Final Report

Advanced Mobility for People with Disabilities: Autonomous Wheelchair Pilot Deployment at the BWI Airport- Phase 3

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This project developed and piloted an autonomous wheelchair system and smartphone-based navigation app at BWI Airport to enhance independent mobility for passengers with disabilities. The powered wheelchair system uses a collection of sensors, including cameras and LiDAR, to detect objects in its environment, while a cloud-based mobile application allows users to request rides and select destinations throughout the airport. An important part of the system is the integration of QR-code-based location identification, user authentication, and guided navigation, which together create a structured and reliable user experience. Technical milestones include the implementation of guided-route and fully autonomous navigation modes, as well as successful field demonstrations in which the wheelchair navigated from the airport entrance to an airline gate while passing through security at walking speed. Beyond technical validation, the project also contributed to workforce development in universal design and received significant media coverage. These results reflect a successful transition from simulation to real-world deployment while identifying key areas for future refinement, such as localization robustness and system scalability for broader operational adoption.</td></tr>
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Abstract

This project developed and piloted an autonomous wheelchair system and smartphone-based navigation app at BWI Airport to enhance independent mobility for passengers with disabilities. The powered wheelchair system uses a collection of sensors, including cameras and LiDAR, to detect objects in its environment, while a cloud-based mobile application allows users to request rides and select destinations throughout the airport. An important part of the system is the integration of QR-code-based location identification, user authentication, and guided navigation, which together create a structured and reliable workflow. Technical milestones include the implementation of guided-route and fully autonomous navigation modes, as well as successful field demonstrations in which the wheelchair navigated from the airport entrance to an airline gate while passing through security at walking speed. Beyond technical validation, the project also contributed to workforce development in universal design and received significant media coverage. These results reflect a successful transition from simulation to real-world deployment while identifying key areas for future refinement, such as localization robustness and system scalability for broader operational adoption.

Introduction

Providing reliable mobility assistance is essential for access to air travel. Large terminals, long walking distances, security checkpoints, and time-critical wayfinding can create unique challenges for passengers who use mobility devices or who cannot comfortably walk extended distances. U.S. Department of Transportation guidance emphasizes that air travelers with disabilities are entitled to assistance throughout the airport and in key functional areas such as ticket counters and checkpoints (U.S. Department of Transportation, 2025).

This final report documents the work completed during the reporting period for the project titled "Advanced Mobility for People with Disabilities: Autonomous Wheelchair Pilot Deployment at the BWI Airport (Phase 3)." The project focuses on an autonomous wheelchair system that can be summoned and directed using a smartphone application, enabling a passenger-centered workflow for mobility assistance within an airport environment.

From a policy perspective, air travelers with disabilities have rights under the Air Carrier Access Act (ACAA) and its implementing regulation (14 CFR Part 382), summarized in the U.S. Department of Transportation's Airline Passengers with Disabilities Bill of Rights (U.S. Department of Transportation, 2022). DOT guidance also describes required wheelchair and guided assistance across key airport segments, including navigation through the security checkpoint and to the departure gate (U.S. Department of Transportation, 2025). The present project aligns with these expectations by exploring a technology-assisted approach that aims to increase independence while supporting safe and dignified travel.

Project objectives for the Phase 3 airport pilot were to increase traveler independence and control in large public facilities; reduce uncertainty associated with staff-mediated, ad hoc coordination; improve the reliability and user experience of mobility assistance; and demonstrate a scalable model suitable for replication in other complex indoor environments such as airports, hospitals, museums, campuses, and similar facilities.

This report is organized using an Introduction–Literature Review–Methods–Results–Discussion–Conclusion structure. Throughout, the document emphasizes verified information from project records and publicly available coverage of the pilot demonstration and deployment.

