their resistance (Bailey, 2024). In addition, the Institute for Human Centered Design is a consultant of the MBTA currently trying to leverage 3D technology to convert station design maps into physical models (Brelsford and Ross, 2024).

The maps produced by Esri Nederland use a special layered paper, called swell paper, that can be used in a regular printer. After printing, the paper is put into a swell oven. The carbon in the black ink reacts to the heat and rises, providing a binary high-low tactile difference. Texture is dictated by symbology. Esri Nederland would like to automate the process of map production, currently priced at about 1USD, so that "you can print a map anywhere at any time." (Van der Vaart, 2024).

Hurdles to Implementation

At one point, a tactile map *was* created for the entire subway system (Figure 6.5) (Bull, 2024). The MBTA has discussed implementing tactile paths and other tactual indicators at stations based on rider feedback and conversations with other transit agencies (Brelsford and Ross, 2024). This effort is not ongoing, though agency representatives note that significant wayfinding or signage updates at stations will include tactile maps "as part of the contract" (Brelsford and Ross, 2024). They continue to comment that while these devices are not a "frequently used" tool, they raise awareness for low vision and blind riders by signaling that the agency is "working on [accessibility]." However, generating feedback for tactile maps has been unsuccessful, their legitimacy called into question as the MBTA does not consider "tactile signs as total game-changers" (Brelsford and Ross, 2024).

Figure 6.5: Tactile map of the MBTA subway system, courtesy of Perkins School for the Blind

Although there is a lot of potential exterior space, a second hurdle to implementing tactile maps at the MBTA is signage location (Brelsford and Ross, 2024) as riders need space to stand and touch the sign without obstructions (Bailey, 2024). The sign's height and placement dictate the size of the font, which should be code-compliant across the following: text and Braille size, the kerning (spacing) between dots, and the height of dots and raised characters (Bailey, 2024). The standard font height for MBTA signage is six inches for a station name, two or three inches for other wayfinding information, and with Braille text and raised characters to be located between 48-60 inches above ground (Bailey, 2024). BIA.studio developed a software program that translates Braille into graphics for the MBTA signage manufacturer, best practices dictating reference to local and national codes for full compliance requirements (local code cited as the MAAB 521 CMR, national code cited as the ADA). "If there is a conflict between codes, we refer to the one that is more stringent," says Bailey, who later added that the studio's software program edited the Braille kerning to be compliant with the ADA.

Theme 3: Accessibility

> **Accessible incorporations in the built environment are validating because they suggest to the rider that: "I matter. I belong here."** - Eric Jerman, Perkins School for the Blind

In Signage

Van der Vaart brings up a key point: "The accessibility of *accessing* maps and other resources must also be considered," citing income as a potential barrier to resource access. Other accessibility considerations come in the form of color designation: red and yellow stand out for those with low vision (Jerman, 2024). Barriers to tactile methodology present themselves across space; a methodological barrier borne out of spatial considerations was uncovered when the absence of slope in the tactile maps from Esri Nederland was made apparent to the author. Pathway grade is a legitimate concern in Massachusetts, but not as large a consideration for mapmakers from the flat plains of the Netherlands.

It is hard to design "something for everywhere" because no one system will work for everyone (Bailey, 2024). Some people have better mental maps, while others struggle (Jerman, 2024). Jerman discusses the fact that many with low vision are unable to practice route navigation and orientation often, and that accessible incorporations in the built environment are validating by suggesting to the rider that: "I matter. I belong here." He adds that tactile maps could be a good resource for practice.

At the MBTA

Orientation and mobility can be difficult to teach in subway terminals (Bull, 2024). “Where do people have to stand? The trains don’t pull all the way up, and all the sounds can be disorienting, especially for guide dogs,” says Bull, who explains that typically, those who use physical mobility devices or have multiple disabilities are likely to use paratransit (such as the RIDE). MCB clients tend to prefer door-to-door travel options and need these services on more of an on-demand, private, and direct basis.

Bull outlines that the goal of transit accessibility is to always promote independence for all riders who are willing to participate and learn, which places emphasis on the MBTA when recalling the increasingly sparse opportunities for travel by transit once out of the Greater Boston area. Many communities without a transit authority have few transit options, some of which require riders to meet a qualification (such as local ride programs) (Bull, 2024). At one time the MBTA was investigating a rideshare voucher program with providers such as Lyft and Uber (Bull, 2024). Jerman recalls that about six or seven years ago, Perkins School for the Blind also collaborated with Lyft and Uber for fare reductions, though he couldn’t find information on this initiative in the present day (Jerman, 2024).

The MBTA strives to address accessibility in the written policy by addressing the “...interesting gap in [ADA] regulations” that only require visual information to accompany audible announcements. This one-directional relationship is dismantled by the agency, which requires an audible component for each visual announcement. Visually rich information can be difficult to understand for many riders of all abilities (Brelsford and Ross, 2024). A big solution borne out of the 2006 settlement is RTAG, an autonomous community group that advises the

MBTA on their accessibility considerations for disability and older adults (Brelsford and Ross, 2024).

Theme 4: MBTA

The MBTA is already challenging for sighted vision (Jerman, 2024), let alone for the many low vision and blind riders (Brelsford and Ross, 2024). Three specific issues were discussed:

1. *Clients at the MCB cite that the trains are often late*
2. *The lack of access to real-time information* (Bull, 2024)
3. *Locating the bus stop can be difficult as the location is not always clear, increasing the chances of a bus departing without the rider* (Perkins, 2024; Brelsford and Ross, 2024)

Riders want to be able to independently use the MBTA public transit system, and to learn or relearn how to be a commuter, but it's intimidating (Bull, 2024). MBTA stations are cited to be confusing and difficult, and people don't feel comfortable navigating them (Brelsford and Ross, 2024). While there are system and neighborhood maps in place, station layout maps "don't really exist." (Bailey, 2024).

However, accessibility considerations are present at every level of the MBTA; as an example, both representatives interviewed have the disability perspective (Brelsford and Ross, 2024). They share two primary objectives to be integrated across all departments:

1. *Addressing barriers that have existed from decades of "not-so-great" accessibility*
2. *Taking the chance to be a leader in terms of accessibility for public transportation in the country, seeing as the agency houses the oldest subway system in the nation*

The agency prioritizes system safety, ease, and the disability lens by making sure "rider feedback is part of everything [they] do." Technical user testing is incorporated at the MBTA, and they are working towards ensuring that the way the MBTA communicates is accessible to all riders, citing that they go “above and beyond the policy” by requiring visual *and* audible methods for each announcement. The agency has an automated, closed-loop system that incorporates feedback and provides quarterly reports for tracking complaints and producing change. If any complaint received at the agency has to do with accessibility, it’s automatically sent to a team where an investigation occurs, and action is taken if appropriate. (Brelsford and Ross, 2024).

No matter how great accessibility considerations are for announcements and wayfinding, there “is no substitute for a human being,” (Brelsford and Ross, 2024), though there is no guarantee of accuracy when soliciting advice from other riders (Bull, 2024). Currently, the MBTA is trying to scale up the amount of Transit Ambassadors available at stations (Brelsford and Ross, 2024), who provide personal assistance for riders (or at least, to those with enough vision to identify their characteristic red uniform) (Bull, 2024). There’s also an integrated Mobility Center at 1000 Massachusetts Avenue in Boston, MA, which aims to build rider confidence through free one-on-one and group travel training, trip planning, and with presentations to mitigate dependence on the RIDE (Brelsford and Ross, 2024). In the past, travel trainers have been sent to MCB to work with the Commission’s O&M specialists (Brelsford and Ross, 2024). Bull says that the MBTA is in touch with the MCB often, and that they recently reached out to try and update the system’s subway station Braille text.

Backed by feedback from RTAG, existing priorities at for the SWA campaign include: improvements on paths of travel by closing the physical gap between platform and car and by providing working elevator access; mitigating ice at bus stops and ramps; wage increases for bus operators; keeping restrooms clean; and, of course, providing compliant wayfinding. Tactile paths and other tactual indicators have been discussed both internally and with feedback from conversations with riders and other transit agencies, though the initiative is not being implemented on a large scale at this time.

As stated, a major goal outlined by the MBTA is the providence of accessible wayfinding, and though several tests to wayfinding have been piloted, a "solution that has proven very viable" has not yet been identified. "The MBTA is putting a lot of energy into this area, as [we] are about to pilot another wayfinding solution." (Brelsford and Ross, 2024).

Signage Unification Project

Consistency across a system is an important element of efficient wayfinding (Bull, 2024). In the past, signage at the MBTA was very inconsistent across elements such as color, font, placement, and a variety of graphic systems. The 2006 Daniels-Feingold settlement addressed this inaccessibility by assigning BIA.studio to the agency to collaborate and develop a unified signage system. What was initially a small part of the total agreement grew into various phases, pilot projects, and final products. (Bailey, 2024).

