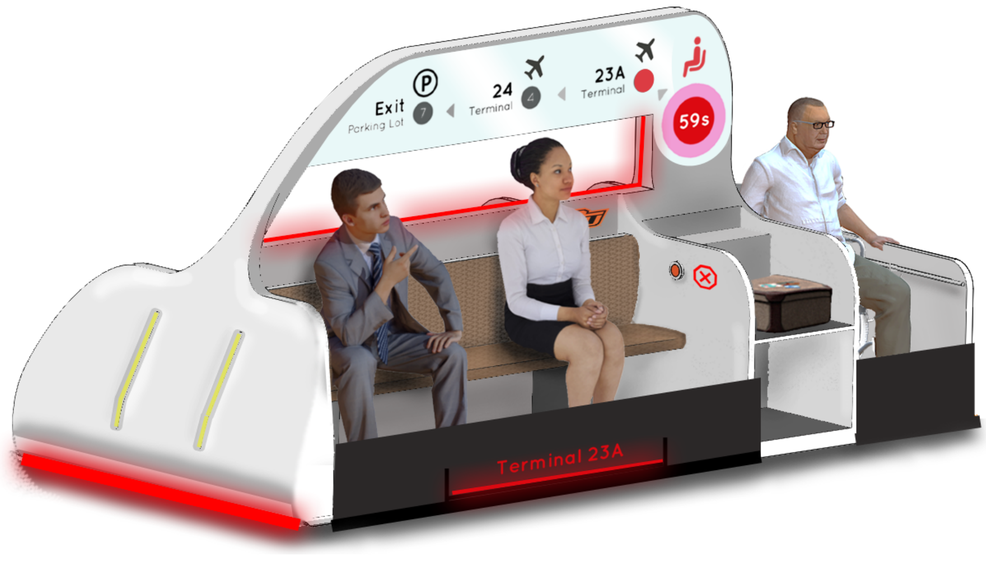
2022-2023 ACRP University Design Competition (Spring 2023)

Automated Trolley Loop Assistance System (ATLAS)

Improving Airport Navigation Through Inclusive Transit



Design Challenge (2022-2023) - Airport Management and Planning

Innovations to Accommodate the Aging Passenger Demographic in Airports

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COLLEGE OF
ENGINEERING, ARCHITECTURE
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Executive Summary

An autonomous interior passenger trolley system (ATLAS) is proposed as an innovative solution to accommodate aging passengers in airports for the 2022-2023 ACRP Design Competition (Airport Management & Planning). Elderly passengers often face several physical and cognitive challenges while traveling, such as carrying luggage for long distances and difficulty understanding signage. One of the more concerning risks these passengers face while in airports is the risk of falls and trips. Some existing solutions to assist elderly passengers include smartphone apps and maps, but these passive solutions may not be useful as smartphone ownership is reduced among those aged 65 and older.

We reviewed existing literature to understand how to develop a more active solution to meet the needs faced by these passengers. By understanding existing solutions and using an iterative design process, our team designed an inclusive system to alleviate several mobility and cognitive challenges faced by elderly passengers. ATLAS is designed around inclusion, dignity, and independence to accommodate several types of passengers. This inclusive system is designed to reduce passenger walking distance, increase mobility and independence, and reduce airport assistance and escort costs. The ATLAS system can be easily integrated into medium-sized airports without substantial changes in infrastructure requirements (such as dedicated tramways) while still allowing similar increases in traffic flow within the airport. The ATLAS system incorporates a wheelchair locking mechanism for increased mobility for passengers using existing wheelchairs.

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Problem Statement & Background

Elderly passengers face several physical and cognitive difficulties which may be amplified by travel. Potential mobility challenges include walking long distances, wheelchair use, and carrying luggage through crowded areas. These passengers may also have difficulties remembering gate numbers, understanding signs, or being able to hear airport announcements. The potential for injuries due to falling is a major concern. According to a study by the CDC, “falls are the leading cause of injury among adults aged ≥65 years (older adults) in the United States,” and “27.5% of older adults reported falling at least once in the past year, and 10.2% reported an injury from a fall in the past year **[1]**.” The demand for solutions to these challenges is going to grow as the population ages.

Current Conditions

Passive approaches to meet these challenges and accommodate passengers has been the integration of QR codes, localized service apps, and digital maps within airports, but some individuals may not be able to access these services due to a lack of smartphone ownership. According to a recent study, “96% of those ages 18 to 29 own a smartphone compared with 61% of those 65 and older, a 35 percentage point difference **[2]**.” Even for elderly travelers with smartphone access, there are still potential mobility, cognitive, and sensory challenges that need physical alternative solutions. Escort and wheelchair services can accommodate most of the challenges for elderly passengers but require significant airport resources through individualized employee assistance. Innovative approaches to integrate automated services into airports have been designed in the past, including a previous ACRP design competition submission featuring an autonomous and user-friendly wheelchair known as the AUSW **[3]** and well as the self-driving Multimobby carts at Brussels Airport in London **[4]**.

Proposed Solution

To build on the potential of autonomous systems and address the challenges and concerns facing elderly passengers, we propose a safe and intuitive airport navigation system for the 2022-2023 ACRP University Design Competition. Our proposed navigation system, called the Automated Trolley Loop Assistance System (ATLAS), prioritizes safety, independence, and mobility for aging passengers. The 2021-2022 ACRP winning design **[3]** revealed how automated systems can be viable solutions to meet these challenges. ATLAS aims to improve on these concepts through simplicity and fast integration with existing airport infrastructure.

Summary of Literature Review

We reviewed several ACRP publications as well as appropriate publications outside the ACRP on a variety of topics: safety, elderly cognition, and current technological solutions that can meet the growing demand for accommodations. Each publication was vital to validating design features and reinforced assumptions made early in the design process.

Literature on Elderly Safety & Risk Management

Reviewing safety and risk management literature was vital to understanding the feasibility of designing the ATLAS system for busy airports. The FAA's *Safety Management Systems for Airports* **[5]** and the *Safety Management System Manual* **[6]** by the ATO are sources we reviewed for our Safety Risk Assessment. These sources provide the methods to *describe the system*, *identify the hazards*, *identify the risks, assess the risks,* and *treat the risks* with the goal of providing the safest experience possible for passengers which are detailed in the risk section of this report.

Literature on Interior Logistics & Autonomous Vehicles

To understand the issues of current implementations of transport and escort services for elderly passengers, we reviewed ACRP literature focusing on the logistics of movement throughout airports. *Impacts of Aging Travelers on Airports* **[7]** was a key resource for the design process as it describes wayfinding design guidelines (active and passive), compact transit systems, and the impact of long walking distances on elderly passengers. Several design guidelines describing navigation cues were reviewed for understanding how passengers perceive and interact with airport infrastructure. This influenced the aesthetic design choices such as color and context clues for ATLAS passengers. The text also describes the issues of wheelchair and scooter use between floors, requiring elevators to be constructed near gates. Independent scooters are described as reducing elderly passengers' dependence on staff while enhancing revenue due to their increased mobility. One downside mentioned in **[7]** is the potential for congestion issues.

In *Planning and Decision-Making for Autonomous Vehicles* **[8]**, methods relevant to the safe design and integration of autonomous vehicles are described. Simulations and neural-network systems are utilized in the design process for environment and hazard navigation. Their description of 'behavior-aware motion planning' is a potential solution for predicting pedestrian movement around individual ATLAS vehicles. One interesting observation described in *Communication Strategies for Airport Passenger Access and Mobility* **[4]** states that "90% of older travelers request wheelchair assistance at airports even though they typically use no assistive device in their daily lives," which shows that navigation alternatives may be preferable.

Literature on Elderly Challenges & Cognition

Communication Strategies for Airport Passenger Access and Mobility and *Cognitive Aging* **[9]** describe the impact of the growing population of elderly passengers coupled with a noticeable increase in disabling chronic illnesses. In some cases, elderly passengers may not even know they have a disability that they can self-identify. These publications reveal cognition and mobility issues faced by these aging passengers and highlight the importance of elderly accommodation within airports. The texts describe actionable design opportunities that we utilized in the ATLAS system, such as inclusion and independence.

Enhancing Airport Wayfinding for Aging Travelers and Persons with Disabilities **[10]** provides substantial information on ADA compliance as well as more universal design features for a variety of impaired passengers. *Assessing Airport Programs for Travelers with Disabilities and Older Adults* **[11]** describes several needs of older travelers and those with disabilities, including the need to feel equal to others, to be in control of their assistance, and to be treated as individuals. The inclusive design of the ATLAS system incorporated these needs.

Literature on Technology & Touchless Accommodations

By reviewing ACRP literature related to current technological advancements in accommodation technologies, the most useful design aspects could be improved while avoiding potential flaws or weaknesses. This section was important as several accommodation designs are implemented and studied in real airport environments. As previously described in **[2]**, over half of passengers over 65 don’t have access to app-based smartphone accommodations. *Toward a Touchless Airport Journey* **[12]** describes how contactless technology (through sensor or visual context) impacts all traveler age demographics. The benefits include lower disease transmission, decreased interaction requirements, and faster flow through airports. The touchless design concept was integrated into the ATLAS system.

Problem-Solving Approach

The problem-solving approach stemmed from the ideas described in *The Mechanical Design Process* **[13]** by David G. Ullman. The mechanical design process starts with identifying and defining the problem through customer needs and potential risks and works outward towards a final and fully developed design.

