2023 - 2024 ACRP University Design Competition

GlidePath: An Electrically Assisted Aisle Boarding Chair for Airports

(January 2024 - April 2024)

Design Challenge: Passenger Experience and Innovations in Airport Terminal Design: *Innovations to accommodate passengers with disabilities and aging passenger demographics at airports*

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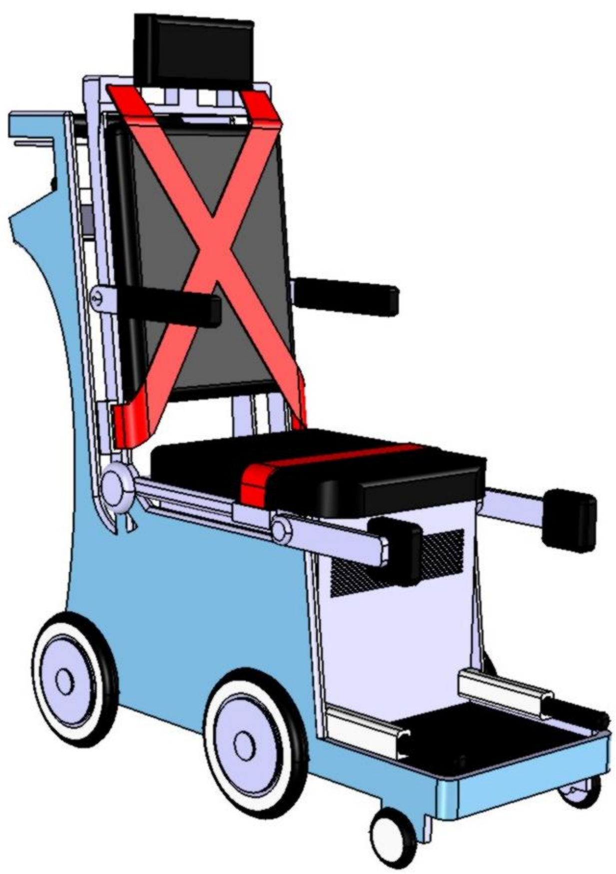

Executive Summary

Accessibility during aircraft enplaning and deplaning are a critical, yet often overlooked, aspect of air travel. Many technology-enabled wheelchairs have been researched and designed; none reach past the airport gate. Therefore, we propose an innovative design for an electrically assisted aisle boarding chair to enable enplaning and deplaning for persons with reduced mobility (PRM). The design will address the **ACRP Passenger Experience and Innovations in Airport Terminal** design challenge, subcategory B - *Innovations to accommodate passengers with disabilities and aging passenger demographics at airports*.

The design process began with a literature review to identify gaps in technological applications that improve airport accessibility. Throughout this process and into the design phase, the team held semi-structured meetings with industry experts from four airports (DFW, PHX, SAV, IAD) in addition to four government and non-government organizations. Their feedback informed our team's problem-solving approach, which ultimately resulted in a solution that promotes the safety of both the passenger and attendant by eliminating excessive push/pull forces and decreasing the seat transfer gap, all while decreasing boarding time. A benefit-cost analysis and sustainability assessment were performed to assess the viability of the proposal. Our solution is expected to cost **$347,611** and the anticipated benefits are **$2,156,224**. The benefit-cost ratio was calculated to be **6.20** for ten years of operation per gate in one medium-hub airport. Our solution's sustainability was assessed using an EONS model, evaluating economic vitality, operational efficiency, natural resource conservation, and social responsibility (ACI, n.d.). It also addresses the United Nations' (UN) Sustainable Development Goals (SDGs) 5, 8, 9, 10, and 11. This proposal presents an innovative solution that intends to promote sustainability and accessibility in air travel.

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Problem Statement and Background

Between 2017 and 2021, 55% of the accessibility complaints received the by United States Department of Transportation (DOT) were related to wheelchair users (DOT, 2017; DOT, 2018; DOT 2019; DOT 2020; DOT, 2021). According to the U.S. Census Bureau, as of 2021, about 13.5% of the U.S. population has some type of disability, with the most common being ambulatory disabilities. Of those with ambulatory disabilities, roughly 30% are over the age of 75 (Elflein, 2023). The aging demographic and increase in disabilities will require airports to adopt new technologies to increase accessibility. Many commercial efforts are attempting to capitalize on technological advances to improve the travel experience for persons with reduced mobility (PRM). An opportunity exists to integrate existing technologies into an aircraft boarding aisle chair to reduce wheelchair attendant injuries, ease PRM seat transfer, and decrease total enplaning/deplaning time for PRM.

The global population has seen a significant shift marked by an aging population. By 2030, 1 out of 6 people will be 60 years or older (WHO, 2022). In 2020 alone, the number of people aged 60 years and above outnumbered children younger than 5 years of age (WHO, 2022). According to *Airport Cooperative Research Program* (ACRP) *Report 210*, an estimated 10,000 people per day turn 65 years old in the U.S (ACRP, 2020). According to a report by the Administration on Aging, the population of individuals in the US aged 65 and older is projected to increase from 55.7 million in 2020 to 94.7 million in 2060, a 70% increase (Administration on Aging, 2021). This shift in demographics is indicative of the population that airports may increasingly encounter in the coming decades.

Airports are aware of this growing demographic and work hard to ensure the well-being and safety of disabled passengers. Yet current efforts are not perfect. Statistics provided by the

Department of Transportation (DOT) reveal that the total number of disability-related complaints increased from 32,047 to 36,434 from 2021 to 2022; a 13% increase (US DOT, 2023). Airports must continue to coordinate with Airlines to provide innovative solutions that meet the needs of PRM travelers.

Past ACRP design competition proposals and various companies already provide solutions to help accommodate passengers with disabilities. Specifically, many design mobility assistance tools, such as wheelchair designs, to assist the elderly and mobility-restricted passengers. Ha et al. (2022) provided a design for an autonomous wheelchair called AUSW to help with mobility and wayfinding issues. Blueberry Technology (2023) and WHILL (2024) have designed autonomous wheelchairs that are already being trialed at airports.

However, these solutions only focus on the restricted mobility passenger experience within the airport environment. A major gap still exists in addressing the challenges associated with airplane enplaning/deplaning, specifically for PRM. The process of transitioning passengers from the airport gate onto the aircraft has received little to no attention in terms of product design. By specifically designing a boarding chair to help with the boarding process, this current gap in accessibility efforts will be addressed, while also increasing operational boarding efficiency and empowering disabled passengers in the airport.

Gaspar (2016) elaborates on how passengers with reduced mobility represent a market with many opportunities. *ACRP Report 210* shows how 71% of adults with disabilities traveled at least once in a two-year period since 2002 (ACRP, 2020). The same report mentions how more than one in four travelers with disabilities traveled internationally in the past 5 years, spending around $2,500 on travel-related expenses. The disability travel market alone accounted for $4.5 billion in 2015 (ACRP, 2020).

This proposal focuses on the **ACRP Passenger Experience and Innovations in Airport Terminal** design challenge. The proposed wheelchair design aims to address the challenge by enabling safe and efficient enplaning/deplaning of PRM. A more effective boarding process for PRM will improve the safety and comfort of both the attendant and passenger and decrease turnaround time. If not prepared, airports could miss out on this growing market, and suffer losses in terms of employee injury, employee turnover, passenger injury, and overall throughput.

Summary of Literature Review

Regulatory Compliance for Accessibility

Airports and airlines operating in the United States are legally required to provide accessibility and mobility assistance to disabled passengers. Three federal policies govern accessibility in air travel in the United States: Section 504 of the Rehabilitation Act of 1973, The Americans with Disabilities Act of 1990, and The Air Carriers Access Act of 1986.

Section 504 of the Rehabilitation Act (1973) prohibits disability-based discrimination in facilities receiving federal funding. An airport's legal requirement to adhere to Section 504 is dependent on receiving federal funding. However, reliance on federal funding for infrastructure developments continues to increase. In 2023, airports in 55 US states and territories received federal funding for infrastructure projects through the FAA's Airport Improvement Plan (FAA, 2023).

The American with Disabilities Act of 1990 (ADA) prohibits discrimination based on disability in various areas of life (ADA, 1990). *ACRP Synthesis 51: Impacts of Aging Travelers of Airports,* adds that the ADA defines a disabled person as "one with a physical or mental impairment that substantially limits one or more major life activities" (ACRP, 2014, p. 4). Title

II of the ADA applies directly to airports operated by local, state, or the federal government. Under Title II airports cannot deny services to any individual based on disability. Title II applies to airport terminals, parking lots, and ground transportation. Title III of the ADA prohibits discrimination in privately held places of public accommodation mandating airport restaurants, shops, lounges, and other facilities be accessible (ADA, 1990).