As a rider's journey could interact with multiple stations or train lines, the studio wanted to think systematically across a whole station to develop a system compliant with every station and their specific conditions to help riders orient themselves no matter where they are. Goals focused on *wayfinding* for the project were a consistent signage system, architectural cues for place identification and as navigation aids, the ability to be oriented towards the exterior with exit navigation and maps, and to promote autonomous travel by incorporating tactile and Braille elements. (Bailey, 2024).

BIA.studio identified the following sign types: entering information, exiting information, mounted information, and wayfinding signage. A "Correct, Clear, Consistent" methodology was developed, which encompassed details around graphics and signage location. Consistency across colors, icons, content (such as the inclusion of end destinations), language, and grammar was established in conjunction with the MBTA's SWA campaign. (Bailey, 2024).

When it comes to color, the studio wanted to move away from associations between color and station not only because of colorblind considerations, but also due to the fact that many stations house multiple lines. It was decided that all transit lines should be listed in an oval with corresponding colors, and that all station names should be written in a single line in white, with a color-coded background. All other wayfinding signage was determined to use black text on a white background. Signage location is regulated by code, and BIA.studio opted to comply with the ADA over the MAAB 521 CMR as the policy provided a bit more nuance. To fulfill compliance, the spacing between characters in the font style had to be altered. Additionally, a code-compliant stand for signage was designed for situations where space isn't available. (Bailey, 2024).

Though there is still older signage present at the MBTA today, new signage is added as stations undergo renovations and when new stations are built. The biggest takeaway for BIA.studio after the MBTA signage unification project is that one "can't find the signs without other cues." (Bailey, 2024). Bailey notes that during the project, there was a discussion around tactile bus signage. The idea was let go, partly because it proved difficult to determine a suitable location for such interactive signage as bus stops are outdoors. However, the studio did standardize the recognizable tombstone shape of current MBTA bus stop signage. (Bailey, 2024).

Tactile Signage

Although BIA.studio “wasn’t originally planning for tactile-Braille,” the methodology for station wayfinding ended up being sustained in a software program built by the studio that could produce wayfinding, bus, and tactile-Braille signage. As a bonus, the studio trained the signage manufacturers on how to use the software. After testing materials and construction, a focus group from the MBTA’s SWA campaign toured the Orient Heights station to test tactile-Braille signage pilots. A simplified approach to signage location was decided after feedback: at each entrance, at the customer assistance station, and to the right of doors along an exit path (with some nuances incorporated for the commuter rail). When it comes to elements of Braille such as vocabulary and capitalization, a consistent system was defined by BIA.studio for the MBTA to use, compliant with the ADA. (Bailey, 2024).

Tactile maps for some downtown multiline stations, such as Downtown Crossing, were developed by BIA.studio because the “accessible entrance isn’t apparent” (Figures 6.6 and 6.7) (Bull, 2024; Bailey, 2024). These maps were meant to help both visual readers and low vision and blind riders (Bailey, 2024). Additionally, tactile bars on the floor of the station perpendicular to the train line were incorporated as cane guidance, leading a rider to the customer assistance area which contains a callbox, bench, and tactile signage (Bailey, 2024).

Downtown Crossing was cited by the MBTA representatives as the most confusing station for riders, so the agency has started a major station rehabilitation and accessibility project there. Similarly, Government Center’s complicated layout features lots of interior space for opportunities to install signage. However, Government Center might be too complicated for a pilot test of such signage. (Brelsford and Ross, 2024).

Figure 6.6: Tactile signage at one of the Downtown Crossing entrances

Figure 6.7: Accessible entrance for Downtown Crossing, seen from the perspective of the tactile map location

Theme 5: Solutions

Tactile Resources

In the Greater Boston area, there is a large tactile map in Harvard Square at John F. Kennedy Street, about seven feet tall and five feet wide, depicting an aerial view of Harvard Square. There is also a store across from the circular kiosk at the Red Line entrance at Harvard Square that has "great 3D maps on the wall." Jerman from Perkins provides a global example of tactile design: in Switzerland, some subway train terminals have a track of lowered tiles designed to guide walking canes. (Jerman, 2024).

At Perkins School for the Blind, low vision considerations were built into the newer lower school by the incorporation of brightly-lit halls and the utilization of a floor material that minimizes glare. Tactile symbols have been installed outside the doors for navigation. Students at Perkins School for the Blind also practice MBTA travel training, the goal being to become as independent as possible, (Jerman, 2024).

Other solutions for at-home tactile maps include Tactile Town, a 3D O&M kit produced by the American Printing House (Jerman, 2024). Both Bull and Jerman reference the Wheatley Tactile Diagramming Kit (Figure 6.8), which is commonly used in work at the MCB and features different Velcro shapes and textures to build a range of simple to complex maps.

Figure 6.8: An example of the Wheatley Tactile Diagramming Kit, courtesy of Perkins School for the Blind

Technology

Both Jerman and Bull mentioned Aira Explorer and Be My Eyes as app-based solutions for low vision and blind wayfinding. From the Aira Explorer website, “Aira is an app that connects people who are blind or low vision to professional visual interpreters for secure access to visual information, anytime, anywhere.” Similarly, Be My Eyes “connects blind and low-vision users who want sighted assistance with volunteers and companies anywhere in the world, through live video and artificial intelligence.”

Jerman provided many examples of app-based assistance for low vision and blind populations. Apple products include Seeing AI and iBeacons. iBeacons uses Bluetooth technology to connect to nearby devices and send push notifications and location-based services. Seeing AI was designed specifically for low vision and blind users, utilizing smartphone cameras and AI to provide descriptions of surrounding people, objects, and texts. (Jerman, 2024).

Outside of Apple, BlindSquare uses existing maps such as Waze, Apple Maps, and Google Maps to read off addresses and tell users where to turn. This app, which costs 40USD, is best for completely blind students. Clew is another application developed by a professor of engineering at Olins University. Using Clew, one can create a route, set digital pins, and walk the route blindly. Advanced students at Perkins like practicing with this app because it is free. (Jerman, 2024).

Jerman brings up Lotfi Merabet, an optometrist who worked with Perkins School for the Blind to create a video game for blind students. A 3D rendering of an existing building contains a “digital treasure.” After practicing in the game, a gamer group and a control group went into the physical building with their O&M instructors. The gamer group scored higher than the control in terms of the ease and accuracy of their navigation. GoodMaps, a mapping service, carried out a 3D scan of Perkins which can be connected to a mobile device for guidance. This scan was sold to Perkins and is currently being tested, as indoor navigation is the last frontier to be conquered when it comes to digital maps. (Jerman, 2024).

BlindWays is an application created by Perkins School for the Blind, with the idea to provide context via crowdsourced information from sighted riders to app users about MBTA bus stops. An example of this information would be a statement like, “Hey, the bus stop is ten footsteps north of the bench.” However, it can be difficult to support crowdsourced applications long-term because of the time and effort required to maintain. They need “staying power.” (Jerman, 2024).

“You can’t rely on tech.” (Bull, 2024). Bull explains that people need back-up skills and to be able to rely on themselves to get out of a problem should they need to. She adds that quick, tech-based solutions are best for “in a pinch” problem-solving, and cites that accessible technology at the MBTA, like the auditory assistance, is “wonderful, but not so reliable.” Jerman notes that tech measures as a solution also depend on the user’s age. In his experience, short texts supplemented by document readers are the most useful for riders with visual challenges and older populations. Digital screens have presented an amazing opportunity to provide real-time information to riders, but some riders don't have visual access to that information (Brelsford and Ross, 2024).

Theme 6: Best Practices

Map information should be uncluttered (Jerman, 2024; Bailey, 2024). It is best to orient the map in the direction a rider faces when viewing (Bailey, 2024). The purpose of maps is not only to enable route navigation, but to also provide general context and spatial understanding (Van der Vaart, 2024). To achieve this, Esri Nederland produces maps at the 1:2000 scale, defined as the neighborhood scale. Their maps mainly feature topography, such as changes in elevation and landmarks such as houses, water bodies, parks, and trees. Like Jerman, Van der Vaart cites that a series of maps work best for all users:

1) *A map with just streets*
2) *A map with streets and buildings*
3) *A map with streets, buildings, and other details*
4) *A final map with all elements, and the route*

Local and national codes must be referenced for full requirements regarding mounting height and location (Bailey, 2024). In general, signage should always be to the right of doors and stairways. The ADA requires visual characters with lots of contrast, for signage to be made from materials that reduce glare, and outlines other specific signage guidance, including a compliance rubric for Braille. (Bailey, 2024).