Literature Review

Smart wheelchairs have been studied for several decades as a pathway to expand mobility and independence for users with disabilities. In a widely cited review, Simpson (2005) summarized the state of the art and highlighted recurring challenges such as safe navigation in crowded environments, robust sensing and localization, intuitive human–machine interfaces, and the need to balance autonomy with user control.

Modern autonomous mobility systems typically rely on a perception–localization–planning–control pipeline. Probabilistic state estimation and sensor fusion are foundational concepts for mobile robots operating under uncertainty (Thrun, Burgard, & Fox, 2005). For indoor environments, simultaneous localization and mapping (SLAM) is often used to estimate position while building or updating a map; comprehensive surveys describe how SLAM methods have evolved to improve robustness and scalability (Cadena et al., 2016).

Indoor navigation introduces additional constraints because satellite-based positioning is unreliable or unavailable indoors. Surveys of location systems for ubiquitous computing and indoor positioning describe a wide range of approaches (e.g., RF, proximity beacons, and marker-based systems) and show trade-offs among accuracy, infrastructure cost, and operational complexity (Hightower & Borriello, 2001; Liu, Darabi, Banerjee, & Liu, 2007). Marker-based techniques such as QR-code landmarks can be attractive in settings where controlled, low-cost infrastructure is feasible and where deterministic "known points" support user workflows (e.g., pickup zones and checkpoints).

Safety and human–robot interaction are central to deploying autonomous devices in public spaces. ISO 13482:2014 specifies safety requirements and hazard considerations for personal care robots that operate in close proximity to humans (International Organization for Standardization, 2014). While an autonomous wheelchair deployed in an airport is not necessarily regulated as a medical device in this context, the standard's emphasis on risk reduction, predictable behavior, and human-aware operation provides relevant engineering guidance for public-facing deployments.

Methods

The project method combined (i) system engineering of a sensor-equipped powered wheelchair platform, (ii) development of a mobile application and cloud backend to support passenger-facing workflows, and (iii) pilot deployment and demonstration activities in an operational airport environment. The approach emphasized integration, iterative testing, and stakeholder-facing demonstrations to validate feasibility in real-world conditions.

System Architecture and Operating Concept

The autonomous wheelchair platform was built by modifying a conventional powered wheelchair and adding sensing, computing, and control components to support perception and navigation in indoor spaces. Public documentation of the pilot describes the integration of cameras and LiDAR sensors for environmental perception and a single-board computer for onboard processing (Morgan State University, 2025). Project materials also reference computer vision and machine learning components used to support navigation functions (Morgan State University, 2025).

For the airport pilot, the autonomous wheelchair was configured for guided-route operation in the terminal environment. Public descriptions emphasize a design approach that prioritizes reliable operation in busy indoor spaces through a defined operating concept, with sensing and computing hardware supporting perception and safe movement along established routes (Morgan State University, 2025).

Mobile Application and Cloud Backend

A smartphone application was developed to provide a passenger-centered interface for requesting and directing the autonomous wheelchair. Public descriptions indicate that passengers can summon the wheelchair via the app from designated areas, authenticate to confirm the correct user, and enter a destination or scan a ticket for guided travel within the terminal (Morgan State University, 2025; Descant, 2025).

The workflow leverages QR codes placed at designated areas. A passenger scans a QR code to access the app workflow, registers or logs in, and initiates a wheelchair request. The system includes an authentication step to confirm that the person who summoned the wheelchair is the intended user before transport begins (Morgan State University, 2025; AfroTech, 2025). After authentication, the user (or supervised operator during demonstrations) can enter a destination; the wheelchair then follows a guided route through the terminal to the selected location (Morgan State University, 2025).

At a functional level, the digital workflow supports request initiation, pickup-zone identification, destination selection, and status updates to coordinate wheelchair movements. Public coverage also reported that the pilot supports user-directed routing features such as making multiple stops during navigation in the airport environment (Descant, 2025).