The Air Carriers Access Act of 1986 (ACAA) prohibits discrimination on the basis of disability for all air carriers operating in the Unites States (ACAA, 1986). Passengers have the right to receive timely assistance, travel with wheelchairs, mobility aids, and other assistive devices, receive seating accommodation, receive announcements in an accessible format, and speak with a complaint officer (ACAA, 1986). Aircraft accessibility, facility accessibility, seating accommodations, handling of assistive devices, service animals, and personnel training are outlined in the ACAA (Pfeiffer et al., 2023). *ACRP Report 157: Improving the Airport Customer Experience,* states how Airlines in the U.S are generally responsible for wheelchair assistance (ACRP, 2016).

Disability Problems

According to Gaspar (2016), a thorough knowledge of the challenges and needs of passengers with disabilities is essential for the effective design of services for increased accessibility. *ACRP Synthesis 51* provides a list of the most prevalent difficulties that older passengers face when navigating through airports (ACRP, 2014). This list is synonymous to the challenges that mobility-restricted passengers face. These challenges include:

Technology

Technology in the context of airports involves adjusting to the increasing use of automation, self-service machines, automated TSA passenger screening checks, and use of escalators and moving walkways (ACRP, 2014). The elderly and other passengers with needs may have a difficult time adapting to increasingly complex technology. However, of important note is the different generations of the aging population. For instance, *ACRP Synthesis 51* mentions how some seniors from the younger generation were more exposed to technology in their lifetimes and are therefore able to adapt and utilize technology much better than their older counterparts (ACRP, 2014).

Wayfinding

ACRP Synthesis 51 (2014) defines wayfinding in several ways: "unfamiliarity with a complex airport layout, unclear or confusing signage, and difficulty in understanding terminology and signs" (p. 1). Much literature exists detailing the importance of clear wayfinding in airports. Tam (2011) wrote about how wayfinding is often a significant factor in determining the overall level of service of an airport. It should be noted that according to an ACRP survey, elderly passengers prefer to seek directions at staffed booths, as elderly passengers often view staff as more approachable (ACRP, 2014).

Fatigue

Fatigue is defined in *ACRP Synthesis 51* (2014) as "the physical effort involved in standing, waiting in line, lifting heavy bags, and walking long distances" (p. 21). Fatigue is not an isolated issue; it can exacerbate other problems as well. For instance, fatigue can cause further injury for passengers from tripping. The ACRP report further elaborates that very little action is being taken to address specific fatigue issues.

Commercial Solutions

Much technology exists to help accommodate passengers with their needs. Specifically, many attempts and products exist that may provide a mechanized means of travel. WHILL™

Power Chairs provide such a service. WHILL's autonomous wheelchair service allows people to navigate airports and other public spaces using a self-driving mobility device that automatically transports users to their selected destinations (WHILL, 2024). WHILL proposes predetermined optimal routes around the airport. These routes are determined based on traffic flow, congestion areas, and safety requirements. WHILL's Autonomous Service is being tried at Winnipeg Richardson International Airport (KYWG) and at Savannah/Hilton Head International Airport (KSAV).

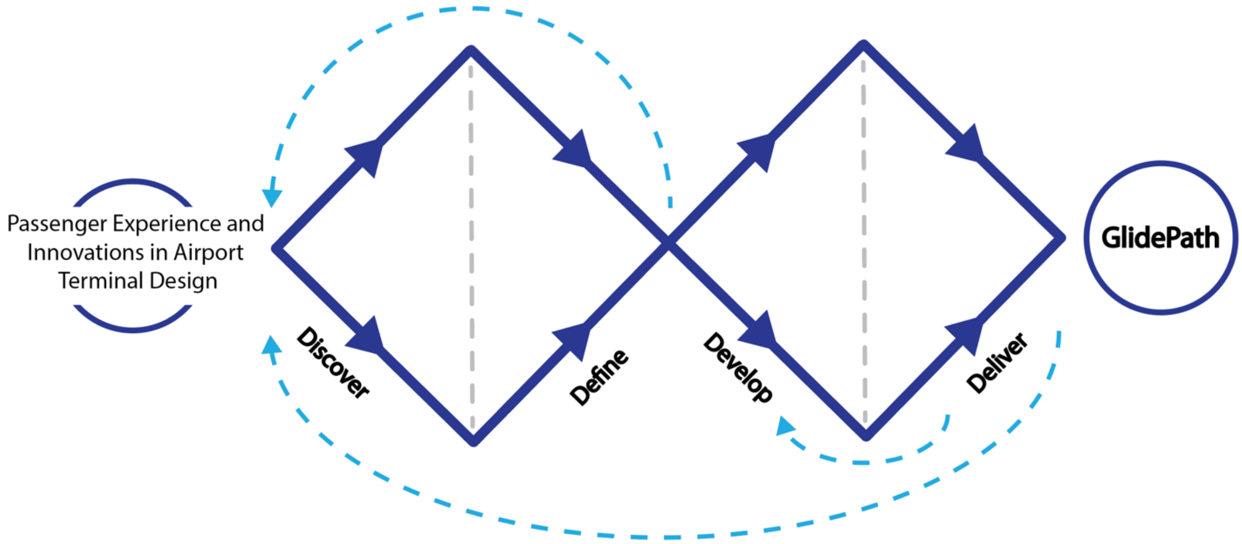
Other motorized travel means includes travel using motorized carts. However, several interviews with airport executives and literature from *ACRP Synthesis 51* (2014) suggest that the operation of motorized carts are often haphazard.

Problem Solving Approach

Our team adopted the double diamond methodology for its structured approach of exploring an issue more deeply (divergent thinking) and taking focused action (convergent thinking) (Design Council, n.d.). Figure 1 illustrates this design methodology. Our team began with a literature review and industry market research to identify commercially available technologies capable of improving airport operations without requiring large capital investment (e.g. infrastructure changes, terminal expansion, equipment upgrades). Given the scope and scale of airport operations, the varying degree of airport design, and the complex relationship between an airport and its tenants, our team sought a technology gap with a clearly defined set of requirements, predictable demand, and measurable impact. The statutory and regulatory framework around disabled passenger travel in the United States provides an opportunity to

Figure 1

Double Diamond Framework



compare the performance characteristics of existing solutions within a structured framework. Based on the high percentage of disability related complaints against air carriers for wheelchair related requests or wheelchair restricted passengers, our team narrowed on commercially available solutions for this population. During our research, we discovered a critical gap in aircraft enplanement/deplanement (gate-to-seat and seat-to gate). Existing solutions do not provide innovative approaches or integration of new technologies into their offerings.

Airside opportunities to use new technologies for PRM mobility and wayfinding can be viewed as security-to-gate and gate-seat. Based on our research, the security-to-gate market is saturated with mobility and wayfinding solutions. An example list with associated benefits and drawbacks is described in Table 1.

During our research and industry expert interactions, we did not identify any new or novel solutions addressing gate-to-seat mobility. A short list of commercially available aisle boarding chairs and their specifications are detailed in Table 2.

Table 1

Commercially available solutions for mobility and wayfinding from security to gate

Technology	Addresses	Positives	Negatives
Autonomous Wheelchairs (Gate to Gate)	Wayfinding	Collision Avoidance	Arrival times are unpredictable based on foot traffic patterns
		Integrated Luggage Rack	Requires a level of technology adoption by the user
	Fatigue	Integrated Touch Panel	Requires centralized loading and unloading areas
		Fleet Management Systems allows control center to monitor all devices	Seat has a low back which could be uncomfortable for passengers
Traditional Airport Golf Cart	Wayfinding	Can carry large groups of people	Requires asset intensive route and load planning
		Attendant Interaction	Requires a robust training program (people interaction and operation)
	Fatigue	Flexible infrastructure requirements	No Collision Avoidance
		Holds multiple passengers	Luggage requires seat space limiting number of passengers
Wayfinding Mobile Apps	Wayfinding	Low Cost	Travelers must be proactive
		Easy to Update	Requires Tech Adoption/Proficiency
AIRA Wayfinding	Wayfinding	Real-time virtual assistance	Requires Subscription

Table 2

Commercially Available Aisle Boarding Chairs

Name	Dimensions	Weight	Weight Capacity
AisleMaster8000	32” L x 16” W x 48” H	40.5 lbs.	400 lbs.
AisleMaster8010	32” L x 13” W x 48” H	39.5 lbs.	400 lbs.
Dalton Medical K09FX13F	16” L x 13.5” W x 40” H (Seat Only)	undisclosed	300 lbs.
Staxi AC020	37” L x 15” W x 40” H	64 lbs.	500 lbs.