Chapter 7. Tactile Maps

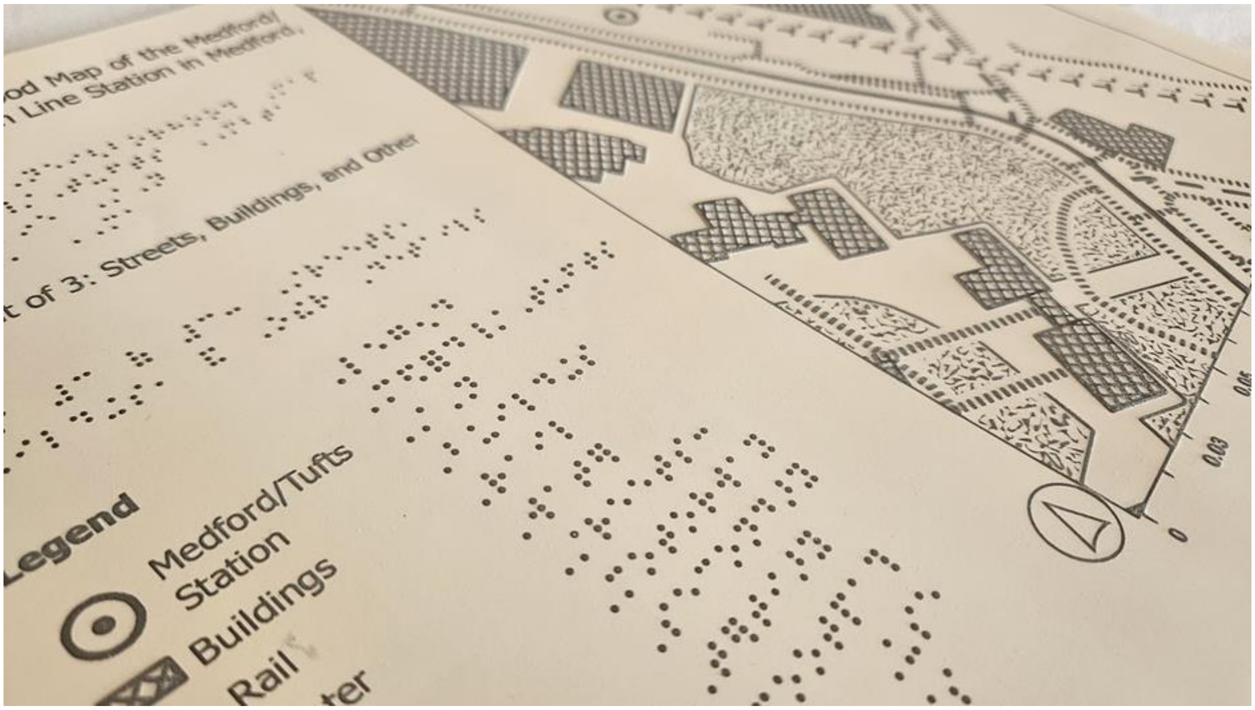

Figure 7.1: Close up of the tactile neighborhood map for the Medford/Tufts station

Records of tactile maps in the United States date back to the 1800s. Perkins School for the Blind's digital collections archive houses a robust digitized tactile map collection. From the school's Flickr album, some maps were "created for use by the blind, some are adapted to be of use and others…contain topographic and embossed elements…meaningful to users with visual impairments." They are helpful to those with visual impairments because of their ability to present spatial information and explain spatial relationships, distinguished by touch. There are multiple ways to create a tactile map: manual methods, such as carving away or etching on materials, or pasting objects onto a surface, and more technical methods such as embossing. Mapping tools such as GIS software is helpful in translating modern topographic data into tactile symbologies.

Based on time and spatial constraints, the Medford/Tufts station on Tufts campus was selected for its familiarity and ease of access for the author. The literature review and interviews indicated that

1) There will never be one solution that fulfills everyone's needs and

2) A variety of solutions is a holistic approach to accessible planning

The two final methods of creating these tactile maps were based on the resources and time available to the author, and each provides a different context for the user.

Orientation Maps

The representative from Esri Nederland noted that their tactile mapping project aims to provide low-cost tactile graphics at the neighborhood scale for "any location," beginning with the Netherlands and based on client requests. The company developed an ArcGIS Pro symbology package which converts open street map (OSM) data to a tactile representation. Map layouts are first printed on swell paper using a standard printer and carbon-based black ink and then put into a thermoform oven (also called a graphic oven or tactile embosser) after printing. A coating on one side of the swell paper causes the carbon-based ink to rise when exposed to heat.

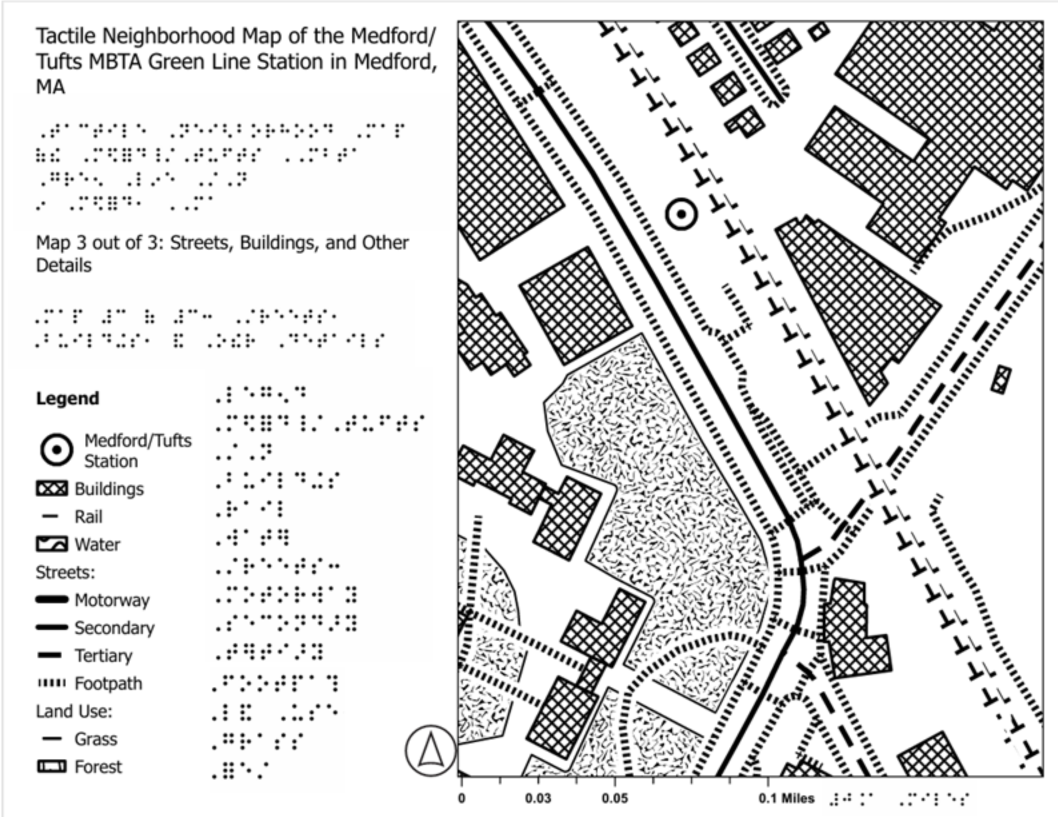

Figure 7.2: Final map layout of the third in a series of three tactile neighborhood orientation maps for the Medford/Tufts station

Process

To create the maps, the author downloaded the package file containing an ArcGIS Project File (.APRX) sent from the Esri and brought it into the ArcGIS Pro software. The file contained an existing map with an accompanying layout and legend for a location in the Netherlands. A new layout was created and the map's frame was adjusted to encompass an aerial view of the Medford/Tufts station at the 1:2000 scale, as that is the level of visibility for the tactile symbology. The map's projection was then changed to be the Massachusetts State Plane projection.

Multiple spatial layers in the file were grouped by continent. The visibility of irrelevant layers were toggled off so that only the following layers in the North America group remained:

buildings; highways (motorways, secondary, tertiary, and footpath); rail; water; and land use (grass and forest). The symbology included a point feature, so a point was added at the location of the Medford/Tufts station. A legend was created and formatted appropriately according to cartography best practices.