Industry Expert Interactions

We contacted industry experts and operators to gain a deeper understanding of what challenges airports are currently facing and justify some design features of the ATLAS system. Not only did they provide crucial information about the needs of individual airports, but also insight into how to strengthen the design of the ATLAS system to meet those needs. These interactions gave us insight to better ATLAS and preparing for incorporation into airports.

David Byers - Industry Expert

We first met with Dr. David Byers, the Principal of Quadrex Aviation, LLC. He provided insight and guidance into the challenges faced by the aging population and the growth expectation that airports need to accommodate. Wheelchairs, golf carts, moving walkways, and signage are common accommodations to help senior citizens maneuver inside an airport. Assisting passengers with disabilities navigate terminals is an ongoing challenge that will grow in the future. Useful information on communication with airports as well as creating a product tailored to individual airports was discussed. We also discussed the importance of thoroughness in our report, specifically the cost-benefit analysis and risk sections.

Dr. I. Richmond Nettey - Industry Expert

Following Dr. Byer's advice, we sought feedback for our Risk Safety Assessment. Dr. I. Richmond Nettey is the President of the ATMAE Safety Division at Kent State University in Ohio. His experience and understanding of safety and risk was instrumental for honing safety concepts and concerns. Useful information was provided on our developed risk management section and the relevance of certain risk topics as they relate to interior passenger systems. Dr. Nettey assisted the team in understanding context-based requirements needed to develop a thorough Risk Assessment section.

Felipe Rodriguez - Industry Expert

Felipe Rodriguez is an Adjunct Lecturer at University of Maryland Eastern Shore for the Engineering and Aviation Sciences Department. He teaches classes on airport management. We spoke with him regarding ADA compliance information and how these requirements fit into the context of airports. Felipe's knowledge was applied to the concept design section to assure the design was compatible with these types of design requirements.

Daniel Pruim - Airport Operator

Daniel Pruim is a project manager at Oakland International Airport (OAK) whose expertise was needed to understand terminal design and passenger expectations. As the Oakland International Airport was originally selected for its unique size and layout, his feedback was critical to understanding the needs of these types of airports as well as other layouts. Though ATLAS wouldn't be feasible at the OAK due to the narrow terminals, Daniel Pruim discussed with us options for newer airports. For instance, the Orlando International Airport does not have moving walkways, even though it is a large airport with long routes. This information led to further development of physical stop stations and corridor spacing considerations. A conversation about tight corridors in OAK also led to the requirement of multiple Virtual Loops for some airport designs.

Project & Product Definition

We considered potential stakeholders (elderly passengers, airports, and vendors inside airports) based on the potential impact and effect of the ATLAS system. The expert interactions and a survey provided to older friends, family, and acquaintances at the beginning of the design process provided the information we needed to determine our stakeholders (*Table 1*), customer needs (*Table 2*), and engineering specifications (*Table 3*). The survey allowed us to define the initial customer needs, highlight design opportunities and map them to engineering specifications. After reviewing ACRP material such as ACRP Synthesis 51 **[7]** and ACRP Report 210 **[14]**, we condensed these tables to the most important details from a larger selection **[15]** for this report.

Table 1: Highlighted Potential Stakeholders

Elderly Passengers	ATLAS will help elderly passengers navigate airports with dignity while reducing walking stress and anxiety. ATLAS allows passengers access to areas they might not have been able to reach or find quickly before, such as food vendors and restrooms.
Airport / Employees	The purpose of ATLAS is to reduce elderly traveler frustration, liability, and ease employee assistance. By providing a cost-effective system for meeting these needs airlines can reduce expenditures and increase flow through airports. Airline employees will be burdened less with calls for assistance and guidance on navigating the airport. With less frustrated travelers, interactions will be more satisfying.
Airline Vendors	Airline vendors, such as restaurants, shops, and vending machine companies could see an increase in sales and traffic from passengers who would otherwise not visit them due to a lack of time, long distances, or knowledge that the vendor exists.

Table 2: Condensed Customer Needs

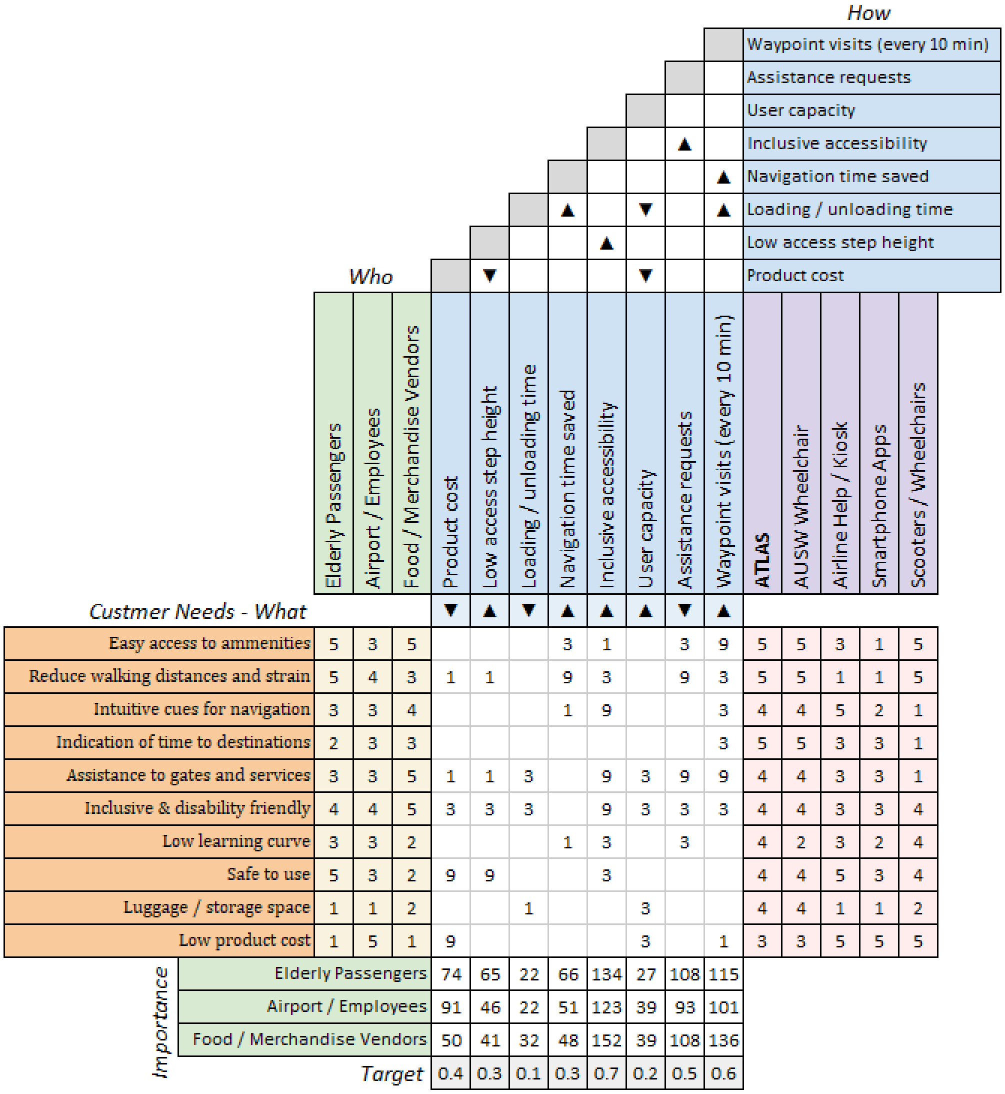
#	Need	Importance
1	Easy access to restaurants, vending, and restrooms	***
2	Reduce walking distances and strain	*****
3	Intuitive audio and visual cues for navigation	****
4	Indication of time or distance to destinations	***
5	Assistance to gates and other services	***
6	Inclusive design for maximum accessibility	****
7	Low learning curve and easy to understand	***
8	Safe to use	*****
9	Luggage assistance and storage	*
10	Low product cost	**
11	Reduces traffic congestion	**

Table 3: Condensed Engineering Specifications

#	Metric	Value	Units	Needs Map
1	Waypoint visits (every 10 minutes)	$x > 6$	waypoints	1, 5
2	Daily airport employee assistance requests	$x < 50$	requests	1, 4, 5, 7, 3
3	User capacity	$x > 5$	people	5, 6, 11
4	Inclusive accessibility (who can use)	$x > 90$	%	1, 6
5	Average navigation time saved during travel	$x > 5$	minutes	1, 2, 3
6	Loading/unloading time	$x < 30$	seconds	9, 7, 6
7	Low access step height	$x < 5$	inches	8, 6
8	Product cost	$x < 50{,}000$	USD	10

Quality Function Deployment (HoQ)

A Quality Function Deployment (*Figure 1*) called a House of Quality (HoQ) compares customer needs, stakeholders, competitors, and engineering specifications. Analyzing the information allowed us to see what the current products' strengths and weaknesses might be. This information determined which aspects to emphasize for potential concepts. The previous ACRP design submission **[3]** was compared among existing solutions as well.