Academic and medical research on the use of boarding chairs and wheelchairs highlights risk to both the PRM (beneficiary) and wheelchair pusher (operator) (Holloway et al., 2015). As such, we set forth to design an innovative gate-to-seat mobility solution (boarding chair) capable of meeting the needs of the beneficiary and operator. Our proposed solution will add value to PRM and operators while simultaneously **decreasing operational costs**.

Safety Risk Assessment

Safety is the cornerstone of our proposal, and as such, a safety risk assessment was completed in accordance with FAA Advisory Circular *AC 150/5200-37A - Safety Management Systems for Airports* and FAA *Order 5200.11A - FAA Airports (ARP) Safety Management System.*

The FAA (2023) defines a safety management system as “an integrated collection of processes and procedures that ensures a formalized and proactive approach to system safety through risk management”. One component of an effective SMS is safety risk management (SRM). SRM uses a standard process to identify hazards and assess their associated risks so that they may be mitigated proactively (FAA, 2023). Figure 2 showcases the five-step processes our team referenced in the development of our SRM hazard assessment, as described in *AC 150/5200-37A.*

Figure 2

Five Steps of SRM Hazard Assessment (FAA, 2023)

Transporting passengers of limited mobility across jetways and between chairs is a sensitive and often uncomfortable process that our team is cognizant of. Many hazards exist within the scope of this process and our team used a risk matrix chart derived from FAA *AC 150/5200-37A* to quantify the risks associated with these hazards, as seen in Table 3.

Table 3

Risk Matrix Chart (FAA, 2023)

Severity / Likelihood	Minimal (1)	Minor (2)	Major (3)	Hazardous (4)	Catastrophic (5)
Frequently (5)	5	10	15	20	25
Probable (4)	4	8	12	16	20
Remote (3)	3	6	9	12	15
Extremely Remote (2)	2	4	6	8	10
Extremely Improbable (1)	1	2	3	4	5

Low	Medium	High
No action required	Monitor, determine if risk can be mitigated to a low risk	Must be mitigated to a medium risk

Using the FAA's SRM process in conjunction with airport operator interactions, our team identified potential hazards that may exist for both the passenger and operator in the operation of an electrically assisted aisle chair including, but not limited to, passengers falling out of the chair, brake failures, thermal runaway of batteries, runaway electric motor, and dead batteries. Per the FAA's SRM hazard assessment process, our team identified the primary risks that are associated with each of these hazards and produced initial risk values using Table 3. Following this, potential mitigation strategies were developed, and a residual risk value was developed for each hazard listed. The result of this SRM hazard assessment may be found in Table 4 below.

Table 4

Potential Risks Associated with Operating GlidePath using Risk Matrix FAA Order 5200.11A (FAA, 2021)

#	Hazard	Effects	Severity	Likelihood	Initial Risk	Mitigation	Residual Risk
1	Passenger falling out of chair	Potential passenger and/or employee injury	5	4	High 20	Lap and shoulder safety belts used to keep passenger in place	10
2	Brake failure	Potential passenger and/or employee injury	5	3	High 15	Redundant mechanical brakes used	8
3	Thermal runaway of battery	Battery fire Potential passenger and/or employee injury	5	2	Medium 10	Adequate ventilation and circuit interrupting thermistors utilized	5
4	Runaway motor	Potential passenger and/or employee injury	5	1	Medium 5	Master switch wired into electrical bus to disable motor	2
5	Battery dies	No propulsion assistance from electric motor	1	4	Low 4	Routine battery charging plan with quick change batteries	2

Industry Expert Interaction

Throughout our team's design process, we met virtually with experts from airports including Dallas Fort Worth (DFW), Savannah/Hilton Head (SAV), Phoenix Sky Harbor (PHX), and Washington Dulles (IAD). These experts included airport managers, operations managers, landside managers, and ADA program managers. Our team also met with industry professionals from Prospect Airport Services, Blueberry Technology, Open Doors Organization, and the FAA. These professionals included regional directors, founders, and research specialists. Every interaction shared between our team and these industry experts aided in the scoping, design, and execution of our project. Table 5 provides a summary of who our group interacted with over the course of this project.

Table 5

Industry Expert Interaction

Name	*Title*	*Airport/Organization*
Alan Gonzalez	Landside Manager	Dallas Fort Worth (DFW)
Curt Bryant	Operations Manager	Savannah/ Hilton Head (SAV)
Ira McCullough	ADA/Title VI Program Manager	Phoenix Sky Harbor (PHX)
Richard Golinowksi	Airport Manager	Washington Dulles (IAD)
Tim Fisher	Regional Director	Prospect Airport Services
Rajeev Ramanath	Founder	Blueberry Technology
Eric Lipp	Founder	Open Doors Organization
Wesley Major	Airport Research Specialist	FAA

Each industry interaction meeting was held virtually over Microsoft Teams and followed a semi-structured approach including an introduction to our team, the ACRP competition, our design challenge, and a series of questions surrounding the logistics and hurdles regarding the application of new technology in mobility assistance solutions at airports. Ahead of these meetings, our team completed a literature review that informed us of the questions asked of our industry experts.

Throughout these industry interaction meetings, our team focused on understanding how accessibility services are contracted, implemented, and maintained not only on paper, but also in practice. We sought after the successes and challenges experienced by several airports that have tested autonomous and electrically enabled mobility services in their terminals, including Phoenix Sky Harbor (PHX) and Dallas Fort Worth (DFW), and those that have already implemented self-drive wheelchair services like Savannah/Hilton Head (SAV).

It is from these meetings that our team was able to close some gaps that existed following the completion of our literature review. For instance, our team learned that special service request (SSR) passenger demand does not necessarily follow the rest of air travel demand trends, with exceptions. Furthermore, it is from the previously mentioned airport operators that we learned that not all airports contract accessibility services the same, nor do they all have terminal layouts conducive to technology-enabled mobility services, like autonomously operated vehicles. Airports may include accessibility services within gate lease agreements, be responsible for a specific terminal(s), or leave the entirety of accessibility services for the airlines to provide, as is required by law. It is often the case that airlines then utilize a third-party contractor to fulfill this legal obligation to provide said accessibility services, utilizing companies like Prospect Airport Services among others. It is from these meetings that our team came to understand that the demand for technology-enabled mobility services must come from the airlines, despite many passengers perceiving these services as complimentary of the airport.

Our team also learned that it is often the airport that is most interested in adopting technology-enabled mobility services, despite most of these services being handled by the airlines and their contractors. While airports are often interested in providing the best passenger experience that they can, it is the airlines that the demand for improved mobility services must come from, as they own and operate these processes. Often, the airlines are hesitant to change a system and technology that, from their point of view, works well enough.

Our meetings with Blueberry Technology and the Savannah Airport Commission highlighted the current applications of technology-enabled wheelchairs, whether completely autonomous or user-guided. Blueberry, a San Jose startup, is a manufacturer of autonomous wheelchairs intended to aid passengers in navigating the airport independent of traditional wheelchair pushers. Savannah/Hilton Head Airport is also currently operating self-drive wheelchairs manufactured by WHILL, another manufacturer of technology-enabled wheelchairs. While these technology-enabled chairs are fantastic in terms of enriching customer experience and passenger wayfinding, our team noticed that they are unable to deliver passengers to a seat in the aircraft itself. Because of this, a traditional aisle chair is used. These conversations, in addition to our literature review and market research, highlighted the gap that exists in technology applications surrounding personal mobility in airports: no one is addressing the gate to seat on the plane transit.

By meeting with both a member of the FAA and the Open Doors Organization, our team received invaluable feedback on the challenges and pain-points associated with boarding aircraft as a wheelchair user. Some areas of focus that our team took away from these talks include bridging the seat transfer gap, improving restraints, and protecting the passengers being transported. All feedback received from our industry experts has informed the design and operation of our aisle boarding chair.

Description of Idea

We propose the adoption of an electrically assisted aisle boarding chair for airports (GlidePath). Based on our information, GlidePath meets federal statute and regulations for aircraft aisle boarding chairs while considering the health and well-being of the restricted mobility passenger and the chair operator. GlidePath integrates commercially available technologies into an innovative design to provide a seamless enplaning and deplaning experience for the air traveler and reduce push/pull forces on the operator. GlidePath is designed to reduce enplaning and deplaning time by considering aspects particular to the boarding process. The overarching intent is to decrease turnaround through product design. Traditional boarding chairs are designed for compliance. GlidePath is tailored to the operating environment. GlidePath was designed through CATIA v5, a computer-aided design (CAD) software. Detailed illustrations and key features of GlidePath are shown in Figures 3 and 4.

