2021 - 2022 ACRP University Design Competition

Airport Unmanned Self-Driving Wheelchair (AUSW)

(January 2022 - April 2022)

Design Challenge: Airport Management and Planning: *Innovations to Accommodate the Aging Passenger Demographics at Airports*

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Executive Summary

This paper proposes an Airport Unmanned Self-Driving Wheelchair (AUSW) design to address the ACRP **Airport Management and Planning** Design Challenge Problem A - *Innovations to Accommodate the Aging Passenger Demographic at Airports*. The population is rapidly aging in many countries, shifting their demographic distribution towards the elderly. Although the elderly increasingly contribute to the demand for air travel, airport support facilities are still inadequate to help them overcome their physical and psychological impairments. The existing wheelchairs available at airports are inefficient and inconvenient. The AUSW is designed to make airports more inclusive by alleviating major mobility and wayfinding issues. More broadly, the implementation of AUSW will improve safety, efficiency, convenience, and suitability.

The project team started by reviewing literature from academic papers and ACRP documents. The team then talked to several industry experts to understand wheelchair usage, the implementation process, and to obtain design feedback. This input was developed into the problem solving approach, risk assessment, and design requirements. A cost-benefit analysis and sustainable assessment evaluating economic vitality, operational efficiency, natural resources, and social sustainability (EONS) model were developed (SAGA, n.d.). Per four units, the AUSW is anticipated to cost an airport **$2,220,446** and save **$7,859,900** for 10 years of operation and yield a benefit to cost ratio of **3.54**. This proposal corresponds to United Nations (UN) Sustainability Development Goals (SDGs) No. 9, 10, and 11, which covers Industry, Innovation & Infrastructure, Reduced Inequalities, and Sustainable Cities & Communities respectively. Overall, this proposal demonstrates high implementation feasibility.

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Background

The population is rapidly aging in many parts of the world, skewing a country's demographic distribution towards the elderly. The United Nations Department of Economics and Social Affairs (DESA) (2020) identifies the root cause of this problem as low levels of fertility and mortality, which causes the elderly population to increase at rates faster than the youth population. According to a report written by Vespa et al. (2018), every person in the "Baby Boomer" age cohort will be more than 65 years old by the year 2030.

As people age, they become increasingly encumbered by physical and psychological limitations, which can make daily life more difficult. Among those 65 years and older, 34% reported having some sort of physical issues - 14% reported hearing impairments, 6% reported vision issues, and 8% reported cognitive difficulties (Administration for Community Living, 2020). These issues can make it burdensome for the elderly and passengers with reduced mobility (PRM) to travel, especially through airports.

Previous ACRP design competition submissions put forward various solutions to help the elderly overcome challenges at airports. Asgarali-Hoffman et al. (2016) proposed an accessible cart system, offering assistance, additional seating, recomposing areas, and integrating information kiosks. Jin et al. (2019) proposed creating a mobile app that can be used at all airports aiming to solve several aging passenger issues. Despite this being an innovative idea, the older population tends to be less proficient in using mobile apps & technologies, raising new issues related to airport navigation. Another system currently in place is the utilization of electric golf carts to shuttle passengers around. However, Charlotte Douglas International Airport (CLT) has decided to move away from this, citing safety & congestion, customer service, efficiency, and rapidity as reasons (Bell, 2019).

Problem Statement

Van Den Berg et al. (2011) argues that despite the elderly contributing to the demand for travel, their needs for suitable transportation are not well met – especially in the realm of air transportation. *ACRP Synthesis 51* (Mein et al., 2014) reports that one of the larger issues associated with aging passengers that need to be addressed is wayfinding. Airports can be confusing & hectic environments, and currently there is a lack of special attention paid to assisting and guiding elderly passengers and their families (Donorfio et al., 2009). Because the aging population is forecasted to increase each decade, industry and airport operators alike should focus on providing better services for them and for passengers with reduced mobility (PRM) to help them overcome their physical and psychological hurdles.

Therefore, the broad purpose of this ACRP proposal is to make the airport a more inclusive environment, especially for lesser-accommodated and disadvantaged groups. Specifically, this project introduces an airport unmanned self-driving wheelchair (AUSW) to diminish mobility and wayfinding issues. This design tackles the **ACRP Airport Management and Planning Challenge** by innovating to accommodate the aging passenger demographic at airports.