The mobile application was designed to guide users through each step of the process in a clear way. The goal of the design was to reduce confusion and make the system easy to use, especially in a busy airport environment where quick interaction is key. This structure also helps make sure that the system operates well by showing the user through a consistent workflow from request to navigation.

Pilot Deployment and Demonstration Planning

Pilot deployment required coordination with airport stakeholders and planning for safe operation in public-facing corridors. The pilot included a public demonstration event at BWI Airport attended by transportation and aviation leadership, disability advocacy leadership, and university leadership, showcasing the wheelchair's operation in a live terminal setting (Morgan State University, 2025).

During demonstration operations, student operators supervised the wheelchair while issuing mobile commands, directing the system along a predefined path. Public documentation describes a route that began at an airport entrance, proceeded to a ticket counter, and continued through a security checkpoint. The wheelchair and its occupant then successfully completed security screening with Transportation Security Administration personnel (Morgan State University, 2025; Black Enterprise, 2025). This demonstration provided a full end-to-end test of the system, including user interaction through the mobile application, authentication, and guided navigation through multiple airport locations. It helped prove both the technical performance of the wheelchair and the effectiveness of the mobile workflow in a real-world environment.

Operational speed was intentionally constrained to walking pace during demonstration activities (Morgan State University, 2025; AfroTech, 2025). This constraint supports safer interaction in crowded environments and aligns with the broader emphasis on predictable motion and risk reduction recommended for robots operating near people (International Organization for Standardization, 2014).

Testing, Verification, and Project Coordination

Testing and verification proceeded in staged fashion, progressing from controlled evaluations to public-facing operations in the terminal environment. This staged approach supports risk reduction by validating the passenger-facing workflow and wheelchair behavior prior to broader scaling in crowded facilities. This allowed for routine improvements to both the navigation system and the mobile application. Making sure that issues could be found and fixed before full deployment in a live airport environment.

Project coordination supported iterative refinement and readiness for stakeholder-facing events, including integration between the wheelchair platform and the mobile workflow, preparation for demonstrations, and planning for facility-specific testing considerations.

Workforce Development

Workforce development was embedded throughout the project through hands-on engagement of graduate researchers in engineering, testing, demonstration support, and stakeholder communication. Public documentation of the airport demonstration highlights the role of student researchers in operating and supervising the system during pilot activities (Morgan State University, 2025). This hands-on involvement gave students experience in systems integration between hardware and software, mobile application development, and real-world testing, which work to improve both technical and practical skills of accessible transportation systems.

Results

This section summarizes documented outputs and outcomes from the reporting period, including implemented system components, pilot deployment activities at BWI Airport, dissemination, and readiness considerations.

Implemented System Capabilities

Implemented outputs from the reporting period include: (i) a mobile application for requesting and directing the autonomous wheelchair; (ii) supporting digital services for managing requests and routing information; and (iii) an operational autonomous wheelchair configuration suitable for guided-route movement in an airport terminal (Morgan State University, 2025; Descant, 2025). These parts work together to create a system that allows a user to request, authenticate, and navigate through the airport in a coordinated way. This integration is important because it connects the mobile application with the wheelchair, allowing for a full end-to-end solution.

Public coverage and university documentation indicate that the pilot operated multiple autonomous wheelchairs as part of the deployment, and that the project team anticipated the potential to expand the pilot fleet (Morgan State University, 2025; Descant, 2025; AfroTech, 2025).

Table 1. Implemented system components and documented functions.