How	Product cost	Low access step height	Loading / unloading time	Navigation time saved	Inclusive accessibility	User capacity	Assistance requests	Waypoint visits (every 10 min)
Waypoint visits (every 10 min)								
Assistance requests								
User capacity								
Inclusive accessibility							▲	
Navigation time saved								▲
Loading / unloading time				▲		▼		▲
Low access step height					▲			
Product cost		▼				▼		

Custmer Needs - What	*Who* Elderly Passengers	Airport / Employees	Food / Merchandise Vendors	Product cost	Low access step height	Loading / unloading time	Navigation time saved	Inclusive accessibility	User capacity	Assistance requests	Waypoint visits (every 10 min)	**ATLAS**	AUSW Wheelchair	Airline Help / Kiosk	Smartphone Apps	Scooters / Wheelchairs
				▼	▲	▼	▲	▲	▲	▼	▲					
Easy access to ammenities	5	3	5				3	1		3	9	5	5	3	1	5
Reduce walking distances and strain	5	4	3	1	1		9	3		9	3	5	5	1	1	5
Intuitive cues for navigation	3	3	4				1	9			3	4	4	5	2	1
Indication of time to destinations	2	3	3								3	5	5	3	3	1
Assistance to gates and services	3	3	5	1	1	3		9	3	9	9	4	4	3	3	1
Inclusive & disability friendly	4	4	5	3	3	3		9	3	3	3	4	4	3	3	4
Low learning curve	3	3	2				1	3		3		4	2	3	2	4
Safe to use	5	3	2	9	9			3				4	4	5	3	4
Luggage / storage space	1	1	2			1			3			4	4	1	1	2
Low product cost	1	5	1	9					3		1	3	3	5	5	5
Importance Elderly Passengers				74	65	22	66	134	27	108	115					
Airport / Employees				91	46	22	51	123	39	93	101					
Food / Merchandise Vendors				50	41	32	48	152	39	108	136					
Target				0.4	0.3	0.1	0.3	0.7	0.2	0.5	0.6					

Figure 1: A Condensed HoQ Breakdown

After accessing the customer needs and evaluating existing solutions, the project required a product that would be intuitive and easy to use while using fewer airport resources. Additionally, our research highlighted a need for a solution that could assist multiple passengers without causing additional congestion. This was relevant as higher congestion was reported for airports utilizing a larger number of individual mobility carts **[7]**.

Concept Design

After these initial steps, the ATLAS system was designed around safety, passenger dignity, inclusion, easy airport integration, and cost. Continuing to follow the *Design Process* from David G. Ulman's *The Mechanical Design,* we refined our concepts through the iterative stages of *concept generation*, *concept screening*, *concept scoring & selection*, and *concept improvements*. Continuous self-improvement and refining were built into the entire process. Solutions to specific design challenges seemed to converge on existing concepts and features, but we noticed opportunities for innovation. By reviewing the problems and solutions by previous designs **[3]**, the strengths could be maximized while weaknesses could be developed.

Concept Generation

During concept generation, we brainstormed innovative concepts to accommodate elderly passengers and make travel more comfortable while meeting the engineering requirements. Five main concepts are presented that showcase ideas potentially useful for solving the design challenge. Other concepts consisted of motorized scooters, active directional signage, intuitive handheld devices, and motorized 'pets' that would accompany passengers **[15]**.

Table 4: Condensed & Refined Concept Ideas

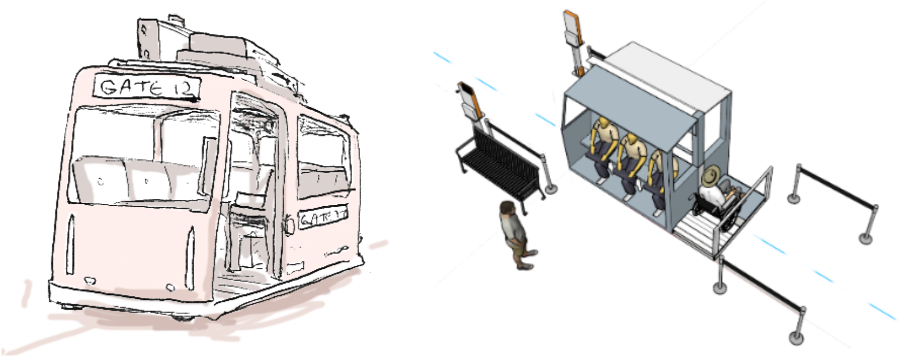


Figure 2: Trolley Bus with Interactive Menu (Concept 3)

Figure 3: Print Kiosk (Concept 7)

Figure 4: Directional Projection (Concept 12)

Figure 5: Handheld Map (Concept 15)

Figure 6: Smart Glasses (Concept 16)

NOTE: Images developed from free-use base images at Noun Project, PixelSquid, iStockPhoto, and PNG Mart

Concept Screening

To define and quantify the concepts while also accounting for drastically different designs, two comparison matrices **[15]** tested related concepts with similar control references. This ensured a normalized and reasonable comparison between concepts. Each concept was assigned a zero if it met a specification equally relative to the reference, a one if it exceeded a specification relative to the reference, and a negative one if it was less effective at addressing a specification relative to the reference. The concepts with the highest scores moved on to *Concept Scoring*. After reviewing these concepts, we combined and modified the concepts before the next comparison matrix.

Concept Scoring & Selection

After screening, we adjusted concepts to counter risks determined during risk assessment analysis. Similarly to *Concept Screening*, *Concept Scoring* compares concepts to a reference in regards to meeting specifications; however, each specification is given a weight based on their relative importance to the design challenge. We chose a reference concept by considering the relative standard for each specification. We selected a final concept for development by comparing the scores (*Table 5*).

Table 5: Concept Scoring Table

Specifications	**Wt**	**Concept 3**		**Concept 7**		**Concept 12**		**Concept 15**		**Concept 16**	
		Rate	Score	Rate	Score	Rate	Score	Rate	Score	Rate	Score
Increase Traffic Flow	7	4	0.28	4	0.28	2	0.14	3	0.21	2	N/A
Locate Goods Easily	2	2	0.04	3.5	0.07	3	0.06	3	0.06	1	N/A
Help in Emergencies	5	5	0.25	3	0.15	4	0.2	4	0.2	1	N/A
Weight	1	1	0.01	3	0.03	5	0.05	4	0.04	3	N/A
Durable	5	4	0.20	4	0.20	2	0.10	3	0.15	4	N/A
Ease of Installation	5	1	0.05	3	0.15	4	0.20	4	0.20	3	N/A
Recyclable	2	3	0.06	2	0.04	1	0.02	2	0.04	2	N/A
Amount of Storage	4	2	0.08	3	0.12	4	0.16	4	0.16	3	N/A
Costs of Repair	7	2	0.14	3	0.21	2	0.14	4	0.28	3	N/A

Specifications	Wt	Concept 3		Concept 7		Concept 12		Concept 15		Concept 16	
		Rate	Score	Rate	Score	Rate	Score	Rate	Score	Rate	Score
Universality	6	3	0.18	2	0.12	3	0.18	3	0.18	1	N/A
Confusion Prevention	8	4	0.32	3	0.24	2	0.16	2	0.16	1	N/A
Setup Cost	7	2	0.14	3	0.21	3	0.21	3	0.21	3	N/A
Usability Range	5	3	0.15	2	0.10	2	0.10	2	0.10	1	N/A
User Capacity	6	5	0.30	4	0.24	2	0.12	3	0.18	3	N/A
Lifetime	5	5	0.25	2	0.10	1	0.05	3	0.15	2	N/A
Supported Languages	6	4	0.24	4	0.24	3	0.18	4	0.24	3	N/A
Time to Gate	8	5	0.40	3	0.24	3	0.24	3	0.24	3	N/A
Maintenance Cost	7	3	0.21	4	0.28	1	0.07	3	0.21	3	N/A
Anti-Theft	1	5	0.05	5	0.05	3	0.03	1	0.01	5	N/A
Accessibility	3	5	0.15	3	0.09	1	0.03	2	0.06	3	N/A
Net	**100**	**3.5**		**3.16**		**2.44**		**3.08**		**2.41**	
Rank		**1**		**2**		**4**		**3**		**5**	
Continue?		**Y**		**Y**		**N**		**N**		**N**	

Concept Improvements

We made several improvements to enhance the safety and utility of the final concept design. The original concept featured a touch screen at waiting areas and on each trolley for waypoint selection. For a multi-user vehicle system with multiple destinations, there was a concern about waypoint priority and confusion. After studying the benefits of touchless technology **[12]**, the touch screen feature was removed in favor of an automated Virtual Loop system that would visit all waypoints and operate similar to existing subway systems with passive vehicle interactions. This system would feature customizable airport-specific stops around key locations including gates, restaurants, bathrooms, and loading/unloading areas.

Problem-Solving Approach Continued: Final ATLAS Design

The final design of the ATLAS system is composed of several safety features and airport integration systems. The ATLAS system offers airports a simple way to improve traffic flow, assist elderly and disabled passengers passively while allowing independence, and integrate a transit system without large changes to infrastructure. The section is divided into *Design Features*, *Customized Airport Setup & Integration*, *Virtual Loop Design & Function*, and *Further Development*.