Summary of Literature Review

Effects of Elderly Passengers and Passengers with Reduced Mobility (PRM) on Airports

Elderly and Passengers with Reduced Mobility (PRM)

The Organisation for Economic Co-operation and Development (OECD) (2022) defines the elderly as people aged 65 and over. This population cohort faces certain challenges and reductions in physical & psychological capabilities related to their aging, causing problems in mobility and wayfinding. Aside from elderly passengers, many younger disabled passengers also face similar issues. Since it will be difficult to distinguish the needs of an older traveler from a disabled traveler in terms of airport accessibility facilities, the European Union (EU) (2006) categorizes them as Passengers with Reduced Mobility (PRM). The European Regions Airline Association (ERA) (2018) defines PRM in one of three categories: 1. a passenger who is unable to walk long distances; 2. a passenger who is unable to ascend stairs; or 3. a passenger who is completely immobile. This term is more general to address the mobility needs of passengers regardless of age group.

Effects on Airports

Airports are usually quite hectic environments, and most of the time are not designed around the elderly and disabled. This creates an effect where accessibility is an afterthought. In recent years, the fierce competition in the air transport market has begun to change the way that aviation companies view products & services and have led them to choose the most innovative solutions. Despite this, there is still little time and resources spent on researching and developing technical solutions focusing on ways to facilitate air travel among the elderly and resolving issues that they specifically face (Arcidiacono et al., 2015). Easing access to air transport services for the elderly will enable airlines and airports to take advantage of the growing market demand (Chang & Chen, 2012).

Mobility, Wayfinding, and Psychological Issues

Mobility Issues

Old age, impaired strength and balance, and chronic diseases such as diabetes and arthritis are frequently natural causes of mobility issues (Harvard Health Blog, 2013). Loss of limbs or genetic disorders from birth can also cause these problems, affecting both PRM and the elderly. This leads to reductions in strength, endurance, and balance – skills essential in traveling through airports. Additionally, this may introduce difficulties in going through security, carrying luggage, waiting in lines, and so forth. In turn, these challenges may make the air travel process less enjoyable and more frustrating to these travelers.

Rosenbloom (2009) and Ipingbemi (2010) report that the aging has difficulty traveling long distances on foot, especially if they do not have enough places to sit or rest along the way. Considering that airports are not typically designed with the elderly and PRM in mind, seating and rest areas may become a significant problem. In addition to this issue, Ipingbemi (2010) also reports that long waits in queues - for instance, security checkpoints and aircraft boarding lines reduce effective elderly mobility. Additionally, the elderly and PRM often have difficulty lifting heavy objects, like luggage (Waara et al., 2015). As discussed previously, the elderly may be often susceptible to chronic diseases that affect joints and muscles. This makes lifting heavy luggage extremely burdensome and may potentially injure or strain them.

Finally, the elderly experience a reasonable fear of falling because it is the leading cause of death and disability among seniors (Jung, 2008). Travelers over 65 constituted a significant portion of those who fell in the airport. About 96% of the falls occurred at the terminal or on the road that connected between terminals and the parking lot (Howland et al., 2012). This fear of falling is related to declines in balance and sight as the elderly age. Therefore, a system should be put in place to ease the burden of mobility and resolve strength, balance, and endurance issues. Moreover, this system should cover areas throughout the airport facility, from the parking lot to the jet bridge.

Wayfinding Issues

Resolving wayfinding challenges need to be a focus for airports. Wayfinding is the process of entering a place, navigating through it to a particular point using the best path without getting lost, and then retracing the process of leaving that place (Castell, 2012; Wiener et al., 2009). Wayfinding is “The ability to find one's way…and is essential for maintaining independence in the world” (Davis & Weisbeck, 2015, p. S118). Visual and hearing impairments that some elderly travelers suffer from significantly degrade wayfinding abilities. They tend to be slower in comprehending a new route, make a lot of errors when navigating, and be less efficient (Gazova et al., 2013). Understanding where to go and how to get there requires comprehension of information, usually through signage and maps. However, Waara et al. (2015) found that the elderly often have difficulty understanding signage in unfamiliar places. Combined with the fact that gate changes occur frequently, this may make the process of traveling through the airport unpleasant.