Subsystem	Implementation (as documented)	Documented function / role
Wheelchair platform	Modified powered wheelchair with cameras, LiDAR, and onboard computing	Perception, navigation support, and supervised guided-route movement in terminal environments
Mobile application	Cross-platform app developed using Flutter	User registration/login, request initiation, QR-code scanning, destination selection
Cloud services and database	Firebase authentication and real-time database services	Secure user access; storage/synchronization of locations, routes, preferences, and request status
Pickup-zone identification	QR codes at designated areas	Deterministic location identification to initiate requests and support structured workflows
Guided-route operation	Predefined routes in terminal spaces	Improved reliability and predictability in crowded corridors during pilot operations

Authentication workflow	User verification prior to boarding/transport	Reduce misuse and ensure the wheelchair is matched to the intended passenger

Pilot Demonstration Outcomes

At the public demonstration event, the wheelchair was summoned through the smartphone workflow and traveled along a predefined route in the terminal at walking speed. University documentation reports that the wheelchair moved from a terminal entry door to the ticket counter and then proceeded through a security checkpoint, successfully completing screening with security personnel (Morgan State University, 2025). Media coverage similarly described the wheelchair traversing a guided path with a passenger on board and passing through a security checkpoint (Black Enterprise, 2025).

The demonstration also served as an integrated test of the passenger-facing workflow: QR-code-based location identification, user authentication, destination selection, and guided route execution (Morgan State University, 2025; AfroTech, 2025). These results show that the system works in a real-world airport environment while also maintaining a structured workflow. The successful navigation through the terminal demonstrates both technical functionality of the wheelchair and effectiveness of the mobile application in supporting user interaction.

Dissemination and Outreach

Dissemination during the reporting period included stakeholder demonstrations and external media coverage describing the pilot deployment and its intended benefits for travelers with mobility disabilities and other passengers who may have difficulty walking long distances (Morgan State University, 2025; Descant, 2025; Black Enterprise, 2025; AfroTech, 2025). Which helped increase awareness of the system and showed the potential impact it can have on user-friendliness within transportation environments.

Table 2. Examples of stakeholder engagement and dissemination activities documented during the reporting period.

Activity type	Documented examples
Demonstrations / site events	Airport pilot demonstration; additional demonstrations at research symposia and visits (per internal documentation)
Media coverage	University news release and external articles describing the pilot deployment and user workflow
Scholarly dissemination	Conference paper prepared/submitted describing lessons learned from mobile-application development and deployment workflow
Student training	Hands-on training in app development, backend services, sensor integration, and system operation

Technology Readiness and Documented Issues

Available documentation emphasizes completion of a functional system suitable for guided-route operation in a public terminal setting, with the airport pilot serving as a major milestone toward broader implementation and routine operations. Continued validation across additional environments and operating conditions remains important for future scaling.

As with many indoor autonomy systems, reliability depends on robust initialization procedures, clear user feedback, and defensive software design for real-world variability. Ongoing refinement of the user workflow and error handling supports readiness for expanded deployment.

Planned Expansion Testing

Beyond the airport environment, additional facility-based testing was identified as a useful next step to broaden validation, refine navigation performance in corridors and common areas, and gather user-centered feedback related to comfort, convenience, and safety. Expanding testing to more environments will allow for more robust evaluation of system scalability, ensuring that navigation and workflow can adapt to different types of indoor spaces.

Discussion

The autonomous wheelchair pilot demonstrates a promising direction for improving mobility assistance in large transportation hubs. By shifting portions of the workflow to a passenger-directed mobile interface (request initiation, pickup-zone identification, and destination specification), the approach targets known friction points in traditional assistance services such as uncertainty and dependency on staff coordination, while remaining aligned with U.S. guidance on providing assistance to air travelers with disabilities (U.S. Department of Transportation, 2025). This shift to a user-directed mobile workflow is important because it allows passengers to interact directly with the system, reducing reliance on staff and improving efficiency in mobility assistance.

Airports are attractive but challenging settings for autonomous technology: they have a defined footprint, yet contain complex flows of people, equipment, and operational constraints. Media coverage of the pilot highlighted both this opportunity and complexity, emphasizing that such hubs provide many opportunities for efficiency improvements while requiring careful coordination with existing airport operations (Descant, 2025). The project's choice to use guided routes and walking-speed operation during public-facing demonstrations is consistent with risk-reduction practices for robots operating near people (International Organization for Standardization, 2014) and provides a pragmatic pathway to early deployment.