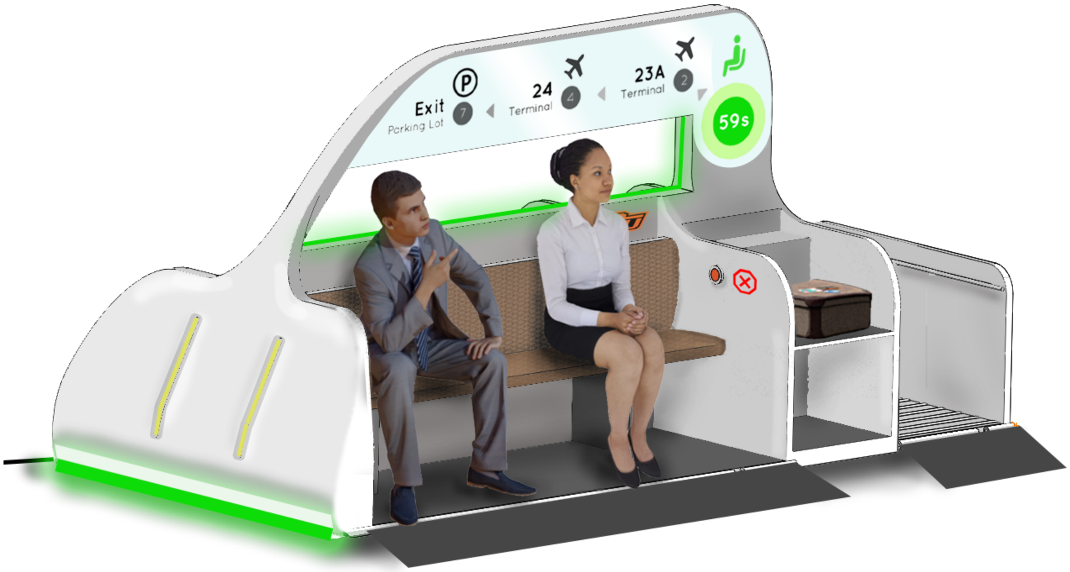


Figure 7: ATLAS boarding with access ramps down

Design Features

Each physical trolley incorporates several safety design features that are based on the initial customer needs, engineering specifications, and ADA compliance and design literature **[16]**. The section overview is divided into *Safety Features*, *Dimensions & System Positions*, *Wheelchair Locking Mechanism*, and *Loop Display Screen*. The safety and design features offer elderly passengers a degree of independence while allowing others to use the service.

Safety Features

The most important feature of the trolley system is object and pedestrian collision prevention. Each trolley is equipped with a multi-camera & audio system, bumpers, and lights to prevent collisions with pedestrians both actively and passively. Other safety features include weight shift sensors, ramps, and a profile designed to mitigate tripping risks.

Camera System, Bumpers, Governor, and Alert & Speaker System

The Camera system communicates with the Control Center for real time distance and object detection. Instead of using a LiDAR system, a camera system is used to categorize visual objects by type and scrutinize them for anticipatory response **[8]**. This system can let the Control Center determine objects' relative speeds, directions, accelerations, and potential for collision. Newer systems can improve safety and anticipate passenger actions & reactions **[8]**. In the event of physical contact, depression bumpers will bring the vehicle to an immediate stop. The smooth and low profile prevents objects and people from becoming trapped underneath the trolley. Vehicles are equipped with a speed governing device that prevents excessive speeds and accelerations for increased safety (pedestrian and passenger). A light and speaker system alert pedestrians of vehicle presence and alert passengers with audio cues for arrivals and departures from waypoints.

Ramps & Low Step Access

To mitigate tripping, both ramps and low step access heights are incorporated into the design of ATLAS. The ramp grading is limited to 1:10 to be ADA compliant **[16]**. While allowing passengers to embark and disembark while stopped, ramps are deployed to reduce the likelihood of a trip. While in operation, the ramps move to a hold position to prevent passengers from moving onto or from the vehicle.

Figure 8: ATLAS moving to destination (ramps moved up)

Smart Weight Shift System

While the trolley is in motion, the seats and floor will have a weight shift sensing system. If there is a substantial shift of weight while in operation (fall, passenger standing or moving, pedestrians accessing the trolley from the outside), the trolley will stop and wait for these shifts to stop before resuming. This system is implemented to reduce injury for passengers embarking or disembarking at non-standard times (while in operation).

Dimensions & System Positions

The main dimensions are displayed in *Figure 9* and *Figure 10* with the trolley system positions. Although the trolley design allows for passengers to be seated on both sides, the thin profile is only 1.83 m (6’) wide and allows each trolley to move through crowded areas similar to existing manned escort carts and vehicles. By having a dual-seating system the batteries and major components can be incorporated conveniently between the seats and back support area of each trolley. ADA compliance requires the width of the wheelchair locking section to be no less than 36 inches wide and a bar height “between 33 inches and 36 inches” should be installed for holding **[16]**. Older airports have some corridors between terminals that are too small to allow regular ATLAS trolley vehicle traffic through without causing congestion or safety risks. For these considerations and areas with transient obstacles such as waiting lines, separate Virtual Loops for each terminal may be required **[17]**. A profile width comparable to existing escort interior suttles would justify the transition to ATLAS systems.

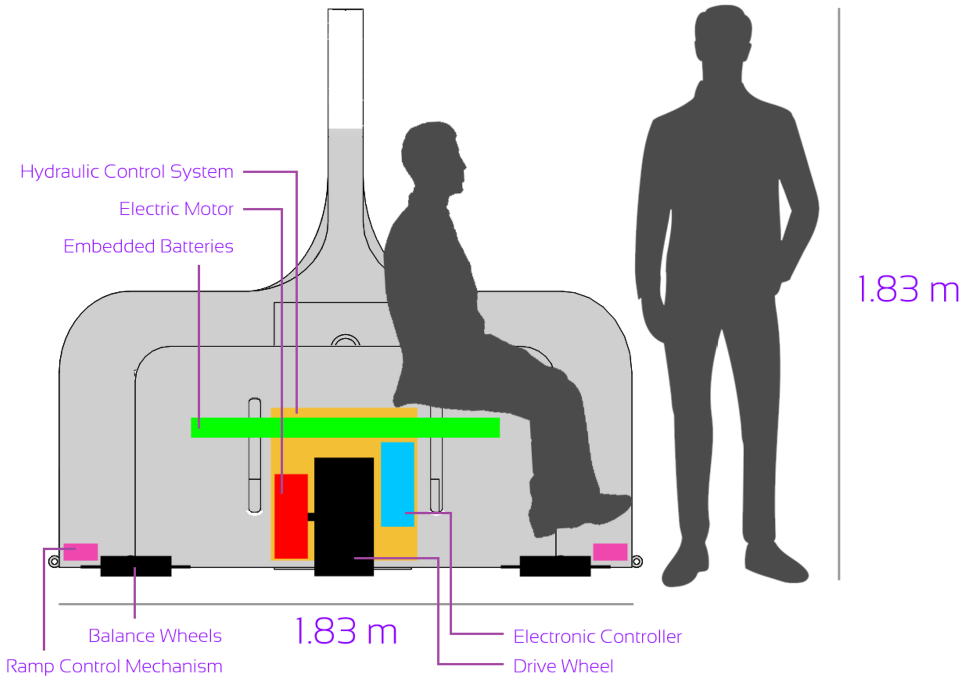


Figure 9: Back view showing design features

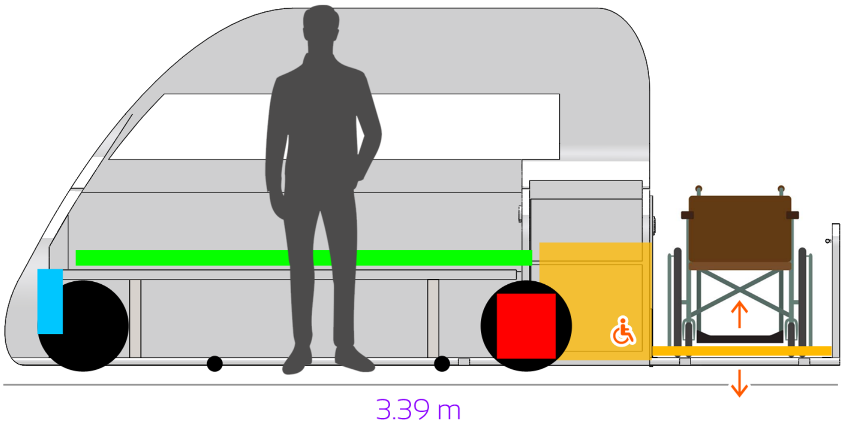


Figure 10: Side view with wheelchair hydraulic mechanism visible

Wheelchair Locking Mechanism

The wheelchair locking mechanism is unique to the ATLAS system and allows passengers in wheelchairs to use the system without airport assistance. The design allows passengers in wheelchairs to embark the vehicle onto a designated wheelchair platform. When the passenger is ready and in position, bars between the fixed wheelchair platform move upward until contact is made with a surface such as a wheel, foot, or bag. Bars that are unencumbered by objects continue to rise.

When the maximum height of the bars is reached, the vertical movement of the bars is locked into the current orientation to prevent changes. This allows for unique profiles, wheelchair orientations, and situations to lock wheelchairs safely for movement without assistance. When the vehicle comes to rest, the bars depress and the platform becomes flat, allowing the passenger to disembark easily. An emergency stop button allows some level of control in the event of an emergency.