Improvements in wayfinding technologies will help increase the level of confidence and self-sufficiency of elderly passengers, giving them back their independence. Jin et al. (2019) proposed an app that can help the elderly navigate through the airport by showing them directions. In 2019, Pittsburgh International Airport (PIT) launched an app that gives turn-by-turn instructions to blind and low-vision passengers (Groot, 2019). Although digitization and automation at airports can generally help speed up the process, these apps may also cause anxiety and confusion. This is especially true for the elderly if they are not familiar with operating the technology, or they might not have a smartphone at all (Graham et al., 2019). The United Nations Economic Commission for Europe (UNECE) (2021) reported that only 24% of those aged 65-74 possess basic or above basic digital skills, compared to 74% of those aged 25-34. Therefore, new proposals and innovations to solve wayfinding issues must be elderly-friendly and tailored to their limits in technological knowledge.

Psychological Issues

The elderly are also susceptible to psychological issues related to cognitive and mental impairments. *ACRP Synthesis 51* found that the aging is often in denial about their reduced physical capabilities even though they tend to be less physically flexible than their younger selves (Mein et al., 2014). Mental handicaps may cause aging passengers to have different travel patterns from others (Hjorthol et al., 2010). This effect also makes it difficult for these passengers to travel comfortably, especially in crowded places.

Elderly and PRM Desires

Specific Travel Information

Because of reduced physical and psychological abilities, the elderly often want to understand all stages of their travel process in detail (Waara et al., 2015). Having access to specific travel information can prepare them to deal with mobility & wayfinding challenges and overcome their limitations.

Facilities Improvements

Another desire of these travelers are facilities improvements that improve mobility in an airport. Poor facilities limit effective elderly mobility (Ipingbemi, 2010). Falling is the leading cause of death and disability among seniors (Jung, 2008). Many of those who fell at the airports were travelers over 65 and mostly occurred in the terminal or the road that connected between terminals or the parking lot (Howland et al., 2012). Therefore, facility improvements should be targeted to these locations and introduce a safer way to improve passenger mobility.

Better Wayfinding System

Wayfinding is a critical part of the travel process. Because of physical and psychological limitations, elderly passengers tend to be slower when navigating a new route, make a lot of errors, and also may not always know or understand where they need to go. Physical degradations, namely poor eyesight or difficulty hearing can cause difficulties in wayfinding as they may not be able to read signs or understand information such as gate changes. In turn, this generates anxiety and confusion for the elderly, as well as causes them to need to rely on others for help. An excellent wayfinding system is one that can reduce confusion and anxiety for the elderly to travel independently by air (Bosch & Gharaveis, 2017).

Regulations and Policies Regarding the Elderly and PRM

U.S. Regulations

There are many regulations and programs in the U.S. that intend to ensure equal treatment of all persons, regardless of age or disability. Some laws, like the Americans with Disabilities Act (ADA) (1990) govern equal treatment in all areas, including in air transportation. Other laws, publications & programs, for instance, the Federal Aviation Administration’s Airport

Disability Compliance Program (ADCP), Air Carrier Access Act (ACAA), Advisory Circular AC 150-5360/14A, and 14 CFR Part 382 govern air travel specifically. In essence, these regulations prohibit airlines and airports from discriminating against persons with disabilities. Moreover, they ensure that airlines, airport operators, and sponsors provide equal services to them intending to guarantee that the disabled have the same rights and opportunities as others in any public accommodation. Wheelchairs must be free to use, as governed by ACAA regulations (U.S. Department of Transportation, 2015)

European Regulations

In the EU, persons with reduced mobility have equal rights and access to travel as able-bodied travelers; airlines may not refuse to carry these passengers, and assistance is provided at no extra charge from the departure airport to the destination terminal (European Union, 2006).

Innovative Technologies to Address Elderly and PRM Needs

AIRA Technology

Sight degradation in airport environments causes difficulties in reading and understanding signage, as well as navigation errors. In 2018, Houston's George Bush International Airport (IAH) and William P. Hobby Airport (HOU) partnered with AIRA to introduce an app and smart glasses that subscribed passengers can use to help with wayfinding. The glasses transmit a live feed to an agent who will then give verbal descriptions of what's in the field of vision and can assist passengers with navigation, reading flight information, identifying luggage, etc. (Houston Airport System, 2018).