Figure 3

GlidePath Concept Design Front View

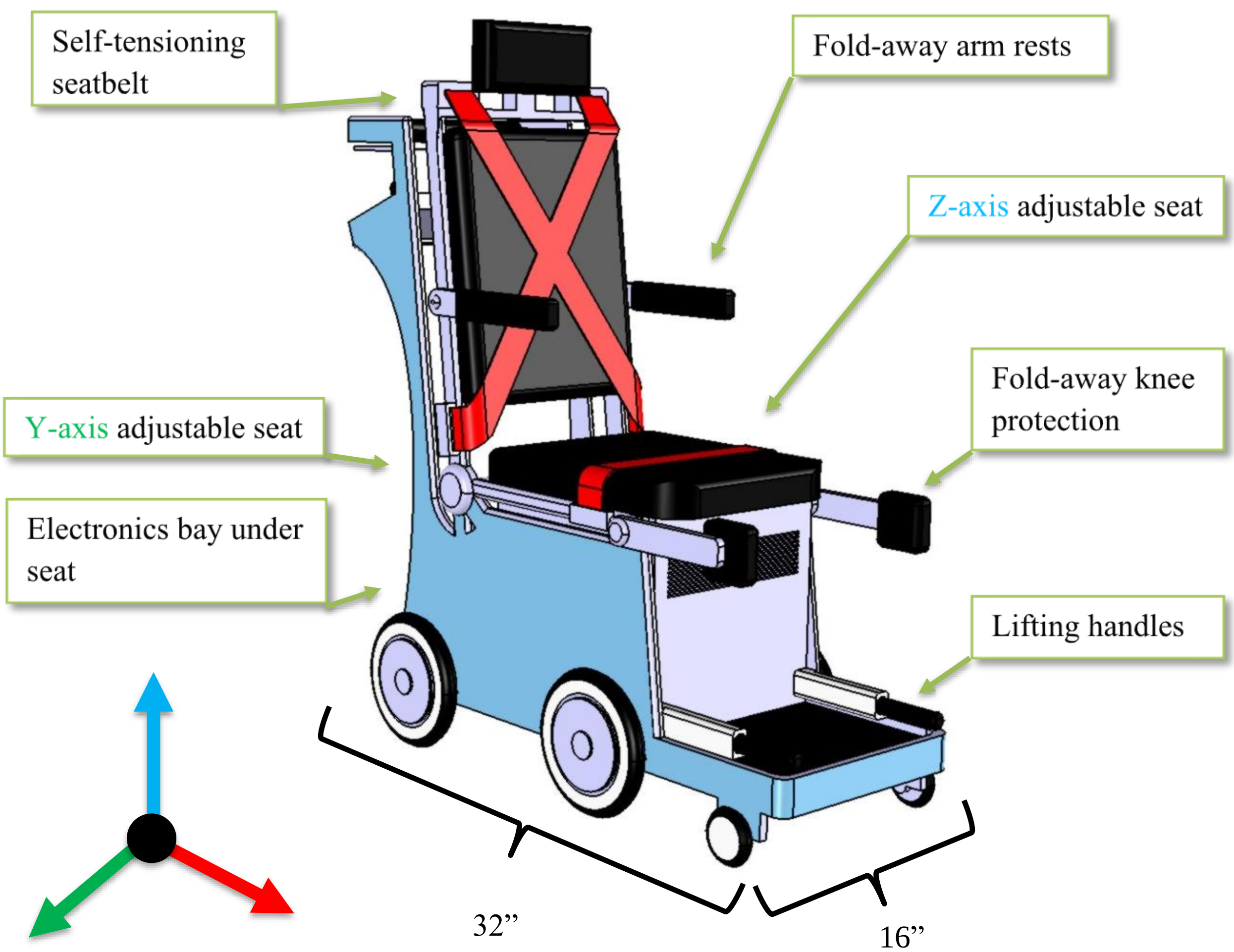
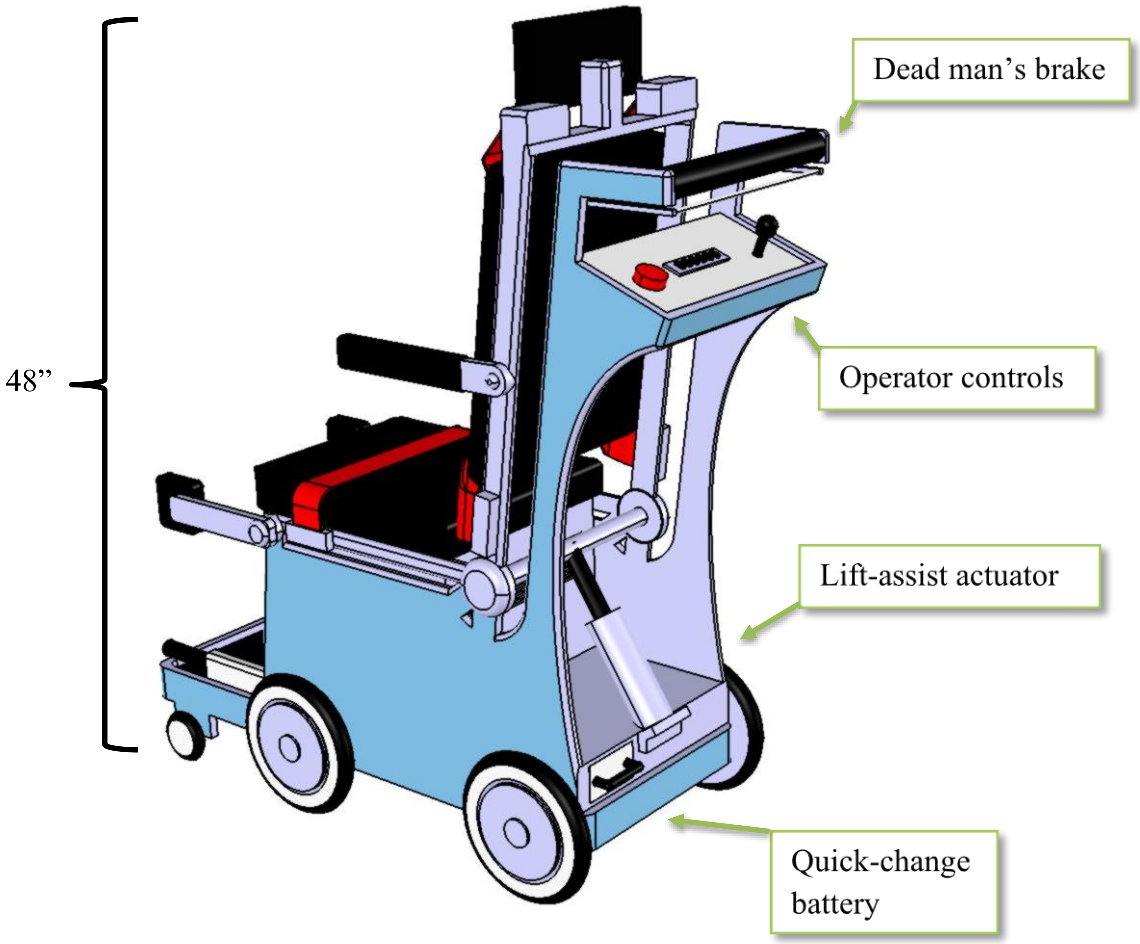


Figure 4

GlidePath Concept Design Rear View



The process of transferring, moving from one surface to another, is essential for wheeled mobility device beneficiaries. Seat height, seat width, transfer gaps, and obstacles affect a wheelchair beneficiaries’ ability to transfer (Koontz et al., 2015). As illustrated in Figure 3, GlidePath features multi-directional adjustment to mitigate all aspects of the transferring process. GlidePath seat height can be adjusted through a fully electric z-axis control mechanism. The z-axis can be adjusted by the beneficiary or the operator to allow for maximum flexibility and account for the traveler’s desires or disability. Similarly, the y-axis can be adjusted by the beneficiary or the operator. Y-axis adjustment is powered by an electric actuator that moves GlidePath seat laterally to close the transfer gap between surfaces. X-axis control is done completely by the operator. The operator should ensure the X-axis is aligned to meet the beneficiary's required transfer method. GlidePath also features a fully electric lift capability to assist the beneficiary to his/her feet should that be the desired mode of transfer. All axis controls are powered through electric actuators. Electric actuators are powered by a single electric motor and single 12 volt 10 Ah Lithium-Ion battery.