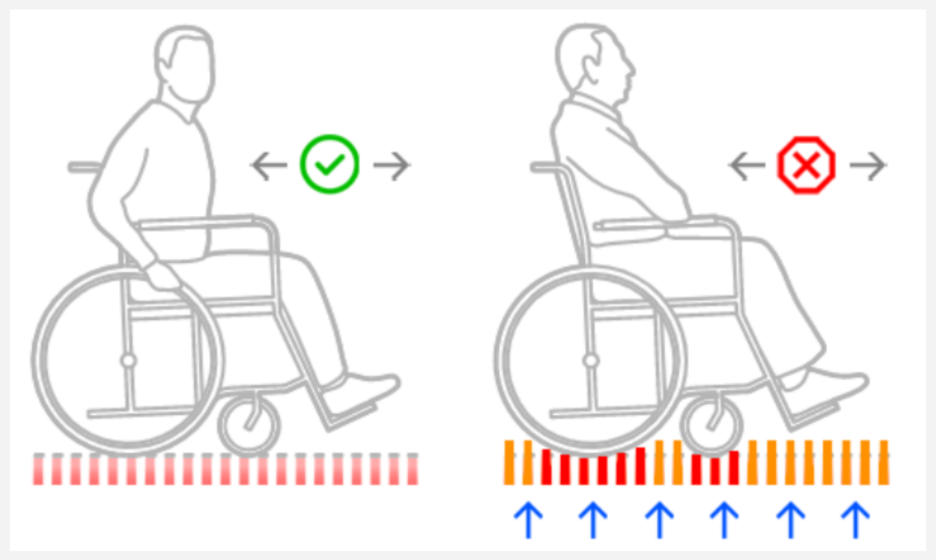


Figure 11: Side view with wheelchair hydraulic mechanism visible

Loop Display Screen

The Loop Display Screen is visible from both sides of the trolley for pedestrians. They can gauge times as the trolley goes by for reference. In *Figure 12*, large lettering with minimal text-based information is used. Pictorial representations are used for language-independence and a low learning curve. Numbers are used to convey times to waypoints. Color and context clues are changed on the display depending on trolley states (embarking / disembarking). Other information can be displayed to show gate delays, gate closures, new shops, advertisements, and more. Variations on the Loop Display Screen can also be used to discourage passengers from using the vehicle during charging, maintenance, or emergencies.

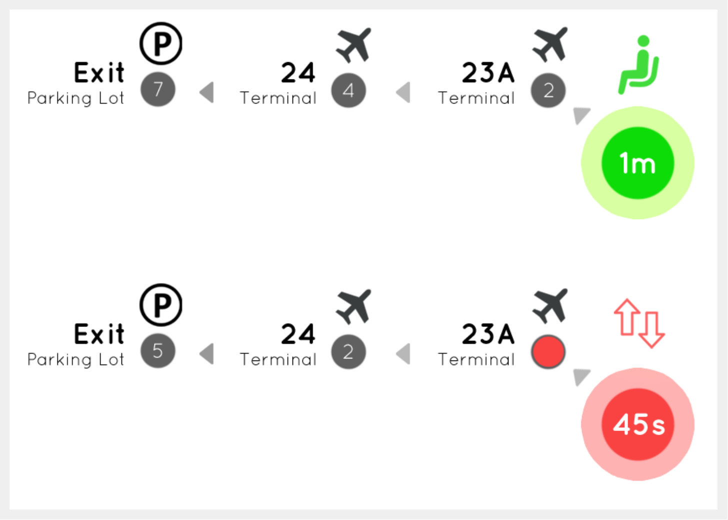


Figure 12: Intuitive display examples: while boarding (green) and moving (red)

Customized Airport Setup & Integration

To ensure seamless transition to integrate the ATLAS system for airports, most of the control systems are designed before physical implementation depending on the design needs of each airport. Each airport has unique challenges and layouts that are perfect for the ATLAS system. The integration requires only a Central Control setup for controlling the trolleys, installation of a Central Control area (which the trolleys can access and use automatically without employee assistance), and dedicated stop areas (outside of the regular waypoint stops) where people can wait to board.

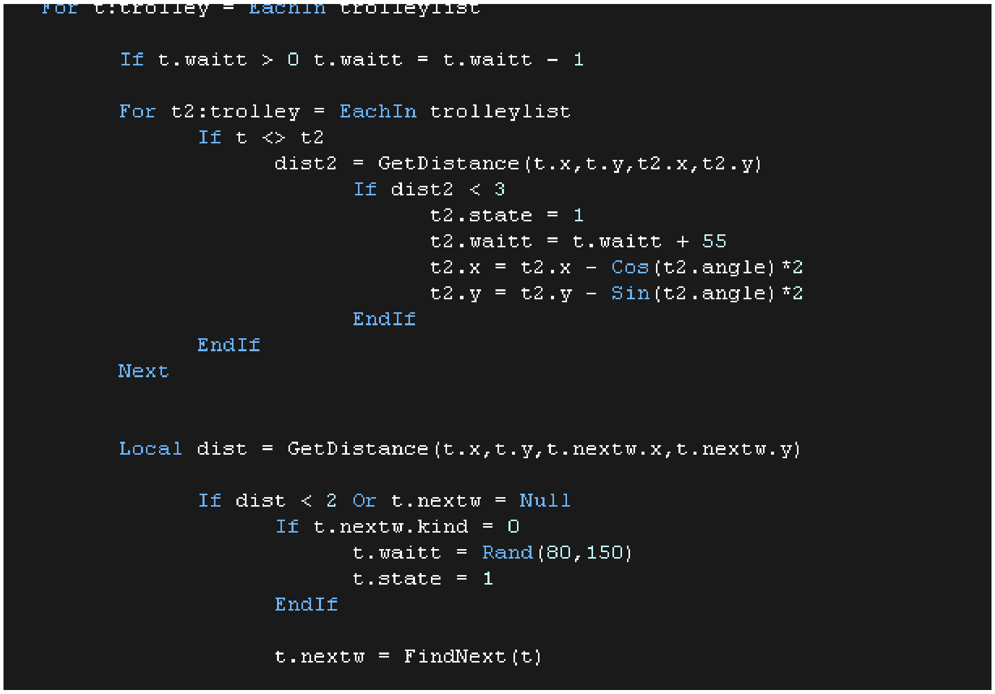
Virtual Loop Design & Function

To work efficiently and safely, each trolley is controlled by (and sends local information to) a central processing computer in the Central Control area known as the Virtual Loop. By passing all communication through the Virtual Loop, realtime information about the entire system can be analyzed and controlled by the airport (or externally by a third party). With the potential of LLMs, image-processing, and neural networks for generalized artificial intelligence

(AGI), adaptable and intelligent trolleys may not require any centralization in the near future and may be able to provide even more user-focused services such as emergency assistance.

Development Testing of a Flexible Virtual Loop

An interactive Virtual Loop simulation **[18]** was designed in BlitzMax, a hybrid C language used for fast prototyping and development (video demonstration **[19]**). This program was vital to understand how a dynamic autonomous system with delays, charging, and real-time processing would work in the airport environment. Oakland International Airport was selected for the design example due to its interesting layout, although the threshold corridors leading to one Terminal may be too small for regularly scheduled trolley passage. In the simulation program, vehicles can be selected along their route for trolley states, including current battery life, nearby waypoints, position, velocity state, etc. Virtual Loop designs can be developed quickly for airports before implementation to reveal how traffic flow can be optimized.



```
For t:trolley = EachIn trolleylist

    If t.waitt > 0 t.waitt = t.waitt - 1

    For t2:trolley = EachIn trolleylist
        If t <> t2
            dist2 = GetDistance(t.x,t.y,t2.x,t2.y)
                If dist2 < 3
                    t2.state = 1
                    t2.waitt = t.waitt + 55
                    t2.x = t2.x - Cos(t2.angle)*2
                    t2.y = t2.y - Sin(t2.angle)*2
                EndIf
        EndIf
    Next


    Local dist = GetDistance(t.x,t.y,t.nextw.x,t.nextw.y)

        If dist < 2 Or t.nextw = Null
            If t.nextw.kind = 0
                t.waitt = Rand(80,150)
                t.state = 1
            EndIf

            t.nextw = FindNext(t)
```

Figure 13: A Snippet of the BlitzMax Simulation Code

```
Trolley 2

X POS: 84
Y POS: 437

Next Waypoint: In Motion Entertainment

Battery: 78.7%
Trolley State: Transiting

Current Occupants: 0
Wheelchair Occupant: No
```

Figure 14: Virtual Loop Simulation of Oakland International Airport

Further Development

Control Center for Charging, Control, and Maintenance

The Control Center can be selected by the airport to ensure convenience and control. The area should be dedicated to the ATLAS system and inaccessible by passengers. This area consists of a trolley charging station (with conductive plates) for automated charging, a repair area in the event of self-diagnosed maintenance or other needs to be managed by a specialist, the computer control system for charging and Virtual Loop control, and a physical reference orientation point for distance and velocity check information.