Panasonic WHILL

Panasonic WHILL is another self-driving wheelchair developed by a collaboration between Panasonic and Whill, Inc. This wheelchair can independently and safely navigate through the airport while detecting and avoiding people and obstacles. In collaboration with All Nippon Airways (ANA), WHILL has completed several test trials at Tokyo Narita International Airport in 2019 (Panasonic, 2019). According to Chang (2020), “WHILL has already completed 11 test trials of its autonomous devices at airports such as Dallas/Fort Worth International, John F. Kennedy International, and Abu Dhabi International, totaling almost 400 passengers” (para. 5).

Problem Solving Approach

After careful consideration of current and proposed solutions regarding wayfinding and mobility for the elderly and PRM at commercial airports, our group decided that the best approach was to take inspiration and improvements from existing smart wheelchair designs and develop our own autonomous assistive chair. We decided on this approach because of lower costs and easier implementation of advanced features. Our design considers the stakeholders' benefits, as well as what our product users, airport operators, and other passengers want. Furthermore, our proposal strives to improve the satisfaction of these groups and **add value** to the passenger compared to current solutions – a critical factor for implementation.

To best formulate the design requirements and understand our stakeholders, we looked at several different sources. Namely, those were: 1. Literature review; 2. Current and proposed solutions; and 3. Expert interviews and feedback. Our literature review helped us learn about the issues and desires of the elderly and PRM. Looking at current and proposed solutions helped us learn about what was out there to help resolve these issues – as well as their benefits & flaws. Finally, expert interviews helped us review design considerations and feasibility requirements. It was also critical to identify the main stakeholders, upon whom the needs and design requirements are based. These stakeholders were: 1. Elderly passengers and PRM (users); 2. Other passengers; and 3. Airport operators. In aggregate, our team found three major issues that our proposed solution would need to address.

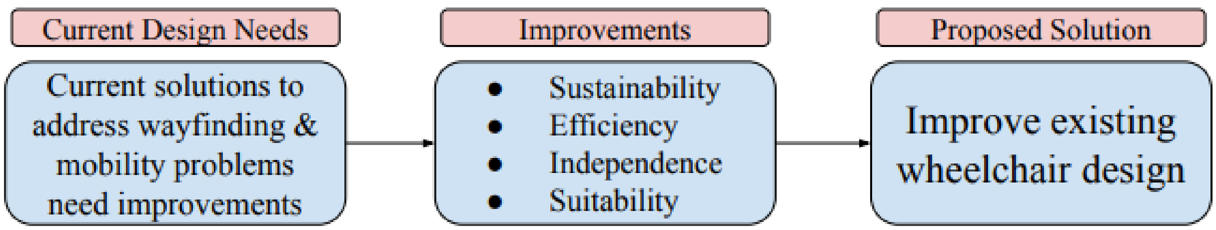
1. Rider Satisfaction
2. Other Passengers' Satisfaction
3. Airport Satisfaction

Our group used a thinking model known as "convergent and divergent thinking" to decide on the three major concerns listed and to come up with our preferred solution to improve on existing products. Convergent and divergent thinking helps find a creative solution to problems. Essentially, an issue is first *diverged* into major areas of concern, from that, a single best solution is *converged* to address these concerns. Cropley (2006) states that divergent thinking requires more creativity and necessitates "making unexpected combinations, recognizing links among remote associates, transforming information into unexpected forms, and the like" (p. 391). On the other hand, convergent thinking is the process of deriving a single best answer to a well-defined question. This process is also "intimately linked to knowledge, requiring manipulation of existing knowledge by means of standard procedures…" (Cropley, 2006, p. 391).

After reviewing current and proposed solutions, we felt that they were simply not good enough. To that, we analyzed the cause and with expert input & review of airport and ACRP literature, diverged and found four necessary improvements. This was then converged into an idea to improve current wheelchair technologies. Figure 1 below shows our convergent and divergent thinking process.

Figure 1

Convergent and Divergent Thinking Process



To come up with the four necessary improvements, our group mainly looked at other solutions to address elderly and PRM mobility and wayfinding issues. These solutions included ones that are currently in use, solutions being tested, as well as previous ACRP design competition proposals. The benefits and drawbacks of each solution were evaluated and are shown in Table 1.