The constant state of strain on a wheelchair operator can result in workplace injury. Forty percent of aviation industry worker injuries are due to overexertion and bodily reactions (Moller et al., 2020). In 2021, worker compensation averaged $49,838 for arm and shoulder injuries, $39,328 for lower back injuries, and $35,439 for upper back injuries (National Safety Council, 2021). Holloway et al. (2015), found the force required to push a wheelchair onto an airplane exceeds the regulatory requirements Health and Safety Executive Guidelines in all cases for women in most cases for men. When adjusted for *AC 150/5220-21C – Aircraft Boarding Equipment*, wheelchair operators cannot push a 200-pound passenger up a 20° incline without exceeding 60 pounds of push force (US DOT, 2012). GlidePath is equipped with electric motors to assist wheelchair operators when pushing or pulling the device. The motors provide up to 100 Newtons (N) of additional assistance. When going downslope the motors reverse to reduce operator load. The optimal operator load when operating GlidePath is no more than 120N based on the weight of a 95th percentile male (308 lbs). Maintaining 120N of force is roughly the equivalent of pushing a 5th percentile female on a flat surface in a traditional boarding chair. Additionally, GlidePath is equipped with omni-directional wheels to minimize turning radius and maximize flexibility with minimal workload on the operator. Armrests can be raised to remove the obstacle during transfer.

GlidePath meets all Guidelines for Design Features as proposed by Part 4 of the US Access Board’s Guidelines for Aircraft Boarding Chairs (1987). Chair dimensions are illustrated in Figure 3 and 4. The overall weight of the chair is heavier than traditional boarding chairs, but still meets the intent to minimize overall weight based on chair design. The electric push/pull assist features more than compensate for the additional weight in terms of reducing operator workload and push/pull forces. The chair is designed to support a weight of 723 pounds. However, at this weight the push pull forces will exceed limitations set in *AC 150.5220-21C – Aircraft Boarding Equipment*. Designing GlidePath to reduce push/pull forces to the regulatory limit (60 pounds) is cost prohibitive based on the small beneficiary size and increased material cost. A 4-point retractable safety harness is integrated to ensure passenger safety. The safety harness utilizes an inertial lock wheel that allows the passenger to move freely if desired but locks automatically in the event of rapid movement, much like a car seatbelt system. The 4-point harness may be locked by the beneficiary or operator if desired/required.

Where possible recyclable materials will be used in GlidePath construction. Seat cushions will be made from recyclable polyurethane foam. Polyurethane production has less environmental impact than other materials (Kemona & Piotrowska, 2020). Seat covers will be produced from sustainably produced fibers. Leather and leather alternatives are undergoing a green revolution due to consumer awareness and environmental policy (Sathish et al., 2016). This revolution should provide a wider selection of durable and damage resistant fabrics.

Projected Impacts of Design

This proposal satisfies the requirements set forth in the 2023-2024 ACRP Design Guidelines for **Challenge II. Passenger Experience and Innovation in Airport Terminal design by addressing** *Topic B. Innovations to accommodate passengers with disabilities and aging demographics at airports*. GlidePath adoption reduces passenger fatigue and solves mobility problems for elderly and PRM passengers. This proposal addresses issues and suggestions discussed in *ACRP Research Report 239: Accessing Airport Programs for Travelers with Disabilities and Older Adults (*Ryan et al., 2023) and *ACRP Synthesis 51: Impacts of Aging Travelers* (Mein et al., 2014) and *IATA Fact Sheet on Air Transport Accessibility* (IATA, 2023).

GlidePath adoption has the potential to decrease turnaround time through expedited enplaning/deplaning of PRM passengers. The design introduces innovative concepts capable of improving beneficiary experience, beneficiary safety, and operator safety through the integration of existing and commercially available technologies. GlidePath design and terminal placement provides an opportunity to increase advertising revenue through selling ad space on the physical platform.

This competition and the research process has made the researchers aware of the problems associated with air travel for PRM, the physical hazards posed to travelers with PRM and wheelchair operators, and a gap in commercial solutions for enplaning/deplaning operations. The ACRP competition and the corresponding research process provides an excellent opportunity for researchers to identify existing problems and propose innovative solutions. Through this competition, the team gained valuable insight into the research process, the aviation industry, and proposal development. Participation in the ACRP Design Competition has improved our problem solving, research ability, and creative thinking as well as provided real world experience applicable to our future career choices.

Benefit-Cost Analysis

We assess the viability of GlidePath adoption through a benefit-cost analysis (BCA). The BCA is conducted as recommended by ACRP competition resources (Byers, 2016). The Alpha stage addresses concept development. The Beta stage addresses design and prototype development. The prototype designed in the Beta stage will serve as the production model and the basis for a 10-year total cost estimate. The cost estimate assumes product commercialization and airport adoption.

Cost Assessment

In the Alpha stage, the design team will frame the customer and beneficiary needs through implementation of a product specific user centered design model. The main goal of model implementation is to understand the final system requirements through iterative interaction with industry experts, operators (wheelchair operators), and beneficiaries (those who require boarding services). The alpha stage is projected to last 12 weeks and cost $34,263, as shown in Table 6.

Table 6

Alpha Research & Development - 12 weeks

Item	***Rate***	***Multiplier***	***Hours***	***Subtotal***	***Notes***
Graduate Student[1]	$23	3 students	300	$20,700	(12 weeks, 25 hrs/week)
Concept Modelling[2]	$0		20	$0	Modeling tool: CATIA v5
ADA Expert[3]	$54	1 expert	30	$1,620	
Airport Expert[4]	$42	1 expert	30	$1,260	
Faculty Advisor[5]	$60	1 advisor	30	$1,800	Project advisor
			Subtotal	$25,380	
			Overhead cost	$8,883	35% of project cost
			Alpha Total	**$34,263**	

Notes.

1. Graduate student stipend is $23/hour
2. Concept modeling tools are provided by Purdue University
3. ADA Compliance Consultant earns an average $54/hour (ZipRecruiter, n.d.) https://www.ziprecruiter.com/Salaries/Accessibility-Consultant-Salary
4. Airport Consultant earns an average $42/hour (ZipRecruiter, n.d.) https://www.ziprecruiter.com/Salaries/Airport-Consultant-Salary
5. Purdue University Faculty Advisor rate is $60/hour

In the Beta stage, the design team will use the requirements developed in the Alpha stage to construct and test a prototype GlidePath. Prototype construction is required for user trials, to verify design requirements, validate system safety, and ensure reliability and complete testing. Testing will be conducted in accordance with *ISO TC173/SCI N3, "Static and Impact Strength Test"* as directed by US Access Board Guidelines for Boarding Chairs (US Access Board, 1987). Beta stage is projected to last 16 weeks and cost $188,098, as shown in Table 7.

Table 7

Beta Research & Development - 16 weeks

Item	***Rate***	***Multiplier***	***Hours***	***Subtotal***	***Notes***
Graduate Student	$23	3 students	400	$27,600	16 weeks, 25 hours/week
Human Factors Engineer[1]	$100	1 engineer	192	$19,200	16 weeks, 12 hours/week
Physical Prototype Construction	$200	1 unit	300	$60,000	
Material Cost				$2,500	
Testing[2]				$10,000	
User Trials	$3,000	2 iterations		$6,000	
ADA Expert	$54	1 expert	32	$1,728	16 weeks, 2 hours/week
Airport Expert	$42	1 expert	32	$1,344	16 weeks, 2 hours/week
Travel[3]				$5,200	Airfare, hotel, per diem, rental car 3pax/4nights
Faculty Advisor	$60	1 advisor	96	$5,760	16 weeks, 6 hours/week
Intellectual Property Protection[4]				$0	Disclosures filed through Purdue Research Foundation Office of Technology Commercialization
			Subtotal	$139,332	
			Overhead Cost	$48,766	35% of project cost
			Beta Total	**$188,098**	

Notes.

1. Integrate human factors for operator and beneficiary into design.
2. Conducted in accordance with *ISO TC173/SCI N3, "Static and Impact Strength Test"* as directed by US Access Board Guidelines for Boarding Chairs.
3. Travel budget accounts round trip airfare, hotel, per diem, rental car for 1 trip of 4 nights/5 days.
4. All patent disclosures, patent filing, and adjudication will be conducted through Purdue Research Foundation Office of Technology Commercialization. These services are provided free of charge for Purdue research.

Procurement and Operating Costs

Our calculations are based on the operating parameters outlined in Table 8. The airport information is based on publicly available data from a major US airport. We assume 2% of total traveler's request a boarding chair for enplaning/deplaning assistance. The jet bridge and airplane loading information is based on estimates from publicly available jet bridge and narrow body airplane information.