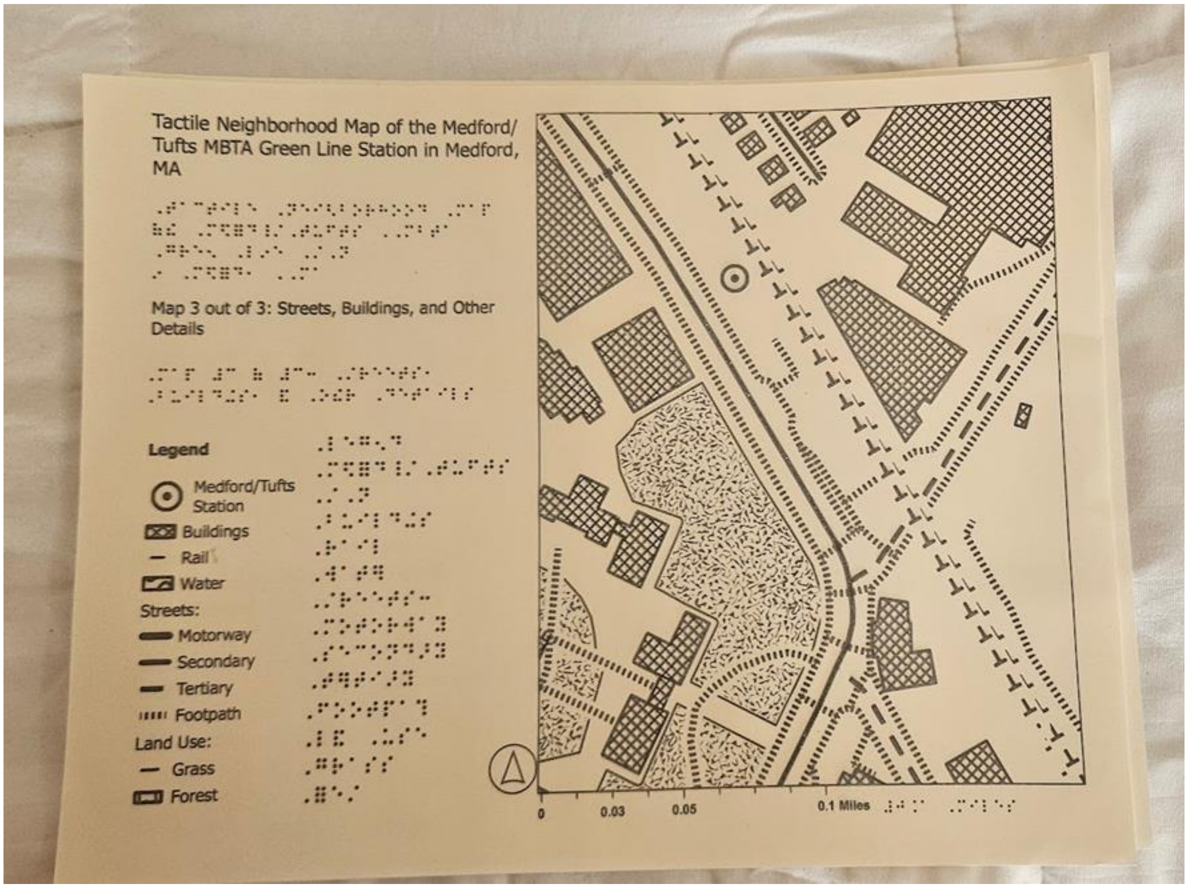

Figure 7.3: The third in a series of three tactile neighborhood maps for the Medford/Tufts station, after going through the PiaF machine

The Esri representative stated that their project usually creates three or four versions of the map at the same scale, ranging from simple to increasingly complex. This method was incorporated by the author for the neighborhood maps. Beginning with a simple layout with the streets and land use layers, complexity was added to the second map with the addition of a building (parcels) layer. The final map contains streets, land use, buildings, rail, and water bodies (Figure 7.3). The purpose of this map series (Figure 7.4) is to provide a user with a spatial understanding of the neighborhood surrounding the Medford/Tufts station, so that they may be familiar with the parcels, waterbodies, and roadways present in the path to the station entrance.

Figure 7.4: The full map series for the tactile neighborhood maps for the Medford/Tufts station, in order from least to most complex

Perkins School for the Blind houses two Picture in a Flash (PiaF) tactile embosser machines. The author reconnected with Eric Jerman, the O&M instructor from Perkins, to utilize this resource. Thanks to him, the final three neighborhood orientation maps were able to be printed on microcapsule paper and sent through the PiaF machine. In total, these maps took about 12-15 hours of time to create from conception, testing the symbology and the layouts, to the final design.

Wayfinding Maps

The literature review and interview process brought attention to the variety of tactile resources that can be produced, with one method being a 3D printer. 3D printers were available at the Nolop makerspace and the Cambridge HIVE makerspace (Figure 7.5). The Tufts Nolop makerspace is open to use for the Tufts community, while the Cambridge HIVE is a hub for all members of the public, regardless of whether they are library card holders or not.

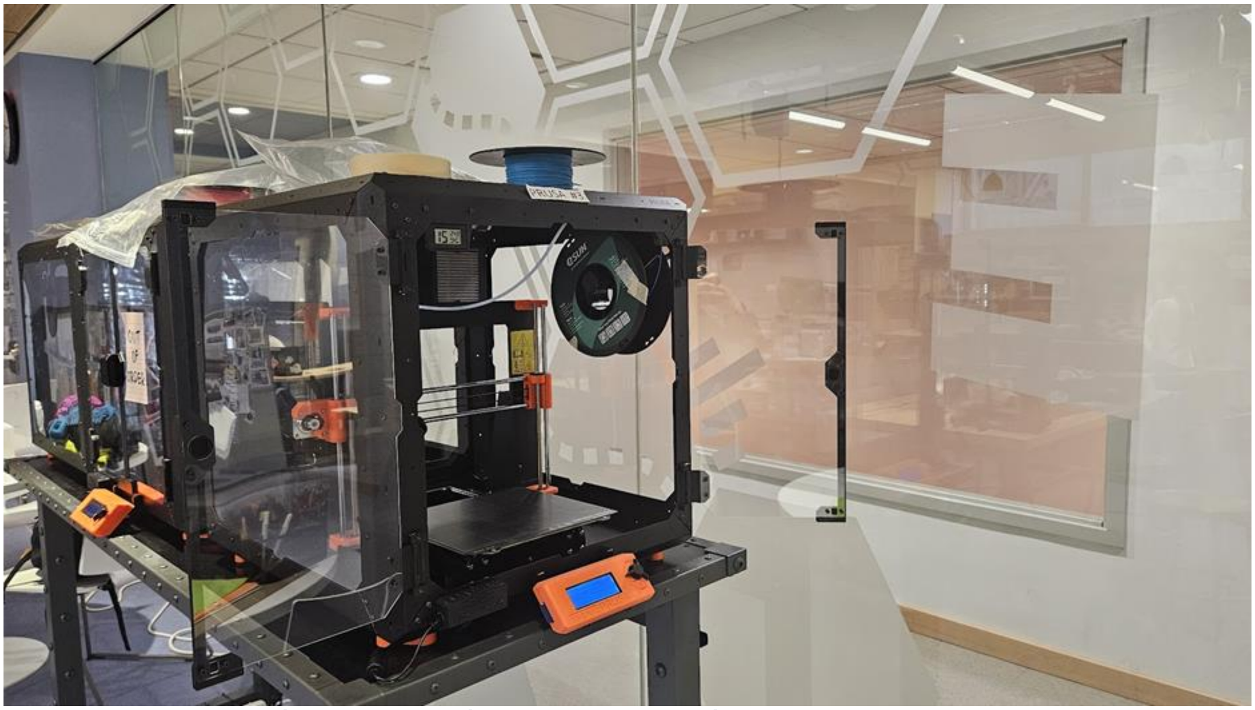

Figure 7.5: 3D printers at the Cambridge HIVE makerspace

Conception

Three individual pieces make up this 3D-printed tactile map collection: the top floor, the bottom floor, and the legend. First, a case study of the station was conducted to understand the layout and relevant station elements. Then after reviewing the literature and key points synthesized from the interview results, a first-draft prototype of the station was designed, incorporating feedback and map design elements from both sources of information and using a free Computer-Aided Design (CAD) application called TinkerCAD, available online.

The map was conceptualized in TinkerCAD by determining symbology and creating a digital design: a 3D route navigation map for the station. Eric Jerman, the interviewee from Perkins, shared a story during his interview about subway tiles in Switzerland incorporating a small, sunken track to guide walking canes. Additionally, the interviewee Sela Bailey, who is a principal architect at BIA.studio, elaborated on the studio's development of a "decision point" when mapping rider routes through a system. These points come at times during a rider's route when they must make a decision, such as to go straight or turn left, or to use the elevator or stairs. From these details, the route through the Medford/Tufts was cut away from the map's base, leaving behind a track to guide a finger through the station's route and with the incorporation of decision points.

The decision points, ticket kiosks, benches, signage, and restrooms were symbolized on the map using built-in TinkerCAD shapes. The symbology for the stairs, doorways, and elevators was designed using basic shapes available in the application. As Bailey pointed out, not all those with low vision can read Braille, so the label for each of the three pieces of this map included text in Braille and with raised characters. TinkerCAD comes with a Braille generator. Based on design guidance from the literature review, Perkins, MCB, and BIA.studio, visual clutter was reduced. Maintenance and access doorways and ramps were not included in the final design. From MCB, exact spatial relationships were not preserved. This is exemplified by the location of the stairs on the top floor map compared to their location on the bottom floor map. Additionally, the spacing between signage and benches on the bottom floor is not to scale. As the literature points to map portability, each piece of the 3D printed wayfinding map for the Medford/Tufts station did not extend past the TinkerCAD workplane, which is 20x20 millimeters.