Table 1

Benefits and Drawbacks of Current Solutions

Technology	Benefits	Drawbacks
Panasonic's WHILL Self-Driving Wheelchair	Obstacle-avoiding and self-driving (through sensors)	Expensive - $15,000 (a)
	Rechargeable	No luggage rack
	Able to navigate to charging station autonomously	Requires use of mobile app to change route
Traditional Attendant-Pushed Wheelchair	Attendant interaction	Stigma that comes from using a wheelchair
	Attendant is able to push user to new gates or add stops	Inefficient – attendant required to push wheelchair and tend to user, cannot tend to other tasks, routing depends on attendant knowledge
	No knowledge of technology involved	No luggage rack
		Not stylish
Traditional Airport Golf Carts	Ability to carry large groups of passengers	Safety concerns – other passengers being hit
	Luggage compartment	Inefficient – routing depends on attendant knowledge, may have to make several stops
	Attendant interaction	Cannot navigate stairs, escalators, or elevators
	Powered by electricity	Congestion – takes up lots of space in terminal hallways
Wayfinding Mobile App	Low cost	Smartphone required
	Does not require manpower	Requires technological proficiency
	Flexibility to add stops or change routing	
AIRA Wayfinding Technology	Ability to get live help virtually	Requires technological proficiency
		Subscription required – not very accessible

Note (a). Price from Peskett, J. (2017, August 9). Panasonic trials begin for autonomous WHILL ‘smartchair’. Access and Mobility Professional. https://www.accessandmobilityprofessional.com/panasonic-trials-begin-autonomous-whill-smartchair/

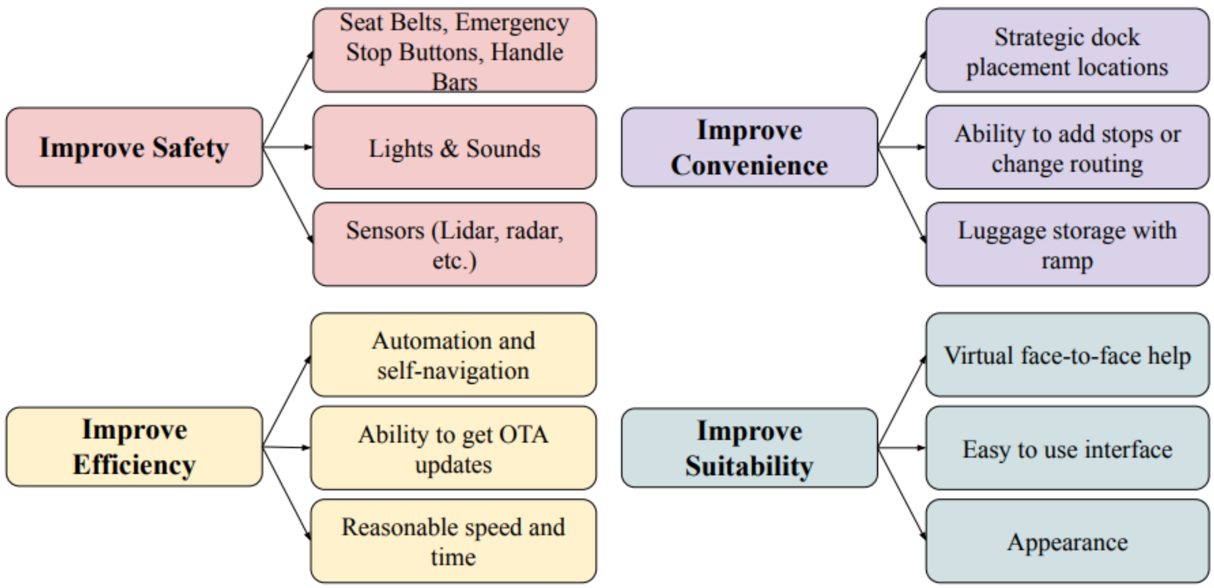
Post-evaluation of benefits and drawbacks combined with the diverging the problem revealed four necessary improvements.