Airport Physical Stop Area Signage, Physical Paths, & Passenger Education

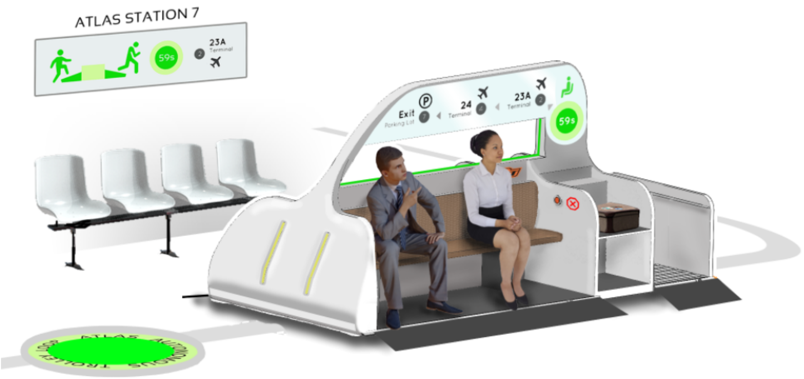


Figure 15: Passenger Stop Station

Physical waiting areas are necessary in airports that won't obstruct crowd pathways while allowing passengers to embark and disembark the vehicle in a known position in airports. These areas will have intuitive signage that displays the wait time for the next trolley as well as seating. There are also non-physical stops built into the Virtual Loop, such as near gates. Advertisements throughout the airport educate pedestrians and passengers of the trolley system. In busier airports, physical rail path sections may be needed to be safely separated from the main pathways to ensure safety. Floor signage increases awareness of anticipated pathways.

Safety Risk Assessment

A Safety Management System (SMS) is used to evaluate the risks associated with a new system or operation. The FAA provides several resources to develop a (SMS), such as the Advisory Circular 150/5200-37A **[20]**, the Safety Management System Manual **[21],** and Order 8000.369 **[22]**. A safety risk assessment was developed using these resources. There are four key components of an effective SMS: *Safety Policy*, *Safety Risk Management*, *Safety Assurance*, and *Safety Promotion* **[20]**.

Figure 16: SMS Components (SRM highlighted)

A thorough Safety Risk Management (SRM) was developed with a focus on Safety Risk Management for this report. The five steps of SRM are: *describe the system*, *identify the hazards*, *identify the risks, assess the risks,* and *treat the risks* **[20]**. With further development, we will work with the airports to develop policies, evaluation methods for controls, training processes, and infographics to complete the *Safety Policy*, *Safety Assurance*, and *Safety Promotion* components of the SMS.

Defining the System

The 5M Model Method **[20]** is used to define ATLAS. ATLAS is a self-driving vehicle designed with the mission to assist the aging demographic with traveling within the airport. ATLAS will have software programmed to follow a designated path with assigned stop stations for passengers to board. ATLAS will be functioning in the airport past the security checkpoint to the terminals, concessions, restrooms, and other areas within the airport.

The FAA's Safety Management System Manual organizes the hazards with five levels of both severity and likelihood **[21]**. Hazards that are more likely to happen are labeled "frequent" and those that are least likely to occur are labeled as improbable. Whereas hazards that are the most severe are "catastrophic" and the least severe are labeled "minimal." The tables below define 'likelihood' and 'severity' for ATLAS. We created the tables below following the formatting in the *Advisory Circular 150/3200-37A* **[20]** and the *FAA Safety Management System Manual* **[21].**

Table 6: Incident Severity

Severity				
Minimal	**Minor**	**Major**	**Hazardous**	**Catastrophic**
No injury, no permanent damage, damage is easily repaired or covered	No injury, non-permanent damage that requires a professional to repair	Minor injury that does not require medical aid, non-permanent damage that makes device temporarily unusable	Injury that requires medical aid, non-permanent damage that makes device unusable for extended amount of time, permanent damage that does not affect usage	Serious Injury that requires intensive medical care or death, permanent damage that makes device unusable

Table 7: Incident Likelihood

Estimated Likelihood (Incidents per 1,000,000 cycles)				
Extremely Improbable	**Extremely Remote**	**Remote**	**Probable**	**Frequent**
$X < 0.1$	$X \leq 1$	$X \leq 100$	$X \leq 500$	$X \leq 5000$

NOTE: Cycle is defined as a full circuit (loop) around the airport

We determined the levels of severity with the consideration that our product will be used consistently by the general population, more heavily by those more vulnerable to injury. This means the product needs to be easily maintained and is safe for regular use. With this in mind, we categorized injuries as major and hazardous, while catastrophic is for serious injuries or death. We also considered damage to the device or its surroundings. Damage that makes the device unusable as major, hazardous, or catastrophic varying on the time it is unusable is considered. The number of cycles each ATLAS vehicle would make in ten years was estimated with incident likelihoods.

Identifying, Analyzing, and Assessing Risks

The first step of the risk assessment is creating a Failure Mode, Effects, and Criticality Analysis (FMECA) table (*Table 8*). We began by listing all the potential hazards associated with implementing ATLAS in an airport. We have types of risks that could result in costs to the airport to mitigate and control to develop the design of ATLAS. We assigned each hazard a severity level and a likelihood level based on the definitions in the previous section **[23]**. Using a 5x5 Risk Matrix, we mapped these hazards and identified each one as "high risk", "medium risk", and "low risk" following the FAA in the Advisory Circular 150/5200-37A **[20]**. "High Risk" hazards are indicated with the color red. These hazards are unacceptable and must be mitigated. "Medium Risk" hazards are indicated with yellow. "Low risk" hazards are indicated with green. Medium and low risk hazards are not required to be mitigated but should if possible **[20]**.

The list below includes risks that impacted our original design. For example, our original design included a functioning tablet for users to select a stop. However, the likelihood of damage or malfunction with an unattended customer-facing tablet was too high and it was removed.

Table 8: FMECA Table to develop Risk Matrix

No.	Hazard	Likelihood	Severity	Control	Verification
1	Object collisions	Remote	Hazardous	Safety bumper/proximity detection	Periodic tests for object collisions in a controlled environment

No.	Hazard	Likelihood	Severity	Control	Verification
2	Human collisions (Injury)	Extremely Improbable	Catastrophic	Speed governor and safety sensors while moving	Periodic tests for object collisions in a controlled environment. Ensure speeds are not exceeded electronically or through position updates.
3	Tripping while onboarding / offboarding (Injury)	Remote	Major	Extremely low step height. Onboarding ramp	Ensure the loading step is visible. Ensure weight sensors are working
3b	Tripping while onboarding / offboarding (non-injury)	Frequent	Minimal	Extremely low step height. Onboarding ramp.	Ensure the loading step is bright and visible. Periodically ensure weight sensors work
4	Cause traffic congestion	Remote	Minimal	Smart avoidance system / dedicated lane	Periodic testing for congestion avoidance
5	Hinder first responders /employees	Extremely Remote	Catastrophic	Remain inactive or move to designated emergency zones	Routinely test for emergencies and check product response
6	Power loss/system failure	Remote	Major	Remote emergency maintenance request with a backup system	Periodically ensure remote emergency system detects failures and request help
7	Falling objects	Remote	Major	Unsecured storage bins	Visual inspection of vehicle, lower bins
8	OS errors (hacked)	Improbable	Catastrophic	Utilize secure protocols and systems	Do safe social engineering or hacking
8b	OS (screen)	Frequent	Minor	Touchscreen display	Remove screen displays
9	Fire Hazard	Extremely Improbable	Catastrophic	Build product from fire retardant materials with suppression system	Ensure fire suppression system works properly monthly
10	Hijacks	Extremely Remote	Catastrophic	Remove access to passenger control	Remote shutdown available to the airline
11a	Mechanical issue (minor)	Probable	Minor	Regular wear and tear	Test potential minor mechanical points periodically

No.	Hazard	Likelihood	Severity	Control	Verification
11b	Mechanical issue (major)	Remote	Major	Equipment malfunction	Test potential major mechanical stress points periodically
11c	Mechanical issue resulting in injury	Extremely Remote	Hazardous	Equipment malfunction	Regular safety checks by airport personnel to monitor functionality of potential contact points
12	Routing problem (closures and obstacles)	Extremely Remote	Major	Coding/OS error	Routinely test obstacles, closures, and updates to normal loop path to ensure correct behavior
13	Theft (Vandalism)	Remote	Minor	Removable parts (seat covers, panels, etc.)	Secure removable parts
13b	Theft (Personal)	Remote	Minor	Unmonitored items	Provide close proximity luggage space. Security cameras on vehicles
14	Takes up too much space	Extremely Improbable	Major	Design	Simulations with variable traffic before implementation

Table 9: Risk Matrix

Description	Minimal (5)	Minor (4)	Major (3)	Hazardous (2)	Catastrophic (1)
Frequent (A)	3b,8b				
Probable (B)		11a, 12			
Remote (C)	4	13	3, 6, 7, 11b	1	
Extremely Remote (D)			11c		5
Extremely Improbable (E)		13b	14		*8, *10 2, 9

Several of our predicted hazards from *Table 8* are within the yellow category of our risk matrix, with a few in the green and red categories. Several hazards are improbable and may be handled by the airport (as with other products within their jurisdiction), but we reduced several simply by changing a single design feature to address the issue. We mitigated some of these risks by reducing step height, removing the passengers' abilities to manipulate the trolley, and ensuring sensors are working correctly. The most dangerous hazards addressed are the injuries to pedestrian collisions and injuries related to leaving and entering the vehicle.