GlidePath electricity costs are detailed in Table 9. We estimate a single GlidePath to travel 969,006 feet per year for an average of 2,655 feet per day. Annual electricity cost for a single unit is negligible but included to address understandable concerns over power requirements for charging electric mobility devices. Procurement and operating costs are detailed

Table 8

Operating Parameters

Airport Information	
Gates	171
Air Carrier Flights (Annual)	590,660
Total Passengers Enplaned/Deplaned (Annual)	81,764,044
Boarding Chair Requests (Annual)[1]	1,635,281
Estimated Pax Enplaned/Deplane per flight	2.8
Distance Traveled	
Jet Bridge Length (ft)	105
Airplane Loading Length (ft)	47
Total Distance Round Trip	**304**

Notes.

1. Based on 2% of total passengers requesting enplaning/deplaning assistance

in Table 10. Procurement and operating costs are broken down by the purchase and operation of 3 units. Based on our estimates, we recommend 3 units to cover a single gate. Our team recommends 3 units per gate to accommodate enplaning/deplaning of 2.8 passengers per simultaneously. All benefit-cost estimates are based on purchase of 3 units and placement of all 3 units at a single gate. Based on this allocation, the cost can be tailored to the individual airport by the number of gates it wishes to upgrade to GlidePath. The 10-year operating cost to upgrade a single gate is $347,611.

Table 9

Electricity Cost

GlidePath Technical Specification		***Electricity Cost***			
Battery Capacity	12 volt 10 Ah Li-Ion	Rate/kWh	Quantity (kWh)	Subtotal	Cost/Unit/Enplanement
Average Range (ft)	31,680	0.173	.12 kWh	0.02076	$ 0.00007
Run Time	up to 15 hours				
Charge Time	~3 hours				

Table 10

Ten Year Total Cost per Gate

Item	***Rate***	***Multiplier***	***Quantity***	***Subtotal***	***Notes***
Alpha Stage				$ 34,263	
Beta Stage				$ 188,098	
GlidePath	$ 3,000	3 Chairs	1 Gate	$ 9,000	
Initial Training	$ 35	3 Chairs	1 Gate	$ 105	
Electricity	$ 0.00007	3 Chairs	1 Gate	$ 0.00246	See Table 9: Electricity Cost for details
Maintenance	$ 150	3 Chairs	12	$ 5,850	Preventative maintenance conducted 1/month
Year 1 Subtotal				$ 237,316.20	
Recurring Training	$ 35	1 unit	9 years	$ 105	Recurring training to account for personnel turnover
Electricity	$ 0.00007	3 Chairs	108 months	$ 0.02213	See Table 9: Electricity Cost for details
Maintenance	$ 300	3 Chairs	108 months	$ 11,700	Preventative maintenance conducted 1/month
Replacement Battery	$ 150	3 Chairs	1 per 5 years	$ 450	Batteries should be replaced once every 5 years
Recurring Years Subtotal				$ 12,255	
10 Year Total Cost per gate					
Year 1 Subtotal				$ 237,316	
Year 2-10 Subtotal				$ 110,295	
10 Year Total Cost per gate				***$ 347,611***	

Benefits Assessment

GlidePath meets all federal statute and federal regulations for aircraft boarding chairs while still considering the health and well-being of the operator. GlidePath integrates commercially available technologies into an innovative design to provide a seamless enplaning and deplaning experience for the air traveler. GlidePath adoption will benefit the airport, airlines, air travelers, and operators.

Literature shows that airports have become more commercially oriented and have started to be more proactively involved in marketing their services to airlines. (Halpern & Graham, 2015). Airport advertising involves the practice of showing prospective customers, in this case air carriers, that the demand and facilities available at an airport can support the air carrier operating profitably out of said airport. (Tretheway & Kincaid, 2016). GlidePath is also designed to enhance airport operational capabilities, which will attract more air carriers to the airport.

GlidePath is designed to reduce enplaning and deplaning time by considering all aspects of the boarding process. The overarching intent is to decrease turnaround through product design. Traditional boarding chairs are designed for compliance. GlidePath is tailored to the operating environment.

Elderly and PRM air travelers have specific and unique enplaning and deplaning requirements. Meeting these requirements can prove challenging, especially when attempting to provide an environment where the traveler can feel independent. GlidePath's design and adjustment features allow the traveler to enplane/deplane with minimal to no assistance. Based on the integrated features, we anticipate all passengers, unless quadriplegic, can enplane and deplane without operator assistance. As a result, only one operator is required per GlidePath.

GlidePath's operators are no longer required to overcome boarding chair design limitations through the application of force. GlidePath's design decreases push force requirements when pushing up ramp, decreases pull force requirements when going down ramp, reduces overall turning radius, and introduces parallel movement. As a result, we anticipate a reduction in workplace injuries and employee turnover.

Tangible Benefits

GlidePath adoption can reduce enplaning and deplaning time, as well as the number of wheelchair operators required to push passengers. This results in reduced labor hours and corresponding savings and shorter turnaround times. Table 11 describes the wage cost savings compared to traditional boarding chairs. Table 12 describes the cost savings to airlines when turnaround times decrease by 30 seconds. Reduced turnaround time provides benefit to the airport and airline. Airlines will generate revenue through the ability to add additional flights. Table 13 describes revenue generated for airports through the addition of one flight per month. Airports will be beneficiaries in terms of increased landing fees and passenger revenue. Additionally, airports will receive intangible benefits associated with a pleasant travel experience. The intangible benefits could be as small as increased traveler purchases from airport vendors up to increasing traveler volume.

Wheelchair operators are nearly always violating safety regulations when transporting a passenger. Holloway et al. (2015), found the force required to push a wheelchair onto an airplane exceeds the regulatory requirements Health and Safety Executive Guidelines in all cases for women in most cases for men. When adjusted for *AC 150/5220-21C – Aircraft Boarding Equipment*, wheelchair operators cannot push a 200-pound passenger up a 20° incline without exceeding 60 pounds of push force (US DOT, 2012). The constant state of strain on a wheelchair operator can result in workplace injury. Forty percent of aviation industry worker injuries are due to overexertion and bodily reaction (Moller et al., 2020). In 2021, worker compensation for arm and shoulder injuries was $49,838, lower back injuries was $39,328, and upper back injuries was $35,439 (National Safety Council, 2021). The increased functionality of GlidePath will allow for a more comfortable, seamless, and expedited enplaning and deplaning process. American

Airlines estimates the Total Direct Operating Cost per Block Minute as $101.18 (American Airlines, 2022). Reducing PRM enplaning/deplaning time will result in significant savings over time. The value of time savings per hour for all travelers in time categories is $57.81 per hour (Landau et al., 2015). Assuming this, GlidePath adoption could save travelers millions annually.

Additionally, the process of enplaning and deplaning PRM can cost millions in legal fees. In 2019, Erica Fulton was dropped while being transferred from a wheelchair to her airplane seat. The settlement cost United Airlines $4 million (Fulton v. United Airlines, Inc., 2021).

Table 11

Annual Wage Reduction

Boarding Chair Requests per gate		9,563
Minute Rate (Based on $7.25/hour)		$ 0.12
	Traditional	***GlidePath***
Average minutes enplaning/deplaning per boarding chair request	10.5	10
Annual minutes enplaning/deplaning	100,412	95,630
Total Pax enplaned/deplaned per flight	2.80	2.80
Operator Adjustment Factor[1]	1.50	1.05
Operators required for total pax enplaned/deplaned	4.20	2.94
Annual Enplaning/Deplaning Wage Expense	$ 50,608	$ 33,738
Total Annual Wage Reduction per Gate		**$ 16,869.21**

Notes.

1. Estimate based on improved functionality provided by GlidePath.

Table 12

Annual Savings to Airlines and Passengers based on Reduced Passenger Loading Time

Annual Air Carrier Flights per gate		3,454
Total Direct Operating Cost Per Block Minute[1]		$ 101.18
FAA Avg. Value of Traveler Time per Minute[2]		$ 0.96
	Traditional	***GlidePath***
Estimated Average Enplane/Deplane Time in Minutes	10.5	10
Average TDOCPBM for Enplaning/Deplaning	$ 3,669,657	$ 3,494,911
Estimate Annual Savings to Airlines		$ 174,746
Estimated Average Enplaning/Deplaning Cost to Travelers[13]	$ 34,945	$ 33,281
Estimated Annual Savings to Travelers		$ 1,664
Estimated Total Savings to Airlines and Travelers / Gate / Year		**$ 176,409.59**

Notes.

1. Retrieved from Airlines for America, https://www.airlines.org/dataset/u-s-passenger-carrier-delay-costs/
2. Derived from (Landau, 2023).

Table 13

Annual Income to Airports

Aircraft Landing Weight (Assumes 737-800 empty weight)	90,710
Landing Rate per 1,000 pounds[1]	$ 2.23
Earnings per month per gate (1 additional flight per month)	$ 202.28
Estimated annual earnings per gate	**$ 2,427.36**

Notes.