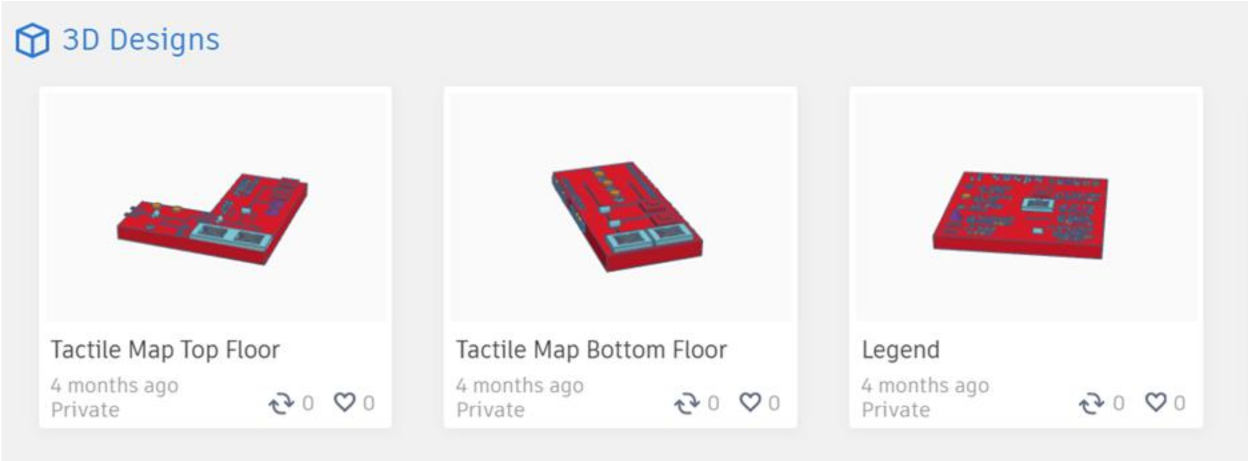

Figure 7.6: Files for the Medford/Tufts tactile wayfinding maps in TinkerCAD

All three pieces were designed in TinkerCAD (Figure 7.6) and printed using Original Prusa 3D printers (models i3 MK3S and MK4). In total, it took over twenty-five hours of time in April 2024 to create all three pieces.

Process

Files generated in TinkerCAD must be exported as a stereolithography file (.STL) and then uploaded to PrusaSlicer, a software program for the Original Prusa 3D printers that "slices", or analyzes and prepares, the file by generating a G-code. G-code is a programming language that instructs the 3D printer on how to move correctly to print the digital design. The design is printed using filament, a long tube of plastic that is heated and piped into the final design. In PrusaSlicer is the ability to modify some of the printer settings. Default settings come preloaded in the software.

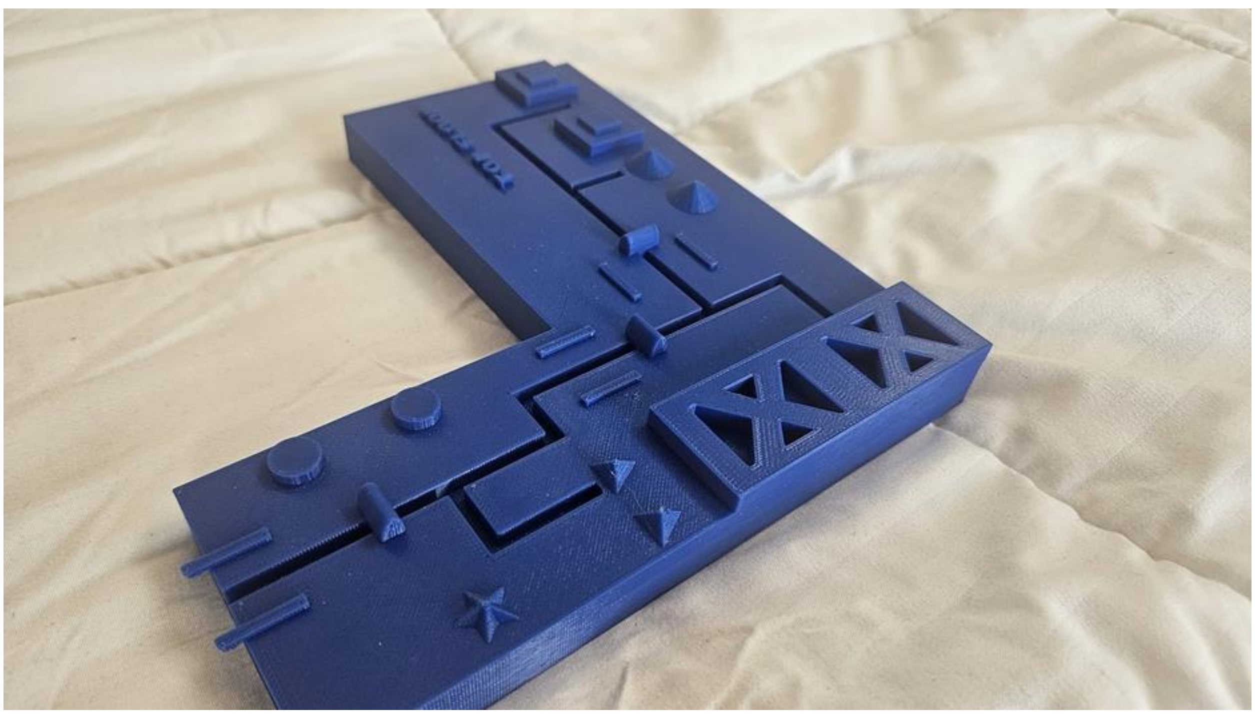

Figure 7.7: 3D-printed wayfinding tactile map for the top floor of the Medford/Tufts station

The top floor was printed in April 2024 using resources at the Cambridge HIVE makerspace, which uses the i3 MK3S model (Figure 7.7). The design file from TinkerCAD was exported as an .STL file onto a Cambridge HIVE USB device. This device was then connected to a Cambridge HIVE laptop and the .STL was uploaded to PrusaSlicer. Here, the print and filament settings were established. Print settings were defined by the default, such as the infill level being set at 15%. The infill defines the density of the filament inside the 3D printed object, and can be changed to make the object heavier, lighter, stable, or to reduce the amount of filament and/or time used in the process. In the “Skirt and Brim” print settings, an inner and outer brim were defined at two millimeters. Brims are extra support printed onto the design by the 3D printer and can be broken off upon completion. They help to stabilize the design when on the moving pad inside the machine and to stabilize or support any delicate or intricate elements of the design that are in danger of breaking off.

After the G-code was generated, it was uploaded to the USB and the USB device was disconnected from the laptop. The USB was then plugged into the HIVE’s Original Prusa i3 MK3S 3D printer. A dark blue filament was selected (Figure 7.8). The printer estimated the time to be about eight hours of printing. The top floor piece features a route through the top floor of the station, with a title written on the top in Braille and with raised characters.