Threat Risk

Considerable design changes focused on addressing the risk of injury from falls. A mitigation plan (*Table 10*) was developed from our hazards along with controls and verifications. Using the mitigation methods below, we updated our design to prevent these hazards from occurring or significantly decreasing the likelihood of occurrence.

Table 10: Risk Mitigation Plan

Hazard	No	Mitigation Plan
Pedestrian/object collisions	1, 2	Maximum speed and acceleration governing with an active detection system. An active detection system would check the proximity of the closest object in front of the trolley as well as detect if any collision has occurred.
Tripping	3, 3b	The threshold access of the trolley will be as low as possible.
Cause traffic congestion	4	Minimize the width profile. For large airports, create dedicated trolley lanes.
Hinder first responders	5	Divert passengers toward exits or stay in position during emergencies.
Power loss/system failure	6	Have a backup battery system or an internal system with fault detection.
Falling objects	7	Remove the luggage roof rack feature and place it at regular height.
OS (hack / touch failure)	8, 8b	Removed the screen system and opted for an automated route with stops.
Fire hazard	9	Fire retardant materials such as FR4 fiberglass and a fire suppression system.
Hijacks	10	Hijacking scenarios are mitigated by removing the screen system.
Mechanical issue (minor)	11	Remotely self-diagnose and alert staff while moving to the repair location.
Mechanical issue (major)	11b	Broken trolleys are lightweight and can be pulled to a safe repair area.
Mechanical issue (injury)	11c	Regular maintenance and safety checks on all components. Review design.
Routing problems	12	Route will update automatically to compensate for obstacles and closures.

Hazard	No	Mitigation Plan
Theft (vandalism)	13	Deterrence system with cameras and visible signage. Remove touch screen.
Theft (belongings)	13b	Deterrence system with cameras and visible signage.
Takes up too much space	14	Minimize the width profile. For large airports, create dedicated trolley lanes.
Graffiti	15	Deterrence system with cameras and visible signage. Easy to clean surfaces.

Projected Impact & Findings

As ATLAS is focused on increasing mobility for elderly passengers while reducing overhead and the resource needs of airports, it is important that the potential impact of the design will be affordable and beneficial to both passengers and airports.

Cost-Benefit Analysis

A Cost-Benefit Analysis details an approximate financial overview of the ATLAS system. Documentation outlining current costs for similar technologies and approaches are referenced for accurate analysis. These design and development costs are also compared to systems currently in use by airports today to show the commercial potential of an affordable ATLAS system.

Design (Alpha), Development (Beta), & Production Costs

The design costs include the ongoing cost to design parts and charging systems, upgrades, part assemblies, airport backend GUI, and the design of the passenger-facing displays and signage. As the design process will be dynamic and continuous due to changing technologies, airport demographics, aesthetics, and passenger needs, several designers and engineers will be needed to meet these challenges to ensure ATLAS can remain competitive in the market. These costs are based on typical median salaries based on initial and predicted roles.

We start our cost analysis by detailing our initial efforts in the research and development of ATLAS. The tables below detail the expense from the initial start of the project through producing a prototype.

Table 11: Alpha - Initial Research and Development Phase (20 weeks)

Labor	Description	Subtotal (~20 Weeks)
Undergraduate Team	Students (3) | $25.00 / hr | 300 hr	$22,500
Faculty Advisor	Advisor (1) | $50.00 / hr | 60 hr	$3,000
Alpha Phase Total		**$25,500**

Table 12: Beta - Growth & Production Phase (20 weeks)

Labor	Description	Subtotal (~20 Weeks)
Mechanical Design Engineer	Engineer (1) | $34.00 / hr | 20 hr / week	$13,600
Software Engineer	Engineer (1) | $35.00 / hr | 20 hr / week	$14,000
Undergraduate Teams	Students (3) | $25.00 / week | 30 hr / week	$45,000
Airport Consult & Advising	$2,500 / Consult | (4) Consults / 20 weeks	$10,000 (Est.)
Prototyping	Small scale models, material costs, labor, and setup	$12,000 (Est.)
Travel Costs	Lodging, fuel, etc.	$10,000 (Est.)
Beta Phase Total		**$104,600**

Table 13: Production - One-Time Costs (with Marketing, & Distribution)

Item	Description	Estimated Cost
ATLAS Vehicle Materials		
Frame & Chassis	Custom-designed steel alloy framing	$1,200
ATLAS Body	Custom 1/4” thick acrylic (outer body) | (100 ft^2 at \$11 / ft^2)	$1,100
Wheels	8” powertrain (2), 2” side rollers (4), and 4” steering (2)	$750
Wheelchair System	Steel framing, electronic controller, pump, and hydraulic system	$1,500

Item	Description	Estimated Cost
Seat Cushions	Aluminum framing, foam padding, and covers	$500
Lights	Lights, housing, and electronics	$500
Speaker System	Electronics controller, housing, amplifier, and speakers (4)	$100
Vehicle Map Display	Framing, electronics, and OLED display materials	$500
Motor	10 HP Baldor KDS 7.5 KW ACIM	$1,500
Wiring	Electrical vehicle wiring | (100 ft at $2.25 / ft) **[29]**	$225
Battery System	8V 415 AH Trojan T-875 (6-pack) **[30]**	$1,600
Camera System	The camera avoidance system for the Virtual Loop system	$500
Automation Control	The entire electronic control system for the Virtual Loop system	$1,000
Miscellaneous	Tools, unspecified materials, and other unforeseen materials	$2,500
	Total / Unit	$13,475
	(6) Units / Airport	**$80,850**
Labor		
Manufacturing	Assembly and testing for (6) units	$45,000
Marketing and Sales	Sales Representative base salary	$36,000
	Advertising and sale pitching	$20,000
Airport Installation Expenses		
Distribution	Trolley shipping, setup, and installation costs	$10,000
Airport Signage	Education signage for interior educational awareness	$5,000
Charging Station	Custom designed to increase efficiency and connection with Airport systems	$5,000
Loading Station	Designated areas for passenger loading and unloading, as well as path (varies by location and number of loading areas)	$5,000
Computer System	The central control computer system for the Control Center	$4,000
	Total	**$210,850**

Table 14: Production - Continuous Costs (Airport Operations & Maintenance)

Item	Description	Estimated Cost
Continuous Expenses		
Lifetime Maintenance	The estimated maintenance costs for a trolley (including replacement parts) / year / (6) units	$30,000 / year
Training	For training materials (tests, software, etc.)	$5,000 / year
Marketing	Interior marketing and signage to raise awareness	$4,000 / year
Charging Costs	Total estimated electrical charging costs	$26,499 / year
	Continuous Expenses (yearly)	**$65,499 / year**

We determined the initial development to cost approximately $25,500. The development of bringing ATLAS from paper to a working model would require expanding our team to a mechanical engineer, a software engineer, as well as airport consultations, costing approximately $104,600. For a medium-size airport, we expect a total of six trolleys to handle the potential requirements and passenger use. The cost of manufacturing, designing, installing, and marketing ATLAS would be approximately $210,850. Recurring maintenance, training, and interior marketing is expected to cost just under $65,500 per year (*Table 14*).

Operational Value Assumptions & Prevention Benefits

To determine the practicality and feasibility of our project, we analyzed the costs and benefits of implementing ATLAS in a medium-size airport. For the purposes of this design report, the Oakland International Airport was used as a reference. We first determined the potential injuries for our major risks, which include fire hazard, object collision, human collision, and hijacking. We then used the most recent value of statistical life determined by the DoT and the multiplier for each type of injury **[24]**. The following formula was used:

$$\Sigma r\ Rate\ \cdot\ Likelihood\ (over\ 10\ years)\ \cdot\ Quantity$$

Table 15: Value Assumptions- ATLAS Operational Risks

Item	Rate	Likelihood	Quantity	Estimated Total (10 years)
Fire Hazard Risk Incidents				
Moderate Injury	$554,600	0.01	10	$55,460
Serious Injury	$1,239,000	0.01	5	$61,950
Critical Injury	$6,999,740	0.01	1	$69,997
Labor	$20 / hr	0.01	20	$40
Object Collision (Onboard Injury) Incidents				
Minor Injury	$35,400	0.5	10	$177,000
Human Collision Incidents				
Moderate Injury	$554,600	0.1	1	$55,546
Hijack Incidents				
Labor	$20 / hr	0.5	30	$300
			Total	**$420,293**

The major and severe risks are mitigated so that the likelihood of occurrence is exceptionally low. However, there are certain failures that can still occur, even with safety measures in place. Calculating the cost of those risks combined, the assumed value over ten years is $420,293. To determine our benefits, we used a similar method. Rather than using likelihood over ten years, we determined the percent change per year. The following formula was used:

$$\Sigma r\ Rate\ \cdot\ Likelihood\ (over\ 1\ year)\ \cdot\ Percent\ Change\ \cdot\ 10\ years$$

Table 16: Value Assumptions Benefits

Item	Rate	Risk (1 year)	Percent Change	10-year Benefit
Minor Injury	$35,400	0.1	-10%	$3,540
Moderate Injury	$554,600	0.05	-10%	$27,730
Serious Injury	$1,239,000	0.001	-10%	$1,239
Severe Injury	$3,138,800	0.0015	-25%	$11,771
Critical Injury	$6,999,740	0.0025	-25%	$174,994
Death	$11,800,000	0.005	-25%	$147,500
Revenue (medium) / year	$5,249,341	N/A	+5%	$2,625,000
Airport Personnel / year	$200,000	N/A	-80%	$1,600,000
			Total	**$4,591,774**

25% of the senior citizen population falls each year and of those falls, 20% result in an injury that requires hospitalization **[25]**. According to the CDC, approximately 0.09% of senior falls result in death. An airport environment increases these odds because of the long walking distances, crowded areas where people are bumping into each other, and baggage weight. Since the passengers will be seated on an ATLAS trolley, the risk for more severe injuries will be decreased substantially. We predict minor to serious injuries to be reduced by 10% and severe injuries through death to reduce by 25%. Using the *FAA report (CATS) Operating and Financial Line Item Report 127*, we calculated the total revenue for terminal- food and beverage along with terminal-retail stores and duty-free, for a total of over $5,000,000 for the year of 2022 at the Oakland International Airport. With the increase in foot traffic, we predict the revenue to increase by approximately 5%.