1. Retrieved from DFW FY2022 Schedule of Charges. https://dwuconsulting.com/images/Ratebook/DFW%20Oct21%20Rate%20Book.pdf

While not all injuries are so severe and all settlements not so costly, the increased risk associated with using existing technology is apparent. Another possible way to generate revenue with the

GlidePath is to sell advertisement space on the device. GlidePath placement at the top of boarding gates will ensure every passenger enplaned/deplaned passes the device. A consolidated list of GlidePath benefits is listed in Table 14.

Table 14

Total 10 Year Benefit per Gate

Item (Annual)	Benefit	Note
Estimated earnings per gate for airports	$ 24,273	See Table 13 for Details
Total Annual Wage Reduction by Gate	$ 16,869	See Table 11 for details
Estimated Total Savings to Airlines	$ 174,746	See Table 12 for details
Estimated Total Savings to Passengers	$ 1,664	See Table 12 for details
Reduced Workman's Compensation	$ 39	Avg Payout*Estimated Injury/gate
Reduced Legal Fees	$ 66	Avg Settlement * Estimated Injury/gate
Advertising Space	$ 36,000	$1,000/month/GlidePath for 12 months
Intangible Benefits	$ 7,500	Estimation of improved revenue based on GlidePath adoption
Annual Benefit	$ 236,883	
Total 10 Year Benefit per Gate	**$ 2,156,224**	

The cost-benefit calculation for a 10-year period is depicted in Table 15. The 10-year total benefit to owning 3 GlidePath and placing them at a single boarding gate is $2,156,224. The 10-year total cost for 3 GlidePath placed at a single gate is $347,611. The benefit-cost ratio is 6.20 making GlidePath adoption beneficial. It is worth noting that when scaled to airport-wide adoption of the undisclosed example airport used in this proposal the 10-year benefit and cost are $364.6 million and $59.4 million respectively.

Table 15

Benefit-Cost Ratio

10 Year Total Benefit	$	2,156,224
10 Year Total Cost	$	347,611
Benefit-Cost Ratio		**6.20**

Sustainability Assessment

Our team references both the United Nations (UN) and Federal Aviation Administration (FAA) when defining sustainability in air transportation. The UN (1987) defines sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs". The FAA adds that airport sustainability incorporates economic, environmental, and social considerations into the planning and design of airport terminals; a concept called "Triple Bottom Line" (FAA, 2018). Additionally, the FAA (2023) says that sustainable actions fall under three main pillars, including reducing environmental impacts, maintaining high and stable levels of economic growth, and achieving social progress, i.e., actions that help organizations achieve their goals in a way that co-benefits the values and needs of the local community. When assessing the sustainability of GlidePath, our team will reference both definitions of sustainability.

To assess the sustainability of GlidePath, our team utilized two assessment methods: the EONS (economics, operations, natural resources, and social responsibility) model and the UN Sustainable Development Goals (SDGs). The EONS model was established by Airports Council

International (ACI) and defines sustainability as a means to promote economic vitality, operational efficiency, natural resource conservation, and social impact (ACI, n.d.). Moreover, the EONS model is the preferred choice for the FAA in measuring sustainability in airports, as per *AC 150/5360-13A: Airport Terminal Planning* (FAA, 2018). Our team's EONS assessment can be viewed in Table 16.

Table 16

EONS Sustainability Impacts Analysis

EONS	Sustainability Impacts	Effect on Airport Sustainability
Economic Vitality	Savings from less injury litigation and settlements	(+)
	Additional revenue from improved airport reputation	(+)
	Priced at competitive rate in line with traditional equipment	(+)
Operational Efficiency	Reduction in time required to board wheelchair beneficiaries	(+)
	Reduction in exertion on behalf of the staff	(+)
	Reduction in exertion on behalf of the passenger	(+)
	Increased operational complexity	(-)
Natural Resource Conservation	Batteries capable of being charged via sustainable sources of power	(+)
	Chair constructed of aluminum and polyurethane, both recyclable and highly sustainable materials	(+)
	Batteries are life limited and contribute to electronic waste	(-)
Social Responsibility	Chair mitigates the use of excessive push force	(+)
	Reduces employee injury caused by overexertion	(+)
	Reduces accessibility inequalities between passengers	(+)

Note: Effects on airport sustainability are denoted as positive (+) and negative (-).

Furthermore, the UN SDGs are the 17 goals under the UN's 2030 Agenda for Sustainable Development that intend to "promote peace and prosperity for people and the planet now and into the future" (UN, 2023). Our team identified five SDGs relevant to GlidePath, as seen in Table 17.

Table 17

Sustainable Development Goals - GlidePath Implementation

SDG	Description	Effect
5 GENDER EQUALITY	**5.8 Promote Empowerment of Women Through Technology**	Reduced push/pull forces allow a larger percentage of women employment opportunities
8 DECENT WORK AND ECONOMIC GROWTH	**8.2 Diversify, Innovate and Upgrade for Economic Productivity** **8.5 Full Employment and Decent work with Equal Pay** **8.8 Protect Labour Rights and Promote Safe Working Environments**	Upgrading boarding chair design increases productivity through innovation Reduced push/pull forces widens candidate pool for wheelchair attendant jobs GlidePath reduces the physical strain on wheelchair attendants enabling a safe working environment
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	**9.1 Develop sustainable, resilient, and inclusive infrastructures**	GlidePath opens regional and transborder travel for PRM travelers
10 REDUCED INEQUALITIES	**10.3 Ensure Equal Opportunities and End Discrimination**	GlidePath adoption offers jobs to those who are not eligible with traditional boarding chairs and eases the burden of traveling on PRM
11 SUSTAINABLE CITIES AND COMMUNITIES	**11.2 Affordable and Sustainable Transport Systems**	GlidePath aims to continue to reduce the barriers to travel and promotes safety for both PRM and wheelchair attendants

Note. Icons and descriptions of SDGs are from the UN Department of Economic and Social Affairs (UN, n.d.) Retrieved from: https://sdgs.un.org/goals

Conclusion

Our team's proposal, GlidePath, intends to address the **Passenger Experience and Innovations in Airport Terminal Design** challenge, with an emphasis on subcategory B: *Innovations to accommodate passengers with disabilities and aging passenger demographics at airports.* The primary goals of our project include mitigating excessive exertion, improving safety and accessibility, and decreasing transport time of individuals attending to and being transported by aisle boarding chairs while enplaning and deplaning. Our electrically enabled aisle boarding chair design innovates by integrating electric motors to mitigate excessive push/pull forces, while also allowing for increased adjustability compared to traditional aisle boarding chairs. Our design was developed using CATIA v5 CAD software and was informed by an extensive literature review of existing solutions in conjunction with feedback from our many industry expert interactions.

Our cost-benefit analysis provides a business case for the development and implementation of our design. The projected benefit/cost ratio is estimated to be **6.20** over a ten-year period for a single gate operation. An EONS model was utilized to assess the sustainability of our proposal, in addition to our design contributing to five of the 17 UN SDGs - 5, 8, 9, 10, and 11. An electrically enabled aisle boarding chair promotes safety for all parties involved in enplaning and deplaning PRM and does so while mitigating unwanted economic, operational, environmental, and social impacts.

Appendix A - List of Complete Contact Information

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Appendix B - University Description

Purdue University is a public university founded in 1869 and named for John Purdue, a leading benefactor in establishing Purdue University as Indiana's land grant college. The School of Aviation and Transportation Technology (SATT) is located at the airport on the system's flagship campus in West Lafayette, Indiana. Founded in 1934, the Purdue University Airport (KLAF) is the first university-owned airport in the US. Our aviation programs have over a thousand undergraduates enrolled in Bachelor's degree programs, and over 150 graduate students seeking Masters and Doctoral degrees. The mission of SATT is to prepare the next generation of leaders and change agents for the transportation sector. SATT is one of six academic departments in the college known as the Purdue Polytechnic Institute.

There are over 200 undergraduate programs, 11 colleges, and over 2,000 faculty and staff at Purdue. Over 50,000 students from over 135 countries study in West Lafayette. Over 100,000 students study in West Lafayette, around Indiana, and across the globe. Purdue is ranked 5th for most STEM graduates in the US according to Forbes, 2021.

Compiled from information at https://www.purdue.edu/home/about/ and
https://polytechnic.purdue.edu/schools/aviation-and-transportation-technology

Appendix C - Description of Industry Contacts

Alan Gonzalez is the landside manager at Dallas Fort Worth (DFW) International Airport. Prior to this position, Alan has also worked as the guest transportation assistant manager and ground transportation supervisor at DFW. Alan holds a Master of Science in Aviation and Aerospace Management from Purdue University and a Bachelor of Business Administration in Finance and Management from The University of Texas at El Paso.