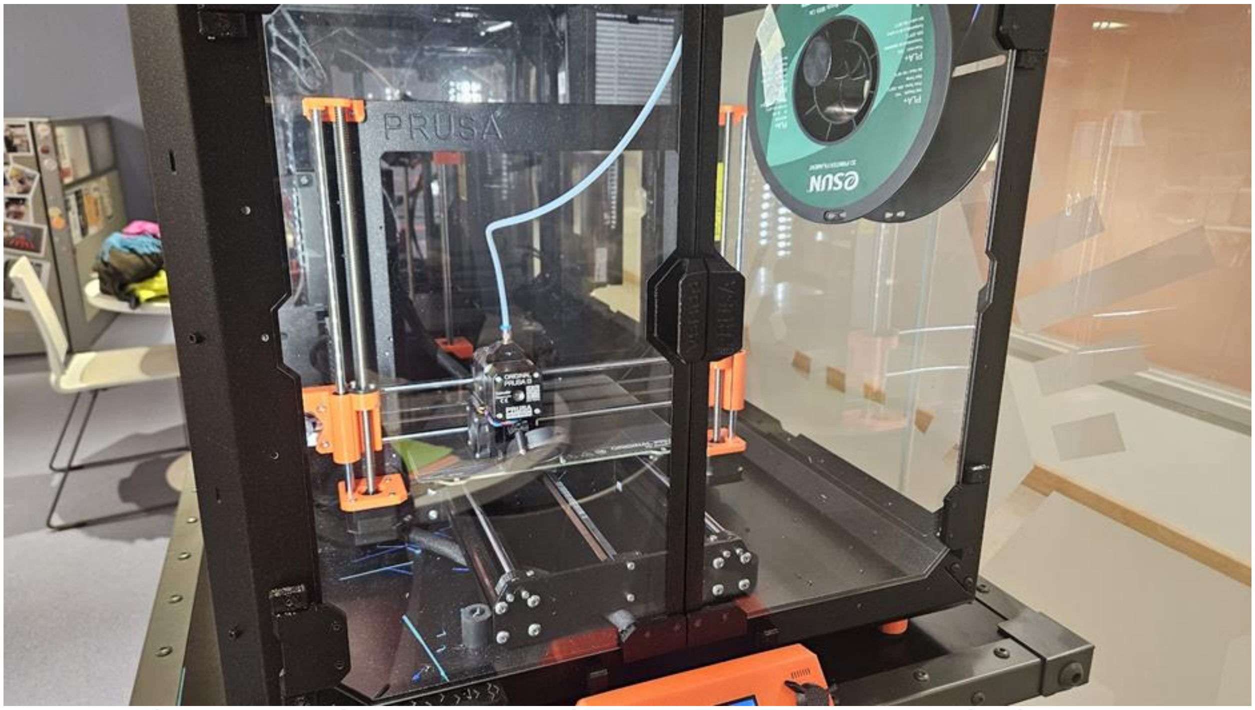

Figure 7.8: 3D printer at the Cambridge HIVE makerspace loaded with filament

The bottom floor and legend were printed at the Tufts Nolop makerspace using the MK4 model. Here, the PrusaSlicer software, version 2.7, was downloaded to the author's personal laptop. The bottom floor and legend designs in TinkerCAD were downloaded as an .STL and uploaded to PrusaSlicer, where default settings were selected and the inner and outer brims were defined at two millimeters. A dark green filament was selected. The print time for both pieces was about four hours. The bottom floor features the route through the station, with labels in Braille and with raised characters distinguishing the Inbound and Outbound platforms. The title of this piece is along the side, in both Braille and with raised characters. Everything printed on the legend is on the top of the piece.

The purpose of these maps (Figure 7.9) is to guide a user through their potential paths within this station system. It draws attention to relevant station elements and provides route options to the platform or to other needs, such as the bathroom. This map series took an estimated 25 total hours of time to complete, not counting print times.

Results

Figure 7.9: 3D-printed wayfinding maps for the top floor, bottom floor, and legend for the Medford/Tufts station

The first completed piece was the 3D-printed route navigation map of the Medford/Tufts top floor. The Braille for the title was not attached properly in TinkerCAD and fell off after printing. Other than that detail, the piece printed correctly. The Braille and raised characters for the title of the 3D-printed bottom floor were not printed correctly, possibly due to the element's location alongside the side of the piece, instead of being flat on the top. A few pieces of Braille throughout the legend (Figure 7.10) also got detached.

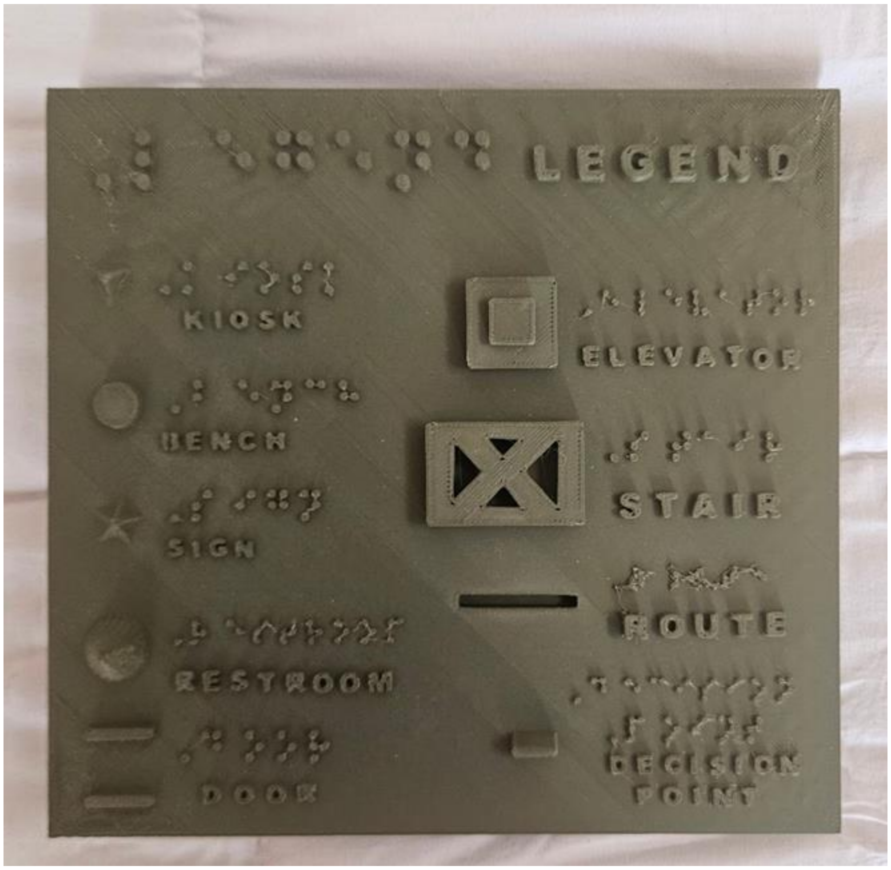

Figure 7.10: 3D-printed legend for the tactile wayfinding map for the Medford/Tufts station

The raised characters appeared to be too small and thick to distinguish individual letters with ease. Larger, thinner characters may help to mitigate this issue. The symbology for the stairs and elevators were much larger than other symbology on the map. While the elevator symbology was effective due to its ease of recognition via touch and closed eyes, the stair symbology was much less distinct. A simple design may have been more effective. Symbology for the ticket kiosks, benches, signage, restroom, doorways, decision points, and the route, all held the ability to be distinguished by touch without vision by the author. The scale of the bottom floor map appeared to be inaccurate, and therefore cramped. It is unclear how effective the use of the TinkerCAD Braille generator is unless tested on human subjects.

Figure 7.11: Close-up of the tactile neighborhood maps for the Medford/Tufts station

Though the neighborhood orientation maps (Figure 7.11) were not large enough to encompass the standard quarter-mile radius seen on the flat neighborhood maps on MBTA signage, the map series was still effective in displaying spatial relationships of the surrounding area outside the Medford/Tufts station. The text characters and Braille used in these maps were not scaled appropriately as both sets of characters are not distinguishable by touch.

Having received a “Not Human Subjects Research” determination from the Tufts Social, Behavioral, and Educational Research International Review Board (SBER IRB), the tactile maps were not tested on any human subjects.

Chapter 8. Discussion, Limitations, and Recommendations

Figure 8.1: Tactile-Braille signage at an MBTA fare kiosk

Discussion

MBTA: Low Vision and Blind Subway Riders

Q1 Discussion: How are needs met, and where are they unfulfilled?

At the MBTA, a space to communicate needs has been created through the establishment of agency trust. Trust was cited in the literature as an invaluable element to accessible transit planning, and it is upheld by intentional and consistent communications about accessibility at the agency. Quarterly reports from the System-Wide Accessibility campaign keep the public informed on the status of new accessibility considerations, such as elevator and escalator upgrades and improved signage at subway stations. In addition, the Access in Motion advertising campaign works to raise rider awareness about disability at the MBTA.

It can be inferred that this trust has been established specifically between the agency and the Riders' Transportation Access Group. When RTAG was informed of the tactile map prototypes created by the author and her connection to the agency representatives (the interview), three members of the group with blind or low vision conditions provided their contact information with an interest to assist. Fear and anxiety around new developments at the MBTA were mitigated, group trust perhaps strengthened by the fact that the MBTA agency representatives, one of whom is present at RTAG meetings, hold the disability perspective themselves.

Consistency has been seen to uphold trust. The SWA campaign acts as a figurehead for accessibility at the MBTA, providing a structure of consistent efforts through reporting and programming. By operating with a closed-loop complaint system, the agency maintains rider trust by providing actionable change to feedback, if applicable. Thanks to the signage unification project and ongoing renovations, riders are invited to partake in a system that fosters independence through standardized signage. This autonomy is promoted for low vision and blind riders specifically through other considerations, such as with tactile-Braille signage (Figure 8.1), the inclusion of raised characters (Figure 8.2), detectable infrastructure, visual cues, elevator and escalator access, bridge plates, passenger assistance stations, customer assistance areas, and the staffing of Transit Ambassadors.