Intangible Benefits

Intangible benefits not depicted in the tables include the *sustainability* of ATLAS. Sustainability is the second initiative of the fourth pillar of the FAA goals **[26]**. The FAA has four categories for sustainability: *Environment*, *Community*, *Economy*, and *Operations* **[27]**.

Table 17: Sustainability

FAA Goal (Pillar Four [26]): Sustainability			
Environment	**Community**	**Economy**	**Operations**
• Electric vehicle • Modular construction & efficient sourcing • end-of-life recyclability	• Inclusive • Language & nationality-independent • ADA-compliant • Elderly empowerment	• Increased mobility for passengers allows access to areas and services that may have been out of reach	• Reduction in airport resource use

ATLAS has been designed with end-of-life recyclability in mind. A sustainable design can be achieved by selecting reusable parts and recyclable materials **[28]**. By designing with the end-of-life in mind, ATLAS parts can be reused for other purposes. For instance, the seating for ATLAS can be reused as a bench and the area for storing carry-on baggage can be used for organizational purposes. To provide a sense of community, we ensured our design is inclusive and ADA-compliant **[16]**. ATLAS is available to provide assistance not just to those with visible disabilities, but invisible disabilities as well. Since anyone can use ATLAS, family and friends can join, preventing users from being isolated or having attention drawn to them. With wayfinding and mobility devices, users can access areas and services previously inaccessible to them. Since ATLAS is self-driving, there will also be a reduction in the need for airport resources, allowing employees to focus on other aspects of airport operations.

Benefit vs Cost Summary

Comparing the data from the tables, we developed a cost summary to determine whether the benefits of implementing an ATLAS system in a medium-sized airport would outweigh the cost and risks of the project. A ratio that can be expected over a ten-year period is presented.

Table 18: Cost Benefit Summary (10 year)

Item	Description	Estimated Cost
Cost		
Development and Research	Tables 11 and 12	$129,500
Production	Table 13	$210,850
Operation and Maintenance	Table 14	$654,990
Fire Hazard Risk	Table 15	$187,447
Object Collision Risk	Table 15	$177,000
Human Collision Risk	Table 15	$55,546
Hijack Risk	Table 15	$300
	Total	**$1,415,633**
Benefit		
Injury Risk Reduction	Table 16	$209,774
Revenue Increase	Table 16	$2,625,000
Labor Reduction	Table 16	$1,600,000
	Total	**$4,591,774**
	Benefit / Cost Ratio	**3.24**

With a Cost/Benefit Ratio of 3.24, the ATLAS system provides substantial savings to airports implementing such a system. In addition to these savings, benefits such as passenger satisfaction and comfort while traveling would provide additional incentive to using an inclusive autonomous vehicle system.

Conclusion

We developed the ATLAS system as an innovative solution to alleviate some of the mobility and cognitive challenges the aging population faces as it continues to grow. The design of the entire system was built from the needs of these passengers while providing benefits to airports and other stakeholders. The system is inclusive and usable by a variety of passengers and allows elderly passengers to feel independence and dignity while traveling alongside other passengers. The design of the ATLAS vehicle and Virtual Loop control system was developed through an iterative design process and allowed for incremental improvements to be made quickly while meeting the needs of these passengers. This report describes in depth the various processes and techniques used to develop ATLAS to the point it is now, as well as the next steps of bringing ATLAS to implementation. This report also describes the reasoning and the justification behind all the major decisions that lead to the final design.

An in-depth risk assessment of ATLAS was developed to identify potential hazards and the potential severity of hazards and their corresponding predicted frequency. The results from this section show that the majority of the risks associated with ATLAS could be successfully mitigated through design considerations and added redundancies to existing safety features. Additionally, a cost-benefit analysis of the ATLAS system shows its potential economic feasibility for modern airports. By implementing ATLAS, airports can offer a safe, affordable, automated, and adaptable escort service that will reduce walking distances and airport resources.

Appendix A: Contact Information

Advisor Contact Information

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Appendix B: University Description

Oklahoma State University Description

"Oklahoma State University is a comprehensive research and land-grant university (founded Dec. 24, 1890) with statewide, national, and international responsibilities. The Oklahoma State University System ("OSU") serves more than 33,000 students from all 50 states and nearly 100 countries on its five campuses, and has over 264,000 alumni around the world. OSU offers more than 315 undergraduate and graduate degrees and options, as well as professional degree programs in medicine and veterinary medicine. OSU's main campus in Stillwater is recognized as a Very High Research Activity (R1) institution by the Carnegie Classification of Institutions of Higher Education **[31]**."

OSU College of Engineering, Architecture and Technology

"The College of Engineering, Architecture and Technology is a community of scholars, innovators and leaders who are changing the world. The preparation of professionals that anticipate the needs of a changing world is at the nexus of society, economy, ethics, sustainability and humanity. The college is committed to training leaders and professionals who innovate, design and build a resilient and sustainable local, regional and world economy **[32]**."

Appendix C: Industry Expert Information

Industry Expert Information

Dr. David Byers	Quadrex Aviation, LLC | Principal of Firm ***dabyers@quadrex.aero*** | (321) 574-5633
Dr. I. Richmond Nettey	Kent State University | President of Safety Division ***inettey@kent.edu*** | (330) 672-9476
Felipe Rodriguez	University of Maryland | Adjunct Lecturer II ***farodriguez@umes.edu*** | (267) 467-6611
Daniel Pruim	Oakland International Airport | Associate Aviation Project Manager ***dpruim@portoakland.com*** | (510) 563-6532

Appendix E: Educational Experience Evaluation

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 Design Competition was inspiring and memorable. As a team, we were able to create a design that we are proud of and believe in. We were able to talk to experts and gain an understanding of the importance of safety and work that goes on in the industry.

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

Some challenges we faced included deeper research, understanding the more nuanced parts of the design process, and speaking with industry experts. We also found that being concise while providing enough context was difficult within the page limit. We faced these challenges through collaboration, compromise, and trusting the process.

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

Our goal for this project was to define our problem through the needs of elderly passengers and evaluate existing solutions. By focusing on the main concerns and challenges faced by these passengers, we could find ways to accommodate them. We then came up with different solutions, and used decision matrices to compare which concepts would best meet our customer needs. Once a concept was chosen, we developed a design and analyzed the risks. With feedback from experts and further research, we refined ATLAS until we reached our end result.

Our hypothesis was that an active solution to accommodate unmet needs could be developed through understanding these needs.

4. Was participation by industry in the project appropriate, meaningful and useful? Why?

The interactions with industry experts was extremely valuable and gave us a glimpse into the industry ‘behind-the-scenes’. Each expert was unique and provided meaningful information that could not be obtained any other way. The interactions were one of the most interesting parts of the design challenge.

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?

We learned how important research and safety are throughout the industry, and how deep some design aspects can go. The project helped us develop several skills, including time management, proactive engagement, and provided insights on what to expect in the industry.

Faculty

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

The students worked very independently as a team and shared leadership and communication roles. They knew when to ask for help and I could trust them with doing their work at a high quality. They learnt the purpose of the design process and how to follow it to identify and solve a problem, to communicate their findings and design through technical writing, to bring together multifaceted skills and work as a team, and to identify skills they will be needing to solve a problem and independently learn and develop them.

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

Yes–this design project started as a class project with some requirements having an overlap with this design competition. Their class project required more work on conceptual design, selection, and development, and their ACRP design report required them to go above the class project requirements on safety and prior literature.

3. What challenges did the students face and overcome?

The students learned about the design process from a sophomore/junior-level class I was teaching in the Fall 2022 semester as part of a bigger team. This smaller subset of the original team decided to apply their knowledge to the ACRP design competition. They have faced multiple challenges at both phases. In both phases, their team consisted of mainly commuters who either drove to campus daily or took advantage of remote learning options. As a result, their team meetings were all online. The competition team is multidisciplinary: each student is pursuing a different major. The multidisciplinary nature of the team has improved their work, but it also means not all students can get course credit towards their plans of study. However, they all chose to continue working on their project, which shows great determination.

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

I plan to continue offering the ACRP design competition as an option for problem ideation in my design class. However, not many students take advantage of this option because the problems in the provided categories sound too technical for them to solve at the undergraduate level.

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

I would like to see some more topics related to product design. Smaller problems would allow more students to participate and still innovate and design great solutions even if they do not have the technical background required for the more advanced problems.

Appendix F: References

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