Curt Bryant is the operations manager at the Savannah Airport Commission. Prior to this position, Curt has also worked with Both Delta Air Lines as a station manager and Air France. Curt holds a Bachelor of Arts in French from California State University, Long Beach.

Ira McCullough is the ADA/Title VI program manager with the city of Phoenix, Arizona. Prior to this position, Ira has also worked as the interim ADA coordinator, compliance and enforcement administrator, and fair housing program manager with the city of Phoenix. Ira holds a Master of Public Policy and Administration from Northwestern University, a Master of Business Administration from the New York Institute of Technology, and a Bachelor of Arts in Political Science from Arizona State University.

Richard Golinowski is the vice president and airport manager at the Metropolitan Washington Airports Authority. Prior to this position, Richard has also worked as the vice president of operations support with the Metropolitan Washington Airports Authority. Richard holds a Bachelor of Engineering from Virginia Polytechnic Institute and State University.

Tim Fisher is the regional director of Prospect Airport Services, a company which operates at 35 airports with over 12,000 employees and provides cabin and passenger services, including limited mobility services.

Dr. Rajeev Ramanath is the founder of Blueberry Technology. Prior to this position, Rajeev has also worked as the head of vehicle programs, head of program management, and senior technical program manager with a number of companies. Rajeev holds a PhD in Electrical Engineering from North Carolina State University, a Master of Science in Electrical Engineering from North Carolina State University, and a Bachelor of Engineering in Electrical and Electronics Engineering from Birla Institute of Technology and Science, Pilani.

Eric Lipp is the founder and executive director of the Open Doors Organization. Prior to this position, Eric has also worked as the national account executive with the MIS Computer Corporation. Eric holds a Bachelor of Economics from the University of Arizona.

Wesley Major is an airport research specialist at the Federal Aviation Administration (FAA). Wesley holds a PhD in Technology from Purdue University, a Master of Science in Aviation and Aerospace Management from Purdue University, and both an Associate of Arts and a Bachelor of Science in Organizational & Community Leadership from the University of Delaware.

Appendix E - Evaluation of Educational Experience

Students

1. Did the Airport Cooperative Research Program (ACRP) University Design Competition for Addressing Airports Needs provide a meaningful learning experience for you? Why or why not?

The ACRP University Design Competition has been a meaningful experience for our team for 3 reasons. First, was the exposure to new problems. Our team does not have a background in airport operations or terminal design. We entered the competition without an agenda and let the research guide our decision. Our team was interested in ways to increase airport capacity without major capital investment. As a result, we sought a specific problem with measurable impact. Throughout the course of the literature review, we noted the PRM population is growing and has identified problems. The problems were well documented in *ACRP Report 239* and could be measured by complaint data (Ryan et al, 2023). The large percentage of traveler complaints associated with wheelchair services was related to persons with reduced mobility. The logical step was to find an existing commercial solution or integrate existing solutions to solve the identified problem.

Given the scope and scale of airport operations, the varying degree of airport design, and the complex relationship between an airport and its tenants, the researchers sought a technology gap with a clearly defined set of requirements, predictable demand, and measurable impact. The statutory and regulatory framework around disabled passenger travel in the United States provides an opportunity to compare the performance characteristics of existing solutions within a structured framework.

The competition and research process led to an area of study none of the team members were familiar with.

2. What challenges did you and/or your team encounter in undertaking the competition? How did you overcome them?

The team does not have a background in airport operations. We were unfamiliar with the statutes and regulations that govern accessibility. Mapping accessibility requirements imposed by ADA and ACAA was time consuming and enlightening. We conducted an extensive literature review on accessibility and consulted multiple industry experts prior to fully understanding who is responsible for accessibility during the different stages of air travel.

3. Describe the process you or your team used for developing your hypothesis.

Our team sought to increase airport throughput via technology application. We brainstormed potential ideas to meet our objective and then conducted market research and literature review to inform our ideas. Through the course of the literature review we identified a high percentage of problems for PRM air travelers. We then mapped the traveler process and identified potential problem areas for PRM travelers and aligned technology solutions against the problem areas. We identified that there were not any modern or innovative solutions being applied to improve the enplaning/deplaning process for PRM. We narrowed our literature review to this topic and identified the workplace hazards associated with the push/pull forces required of wheelchair attendants. We then proposed our hypothesis.

Hypothesis: It is possible to increase airport throughput via improving the enplaning/deplaning experience for PRM. We imposed 2 limitations: 1. Minimal impact to existing airport operations (e.g. no to minimal infrastructure changes, no to minimum process changes, no to minimum contract changes) 2. Maintain a low technology adoption requirement (e.g. passengers and attendants should require minimal training to operate the system).

4. Was participation by industry in the project appropriate, meaningful and useful? Why or why not?

The participation of our industry experts played a critical role in the development and delivery of our ACRP airport design challenge submission. As mentioned previously, prior to this project, none of our team members had any significant exposure to airport operations and airport accessibility. While our literature review was able to clarify many aspects surrounding the regulation and current state of accessibility programs in airports, our industry experts were able to expand our understanding of how these operations take place in practice.

Furthermore, our team was fortunate to meet with industry experts throughout the entire design process and received invaluable feedback on our proposed designs. Our initial interest was in providing an autonomous mobility solution from car to plane. After discussing with our industry experts, we began to understand the scale and complexity of such a model, in addition to the challenges and infeasibility surrounding autonomous operations in areas like security and jet bridges. Our industry experts assisted us in adjusting the scope of our project toward our final proposal, being an improved solution for passenger boarding and deplaning using aisle chairs.

Once a clear scope had been defined, our industry experts continued to highlight pain points and challenges that our project could address in the transportation of mobility restricted passengers onto and off of aircraft. With this feedback in mind, our team was able to deliver our final proposal with confidence in the relevancy and feasibility of our design.

5. What did you learn? Did this project help you with skills and knowledge you need to be successful for entry in the workforce or to pursue further study? Why or why not?

As per the ACRP challenge, our team had no experience in researching airport accessibility prior to this project. As such, we have learned an enormous amount of technical knowledge about how airport operations are structured and the regulations surrounding airport accessibility services. Furthermore, and perhaps more importantly, our team learned and developed a great deal of soft skills throughout the development of our ACRP proposal. These skills include quantifying costs, risks, and benefits surrounding the development, implementation, and operation of our design, leading productive meetings with industry experts, setting clear and actionable goals, and developing a business case for our proposed solution. These skills transcend any one project and will no doubt prove incredibly useful as our team continues in our studies and eventually enters the workforce to hopefully assist future teams in their own pursuits.

Faculty

l. Describe the value of the educational experience for your student(s) participating in this competition submission.

The value of this educational experience is three-fold. First, there is the team response to a Request for Proposal (RFP). Few students leave university that have developed a concept to improve a real airport problem, estimated the cost and benefits, described and mitigated the safety risks, and determined the categories of sustainability analysis. The second is the teaming with those who have different viewpoints than your own: educational, cultural, experiential, and so on. Third, is completing a project on-time and the necessary reassessments of how much is left to do, how much resource do we have left, how many calendar days are left, and how are we going to get to a completed idea and proposal given what we have left.

2. Was the learning experience appropriate to the course level or context in which the competition was undertaken?

This is a graduate class in aviation and aerospace sustainability. One way to fulfil the research and design requirement is to enter the ACRP airport design competition.

3. What challenges did the students face and overcome?

This team started with a chair from curbside to airplane seat (and back), then kept refocusing on what problem they could address more fully given the time allowed. This is why they ended up with from jetway to aircraft seat and back. The first challenge is the challenge that many teams face, and that is to right-size the challenge and the solution. Given that the teams form in late January and deliver in late April, the team members must get to know each other, their strengths and weaknesses, develop the concept in an iterative fashion, speak with experts, and then size, resize, and right size the processes to be improved and the techniques to improve them. The teams complete the analyses and report in 3 months total time. This team struggled with the intended end users – are they aging, are the differently abled (physical or otherwise), are they people traveling alone or in a group. These are very real challenges in real world design, too.

4. Would you use this competition as an educational vehicle in the future? Why or why not?

I plan to continue to use this competition as an educational vehicle. Like most students, learning becomes more fun, engaging, and meaningful when they can learn, do, and compete.

5. Are there changes to the competition that you would suggest for future years?

I really like the new arrangement of the categories this year. In addition, I would add a required sustainability analysis in the airport design competition because sustainability has become important to airport stakeholders.

Appendix F - Reference List

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