Findings show that while current policies in Massachusetts dictating accessibility in the built environment focus on physical and visible disabilities (wheelchair use, hearing loss, and vision loss), low vision and blind conditions often cross over with a range of other physical and cognitive abilities. Other supportive resources at the MBTA include the Mobility Center, reduced fares, and paratransit options. Expert consultants reported that typically, riders with multiple disabilities or with different cognitive functions prefer paratransit options when considering public transportation for the privacy offered and the door-to-door functionality.

There is room for improvement regarding access to the fixed-route system the subway provides for low vision and blind riders. General accessibility considerations are still being met at certain subway stations, and consistency is not felt by clients at the MCB who cite that the trains are often late. Furthermore, riders are cited by the MBTA as being confused or uncomfortable when trying to navigate subway stations, with wayfinding in subway station terminals reported as non-compliant and inconsistent in the November 2023 SWA report.

To continue, a major issue facing wayfinding communication for low vision and blind subway riders at the MBTA is a lack of access to real-time information, as reported in the December 2023 RTAG meeting. While digital displays provide this key need to sighted readers, these gaps in the maps when it comes to relaying temporal route updates (snowy, icy, and wet conditions, delays, and redirections, and new construction) persist as barriers in the policy when considering ADA 216.1.3; that temporary messaging need not comply with the 2010 Standards of Accessible Design. A solution that is already combatting a lack of resources for communication are the MBTA Transit Ambassadors—with a distinctive red uniform and cap, they are trained to provide information and assistance to riders of all abilities.

Barriers to mobility are present in communications for low vision and blind riders outside of signage (and MBTA jurisdiction) in the form of poorly maintained sidewalks and low pedestrian infrastructure to stations. Ice at the bus ramps was another key complaint reported by the MBTA at the December 2023 RTAG meeting.

Figure 8.2: Raised characters inside an MBTA subway car

Q2 Discussion: What future actions are being considered, and which aspects are not being addressed?

The agency strives to move past narrow policy definitions of disability and accessibility to advance integration for low vision and blind ridership by requiring audible counterparts to every visual announcement (recall that only the reverse is required by code). To fully reflect the range of visual, physical, and cognitive disabilities experienced by populations with low vision or blind conditions, the agency must continue to operate beyond these limited definitions and lack of specific guidance reflected in the policies.

It is reported in the interviews that a reliance on tech-based solutions is not sustainable long-term. Anecdotally, loud announcements are disorienting for riders and guide dogs. The research also suggests that a combination of auditory, Braille, and tactile resources work best in developing personal orientation skills, skills stressed in the literature and by expert O&M

consultants as crucial for expanding low vision and blind rider independence (such as route navigation).

To address wayfinding compliance, the MBTA has piloted a number of different solutions. They have yet to find one that is permanent, and don't view tactile maps as "total game-changers" in part due to code compliance specifications around location and the fact that it is an element difficult to solicit feedback on. While expert consultants explained that there should be a map at each station, station layout maps at the MBTA *don't yet exist*. Though, tactile maps at some downtown multiline stations have been created to highlight the rider's route to the accessible entrance.

Q3 Discussion: How can a tactile map meet the needs of low vision and blind subway riders?

Representatives and research agree: while there isn't a unified method to accessible planning initiatives, a holistic approach to accessibility in the built environment builds confidence and trust in a system, the agency, and in riders themselves. It is likely that many riders needing assistance (permanent or temporary) use the MBTA, as the use of visual assistive devices per rider was observed as up to 3 in any ten-minute interval during the observational studies, and with MBTA agency representatives citing that there are low vision and blind riders of the subway. While technology can be a valuable tool in accessible wayfinding, moving away from a reliance on tech-based solutions is key for sustaining accessibility in the built environment. For the MBTA's subway system, riders need to be able to orient themselves even in situations without electric power, the audible announcements, smartphone access, or available WiFi service.

Tactile resources are a low- or no-tech solution that provide confirmation for all riders through sensory connections. Tactile maps also signal that there is a space for low vision and blind riders at the MBTA. While these maps are not considered “total game-changers”, the MBTA must prioritize sustainability and the holistic approach by innovating outside of standard tech-based solutions in accessible planning (such as the auditory announcements and digital displays of information). As the literature’s recommendation to build map skills is backed by O&M consultants interviewed for this study, it’s concluded that the introduction of tactile maps to the MBTA offers all riders, especially those with visual impairments, an opportunity to practice and learn by adding a much-needed wayfinding resource.

A common thread that emerged from this review is the need for tactile map development standards. This lack of order has led to a situation in which the tactile maps are not easy to create and therefore not utilized by those who would benefit, which in turn keeps demand low. Best practices from the literature and interviewees cite the reduction of visual clutter, the importance of a unified methodology for consistency, the benefits of a map series, and the simplification of spatial relationships and symbology. These resources must be consistent across a system and readily available to use.

As seen by the author’s experience, tactile maps do require dedicated time, effort, and resources to develop. It is unclear how much labor at the MBTA can be committed to staffing such an initiative, especially when considering that there are many ways to make a tactile map, each method with its own outcomes and purposes. However, a diverse portfolio of tactile resources fulfills a variety of needs and levels of understanding. As an example, the 3D-printed wayfinding maps convey spatial relationships of station elements and identify the rider’s route in a station layout. In comparison, the tactile neighborhood maps orient the user by describing the spatial relationships of surrounding roads and topographic features relative to the station at a local scale.

Limitations

There are two major limitations to this study:

1) *The author does not hold a low vision or blind perspective*
2) *The study did not undergo Human Subjects Research determination from the SBER IRB*

The essential low vision and blind perspective is missing from this study. This study was meant to highlight the process and challenges of creating tactile resources while reporting on the existing conditions of the MBTA's subway system for low vision and blind riders from inside perspectives, outside perspectives, and a policy perspective. It is not a step *towards* understanding accessibility, as there is no "one way forward" when it comes to accessible transit planning, nor is it meant to be an authority on the subject. Rather, it is a step outward in *expanding* understanding around low vision and blind subway ridership at the MBTA. It is key to note that the study focuses on the blind and low vision condition exclusively; the research shows that visual impairments are often experienced along other physical and cognitive disabilities, which this study does not account for.

Aside from human error, subjectivity was present in the study through determining the coding schema for the policy analysis, the standards for visible assistive devices to observe, and the rider counts for the observational study because the author is not part of the low vision community and may have missed key details. The observations fell across weekdays in June; the hot weather and the lunchtime hour may have contributed to rider use of the subway for those days and may not represent average commuter habits at Charles/MGH.

Tactile map size was dictated by the area of the 3D printing workspace, the digital TinkerCAD workspace, and the limitations of the swell paper needed for the tactile neighborhood maps. Therefore, the author was not able to include code-compliant raised characters and Braille, and these details are not effective the final prototype design.

Policy Recommendations

The MBTA should continue with ongoing efforts in upgrading subway stations to accessible code-compliance. Specific efforts should be focused on the staffing of in-person MBTA Transit Ambassadors and the providence of audible assistance for every visual announcement. In addition, the author encourages the agency to revisit efforts to pilot wayfinding signage at the agency, with the following recommendations.

1) ***Priority:*** *Reconnect with BIA.studio to collaborate and pilot ambulatory and assistive tactile wayfinding maps at key subway stations*

A unified pathway diagram system created by the studio has already provided ambulatory and assistive paths-of-travel for each MBTA station (at the time of development). The studio's signage software, SignMaker (Bertaux + Iwicks, 2015), was created specifically for the MBTA signage unification project and can create accessible wayfinding signage, and materials have already proven durability with the inclusion of outdoor tactile map signage at Downtown Crossing. Signage location, a hurdle to implementation at the MBTA, was determined by BIA.studio during the project and is code-compliant (at each entrance, at the customer assistance station, and to the right of doors). Compliance continues through text and Braille height, kerning, mount height, and the design of the mounted stand for locations without vertical access. When thinking about the rider's experience, the signage operates within the MBTA's "Correct, Clear, Consistent" unified signage methodology and requires minimal user effort.

2) *The author recommends the agency consider augmenting the existing porcelain and enamel rail maps (Figure 8.3) with raised characters, Braille translations, and potentially tactual symbology*

While not specific to route wayfinding within a station, a tactile understanding of the rail line dispels uncertainty and builds confidence in trying a new station.

Future Work

Future research on tactile maps work could include incorporating slope into these tactile resources. The inclusion of slope provides a missing key context for riders, indicating trip difficulty due to the grade of the path. The agency should also consider strengthening ties and unifying goals with municipal public works departments that share the area the MBTA services. This coordination can improve paths-of-travel to MBTA stations by providing safe pedestrian infrastructure (such as mitigating icy conditions at bus ramps).

Another place to focus efforts would be on expanding the tactile OSM symbology borrowed from Esri Nederland to incorporate Massachusetts floodplain zones, wet conditions, and snow and ice conditions. Though not addressing closures and delays, production of such seasonal tactile maps begins to fill a gap in real-time information, providing context for seasonal hazards. These maps could be developed on an on-demand basis, requested at the Mobility Center.