1. Improve Safety - With our interview with Mr. Alan Gonzalez, we learned that safety is the utmost priority for the implementation of new technologies. Airport golf carts are involved in many incidences of other passengers being hit and injured. Improving safety may increase the willingness of the elderly and PRM to use this technology. There is also a need to improve safety for the other passengers.
2. Improve Efficiency - Current human attendant solutions require a person to push the wheelchair. Speed and timing depend heavily on the knowledge of the attendant, the number of other passengers, and their destinations. Having an automated, dedicated solution would improve this.
3. Improve Convenience - Most falls occur from the parking lot to the terminal and inside the terminal. Current wheelchair solutions tend to not be available in remote places like parking lots. Better placement and accessibility of wheelchair services are needed. Current solutions are also not very luggage-friendly, with the passenger being required to check luggage – something not always suitable.
4. Improve Suitability - The elderly tend to have lower rates of technological efficiency and rates of smartphone ownership (UNECE, 2021). Therefore, smartphone apps to help with wayfinding may not be an appropriate solution for the population. Technology should be suitable to the level of technological proficiency of the targeted users.

Our group further diverged these four necessary improvements and proposed features that can help resolve each. These features are listed in Figure 2 and are based on implementing the benefits of the current solutions while improving on the drawbacks. The features of the proposed solution will be further explained in the "Description of Idea" section.

Figure 2

Four Improvements & Corresponding Features of Proposed Solution



Safety Risk Assessment

This chapter evaluates potential risks that may arise from our proposed solution. Safety risk management (SRM) is one of the important steps that must be conducted prior to implementing a new system at an airport, which is part of the safety management system (SMS). SMS can be described as: "The formal, top-down business-like approach to managing safety risk. It includes systematic procedures, practices, and policies for the management of safety (including safety risk management, safety policy, safety assurance, and safety promotion)" (Federal Aviation Administration, 2007, p. 7). The Federal Aviation Administration (FAA) instructs airport operators to conduct systematic and comprehensive SRM processes to identify, reduce and mitigate the hazards in the airport in accordance with Advisory Circular (AC)

150/5200-37 and FAA Order 5200.11A (FAA, 2007; FAA, 2021). AC 150/5200-37 delineates the five phases of SRM, which are: 1. Describe the system; 2. Hazard identification; 3. Risk determination; 4. Risk analysis; and 5. Risk control (FAA, 2007).

Table 2

Risk Matrix Chart using FAA AC 150/5200-37 (FAA, 2007)

Severity / Likelihood	No Safety Effect (1)	Minor (2)	Major (3)	Hazardous (4)	Catastrophic (5)
Frequent (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*

* High Risk with single point and/or common cause failures

Red	High Risk
Yellow	Medium Risk
Green	Low Risk

The FAA provides the risk matrix chart as shown in Table 2 to determine the severity and likelihood level of the risk, and whether it is tolerable. Severity is the degree of impact of a hazard's effect in terms of harm, while the likelihood is the probability that the effect of a hazard can occur (FAA, 2021). The amount of potential risk is calculated by multiplying the likelihood and severity. Hazards with unacceptable or high risk receive priority; the hazards must be controlled and reduced to a lower level of risk. There are four strategies to reduce risk: 1. Risk control; 2. Avoidance; 3. Assumption; and 4. Transfer. The risk management strategy must identify the most feasible option among these options (Air Traffic Organization, 2019).

Table 3

Potential Risks Associated with Existing Mobility Options using Risk Matrix FAA Order 5200.11A (FAA, 2021)

Number	Potential Risks	Likelihood	Severity	Risk Level	Potential Solutions
1	Interactive device not running	2	1	2	Implement red lights and an emergency button that directly alerts the command center
2	Luggage falling	2	2	4	Sturdy luggage rack with adjustable strap to secure luggage
3	Run out of battery and passengers are not able to use the chair as a consequence	3	2	6	Add battery power indication showing remaining lifetime of the battery. Ensure maintenance staff is familiar with conducting checks
4	Passenger cannot use the wheelchair due to equipment failure	3	2	6	Perform scheduled preventive maintenance
5	User confused about wheelchair operation	2	3	6	Ability to virtually face-to-face request help from command center personnel
6	Other passengers are hit by automated wheelchairs	5	3	15	Equip with LIDAR sensors for detecting and tracking obstacles, as well as add lights and sounds to alert others
7	The user bounces off the wheelchair while crossing uneven surfaces	4	5	20	Add independent suspension to absorb impact, install omni-wheel for lateral movement, and secure the user with a seatbelt