From a technical standpoint, the project's QR-code-based location identification is well aligned with known indoor positioning trade-offs. Indoor location surveys emphasize that infrastructure-assisted approaches can provide reliable positioning where GPS is unavailable, but system robustness depends on marker placement, initialization procedures, and fault handling (Hightower & Borriello, 2001; Liu et al., 2007). The airport pilot's emphasis on designated areas and guided routes reflects these practical considerations for real-world indoor deployments.

Several limitations remain. First, available documentation emphasizes functional demonstration and staged testing rather than large-sample passenger trials with quantitative performance metrics (e.g., time savings, user satisfaction, navigation error rates). Second, routine operations in a busy terminal will require continued attention to safe interaction with pedestrians, predictable motion, and clear responsibility boundaries between autonomous operation and human supervision. Third, scaling the pilot (e.g., increasing fleet size or extending to additional airport zones) will necessitate operational planning for charging, maintenance, and incident response. Addressing these limitations will be important for transitioning the system from a pilot demonstration to a deployable solution in large scale environments like an airport.

Based on documented progress and observed needs, the next steps recommended for continued development include: (i) expanding testing to additional indoor facilities to increase environmental diversity; (ii) strengthening localization initialization and error recovery; (iii) formalizing safety and operational procedures consistent with relevant service robot safety guidance; and (iv) conducting structured user studies to quantify benefits, limitations, and user experience outcomes. These steps will help translate a successful pilot demonstration into a deployable service model that supports reasonable access to travel.

Conclusion

During the reporting period, the project advanced an autonomous wheelchair system from integrated software development and simulated validation to pilot deployment and public demonstration at BWI Airport. Documented accomplishments include a smartphone application and cloud backend enabling QR-code-based requests and user authentication, a sensor-equipped wheelchair platform configured for guided-route operation, and demonstration of terminal navigation at walking speed including successful traversal of a security checkpoint under supervision. The integration of the mobile application with the wheelchair platform shows how important it is to combine user centered design with automated system development to create a practical mobility solution.

The work also delivered meaningful workforce development through student training and participation across system engineering, software development, and deployment preparation. While the pilot demonstrated feasibility and generated public and stakeholder visibility, project records also document remaining technical and operational steps required for broader implementation, including robustness improvements for location initialization and expanded validation in additional environments.

Overall, the Phase 2 pilot provides a credible foundation for continued research, testing, and operational planning toward scalable mobility assistance that supports independence and dignity for travelers with disabilities.

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Appendix A. Timeline of Documented Milestones

The milestones below are ordered chronologically and are derived from project documentation and publicly available descriptions of the airport pilot deployment.

Project phase (chronological)	Milestone / activity	Outcome / deliverable
System planning and stakeholder coordination	Coordination with airport stakeholders; demonstration planning and logistics	Structured on-site demonstration plan and stakeholder engagement materials (including run-of-show agenda)
Mobile application and backend development	Development of a cross-platform mobile app and cloud backend supporting login, QR scanning, requests, authentication, and routing	Operational app workflow connected to a real-time database and user authentication services
Staged testing and refinement	Simulated and functional testing of the software stack; identification of location initialization issues	Issue tracking and targeted improvements for QR-code initialization and location handling
Airport pilot deployment and demonstration	Public pilot demonstration of supervised navigation along a predefined route at walking speed, including traversal of a security checkpoint	Integrated demonstration validating end-to-end workflow and guided-route movement in an operational terminal setting
Dissemination and knowledge transfer	Demonstrations to external stakeholders; preparation of scholarly and practitioner-facing materials; media coverage	Public visibility for the pilot, documentation of lessons learned, and dissemination beyond the research team
Planning for expanded validation	Identification of additional indoor environments for broader testing (e.g., HHSC facility)	Test planning to evaluate adaptability, comfort, user-friendliness, and safety beyond the airport setting