Figure 8.3: Porcelain and enamel rail map at Ball Square

References

ADA. "2010 ADA Standards for Accessible Design." *Americans with Disabilities Act*. 15 September 2010. https://www.ada.gov/law-and-regs/design-standards/.

Bailey, Sela. Personal interview with the author. 9 February 2024.

Baldwin, J. and N. Higgins. "New Zealand O&M instructors' perspectives about, and experience in, the use of tactile maps with people with vision impairment." *British Journal of Visual Impairment*, *41*(3), pp.634-645. 5 April 2022. https://doi.org/10.1177/02646196221088019.

Bertaux + Iwicks Architects. "MBTA signage system overview for design consultants." 2015. https://cdn.mbta.com/sites/default/files/engineering/001-design-standards-and-guidelines/2015-03-01-signage-system-overview.pdf.

Brelsford, Laura and Jennifer Ross. Personal interview with the author. 25 January 2024.

Brelsford, Laura, and the System-Wide Accessibility team. "Semi-Annual Accessibility Initiatives Report." *Massachusetts Department of Transportation* and *Massachusetts Bay Transit Authority*. June 2023. https://cdn.mbta.com/sites/default/files/2023-11/2023-11-27-accessibility-initiatives_0.pdf.

Bull, Alyson. Personal interview with the author. 1 February 2024.

CDC. "Disability and Health Data Index." *National Center on Birth Defects and Developmental Disabilities* and *Centers for Disease Control and Prevention*. 10 July 2024. https://www.cdc.gov/ncbddd/disabilityandhealth/.

Cole, Harrison and Anthony Robinson. "Thematic tactile maps for accessible flood mitigation planning: design and evaluation.” *Cartography and Geographic Information Science*, vol. 50, issue 6. 31 October 2023. https://doi-org.ezproxy.library.tufts.edu/10.1080/15230406.2023.2264747.

DiPetrillo, Stephanie, et al. “Improving Pathways to Transit for Persons with Disabilities.” *Mineta Transportation Institute*, Report 12-59. August 2016. https://transweb.sjsu.edu/sites/default/files/1233-transit-access-for-persons-with-disabilities.pdf.

Erin, Jane N. "Traveling by touch: how useful are tactile maps?" *Journal of Visual Impairment & Blindness* 103, no. 5. May 2009. https://link.gale.com/apps/doc/A201801254/AONE?u=mlin_oweb&sid=googleScholar&xid=7d45d44e.

American Foundation for the Blind. “Facts and Figures on Adults with Vision Loss from the National Health Interview Survey (NHIS).” *Afb.org*. Updated February 2024. https://www.afb.org/research-and-initiatives/statistics/adults.

Feucht, Florian C., and Chelsea R. Holmgren. “Developing Tactile Maps for Students with Visual Impairments: A Case Study for Customizing Accommodations.” *Journal of Visual Impairment and Blindness,* vol 112, no. 2. Sage Publications Inc. April 2018. https://link.gale.com/apps/doc/A648084863/AONE?u=mlin_oweb&sid=googleScholar&xid=cffb30ca.

Frye, Anne. “Disability Inclusive Public Transport: Practical Steps to Making Public Transport Disability Inclusive.” *Transformative Urban Mobility Initiative*. 2019. https://www.transformative-mobility.org/wp-content/uploads/2023/03/HVT-Disability_STANDARD_ONLINE_v2A-E49nOR.pdf.

Jacobs Engineering Group. “ADA Transition Plans: A Guide to Best Management Practices.” *The National Academy of Sciences National Cooperative Highway Research Program.* NCHRP Project Number 20-7 (232). May 2009. https://www.fhwa.dot.gov/indiv/docs/ada_transition_plans_report.pdf.

Jerman, Eric. Personal interview with the author. 8 February 2024.

Litman, Todd. “Evaluating Accessibility for Transport Planning: Measuring People’s Ability to Reach Desired Services and Activities.” *Victoria Transport Policy Institute*. 1 August 2007. https://www.vtpi.org/access.pdf.

Lobben, Amy. “Tactile Maps and Mapping.” Journal of Blindness and Innovation Research, vol 5, no. 1. 2015. https://nfb.org/images/nfb/publications/jbir/jbir15/jbir050102.html.

Luxton, K., M. Banai, and R. Kuperman. “The Usefulness of Tactual Maps of the New York City Subway System”. *Journal of Visual Impairment & Blindness,* 88(1), 75-84. January 1994. https://doi.org/10.1177/0145482X9408800110.

Main, Paul. “Tactile Learning.” *Structurallearning.com.* 15 February 2024. https://www.structural-learning.com/post/tactile-learning.

Mather, Mark, Linda A. Jacobsen, and Kevin Pollard. “Aging Baby Boomers to Face Caregiving, Obesity, Inequality Challenges.” *Population Bulletin*, vol 70, no. 2. 13 January 2016. https://www.prb.org/resources/aging-baby-boomers-to-face-caregiving-obesity-inequality-challenges/.

“Mass Transit for Blind Travelers.” *Futurist*, vol 25, no. 1, pg. 41. January 1991. https://web.s.ebscohost.com/ehost/pdfviewer/pdfviewer?vid=2&sid=0b35bd5f-fd44-4312-bcb0-d12b83d4a82e%40redis.

National Aging and Disability Transportation Center (NADTC). “ADA & Paratransit.” N.d., https://www.nadtc.org/about/transportation-aging-disability/ada-and-paratransit/#:~:text=What%20is%20ADA%20complementary%20paratransit,service%20because%20of%20a%20disability.

National Aging and Disability Transportation Center (NADTC). “Best Practices Compendium.” September 2021. https://www.nadtc.org/wp-content/uploads/NADTC-BPCompendium_508.pdf.

Papadopoulos, K., M. Barouti, and K. Charitakis. “A University Indoors Audio-Tactile Mobility Aid for Individuals with Blindness.”. *Computers Helping People with Special Needs*. *Lecture Notes in Computer Science*, vol 8548. 2014. https://link.springer.com/chapter/10.1007/978-3-319-08599-9_17.

Rowell, Jonathan, and Simon Ungar. "Feeling our way: tactile map user requirements-a survey." *International Cartographic Conference, La Coruna*, vol. 152. 2005.

United States Department of Transportation (USDOT). “Draft Strategic Plan on Accessible Transportation.” January 2021. https://www.transportation.gov/sites/dot.gov/files/2021-01/DOT%20Draft%20Strategic%20Plan%20on%20Accessible%20Transportation%20January%202021_1.pdf.

Van der Vaart, Niels. Personal interview with the author. 22 February 2024.

Appendix

Interview Questions - MBTA

1) When it comes to low vision and blind riders, is the MBTA planning any more initiatives outside of Braille, auditory assistance, and free ridership?
2) Does the MBTA have insight into which systems are used by low vision and blind riders?
    a. Are they often using rapid transit, or the bus system? Do many take the Ride?
    b. If they are using rapid transit, are there any stations in particular that are used more frequently?
3) What feedback, if any, has been given regarding the MBTA's efforts with low vision and blind riders?
    a. Do representatives from this population feel that they can navigate MBTA systems autonomously?
    b. If not, what gaps have been noticed?
4) When does the MBTA plan on completing their System-Wide Accessibility (SWA) initiatives? (Currently in-progress)
5) What did the process of creating the SWA initiatives look like?
    a. Were there focus groups with target populations?
    b. Did the MBTA consult with experts on developing these initiatives? Was it a closed process?

Interview Questions - Expert Consultants

1) How familiar are you with tactile maps?

    a. How common is this assistive device in the world of blind and low vision?

2) In your expert opinion, how relevant are these assistive devices?
    a. Is this a need for MBTA riders?
3) For the populations you work with, in general how are they getting around?
    a. How common is it for them to use the MBTA system?
        i. Bus?
        ii. Rapid Transit?
        iii. The RIDE?
    b. Are they using the bus over the subway? Do people tend to not use the MBTA?
        i. If people are dissuaded from using the MBTA - why?
    c. How are people getting around, if not the MBTA?
        i. Personal Drivers
        ii. Personal Vehicles
        iii. Walking
        iv. Other assistance

Interview Questions - Tactile Maps

1) What do modern tactile maps look like?
    a. Popularity/usage
        i. Why are they used?
        ii. Why aren't they used?
        iii. Who uses them?
            1. Demographics of low vision users - age?

2. Used in other contexts?

b. What efforts are required in creating tactile maps?

i. Money

ii. Time

iii. Focus groups?

2) Best Practices

a. Method of creation/development

i. Insight into what method works best where?

Interview Questions - BIA.studio

1) What elements of the station layout are necessary for MBTA signage?

a. How is this information organized according to unified MBTA standards?