The team developed a risk matrix using the same model from FAA Order 5200.11A, as shown in Table 3. The potential hazards are categorized into three classifications: low risk (green), medium risk (yellow), and high risk (red). Low risk is permissible without the need for limitations but needs to be monitored and recorded in the SRM documentation. Medium risk induces a medium threat, which is the acceptable risk limit. This risk level can be accepted if the risk is managed. High risk is unacceptable; the risk in this category must be mitigated before the proposal is implemented. Potential hazards #6 and #7 are high risk, so mitigation is needed with risk control options. To avoid other passengers being hit by the automated wheelchairs, the AUSW will be equipped with sensors for tracking and detecting obstacles and installed with warning lights and sounds to alert others. To prevent the user from bouncing off the wheelchair while crossing uneven surfaces, the AUSW will be equipped with suspensions to reduce impact, front Omni-wheels to facilitate lateral movement, and a seatbelt that the user must fasten.

Industry Expert Interaction

The team interviewed five industry experts related to airport wheelchair services for the elderly and disabled. Questions related to three aspects were asked: 1. Current wheelchair use; 2. Design feedback; and 3. Implementation considerations. The following experts were contacted:

- Mr. Alan Gonzalez - Landside Manager at Dallas/Fort-Worth International Airport (DFW)
- Dr. I. Richmond Nettey - Professor at Kent State University College of Aeronautics and Engineering
- Mr. John van Woensel - National Aviation Planning Manager & Vice-President for Williams Sale Partnership (WSP)
- Ms. Junghye Lee - Deputy General Manager of ESG Management Department at Korea Airports Corporation
- Mr. Mark W. Young - Board Member, Senior Risk Analyst, & ADA Coordinator at DFW Airport

Current Wheelchairs Use

From our interview with industry experts, we learned that the elderly do request wheelchair services frequently - although some try to go through the airport and security on their own without requesting a wheelchair first. Responses regarding the deniability aspect of the elderly requesting a wheelchair were mixed. It was inferred that they would be hesitant in requesting wheelchair services, but in reality that was not the case at DFW airport. We also understood that although wheelchairs may make the elderly look unattractive and helpless, they were useful to those who did not speak English or could not transition between terminals on their own. Additionally, it was brought to our attention that staging wheelchairs near international gates and customs areas are particularly important because the distance between the two areas is quite lengthy.

Design Feedback

The two major, overarching themes of the project are **safety** & **value**. It was reiterated that safety was the #1 priority, for both the rider and other passengers. Value meant that the wheelchair provided convenience for the user in the travel process and brought them a more joyful experience. We learned from Mr. Alan Gonzalez that DFW undertook projects that eased the passenger journey and made it as enjoyable & pleasant as possible.

With expert feedback, several design features were implemented such as luggage racks, making it stylish, adding live interaction help, as well as striking a balance between the AUSW's warning light and sounds to not make it an annoyance to other passengers. These ideas have been implemented in our design. Several logistical concerns were also brought up - namely charging, staging areas, and operational use. Finding places to put the wheelchairs to provide the greatest convenience and solving the issue of keeping them charged were important considerations. Aside from international gates and parking areas, they should also be staged near transportation junctions, like light rail stations & bus stops.

Implementation Processes & Partners

Our group learned that the implementation process depends on the strategic plan of the airport and whether or not they are focused on adopting new technologies. Although major airports usually have more funding, their approval process is also long and extensive compared to smaller airports. Smaller airports might not have the funding and therefore new technology may be harder to implement there. Nevertheless, a trial test should be conducted to identify specific benefits and show cost savings to develop a cost justification plan. Cost justification is critical because airports are typically short of cash and will not be as willing to implement projects that do not bring a significant benefit - in financial terms or proving a better experience for passengers. We learned from Ms. Junghye Lee that we can create & sell some empty areas on the AUSW for brand advertising purposes (e.g. NASCAR and airport billboards also sell advertising). We can convince the airport before entering a lease by letting them try the product at zero cost and letting the airport operator keep the revenue generated. During the test trial, younger passengers can be encouraged to try out the wheelchair to reduce the initial inertia towards the product and lessen the stigma commonly associated with wheelchair users. This will increase the willingness to use the AUSW when it is fully implemented.

We found three airports that have innovation teams - namely DFW, San Diego International (SAN), and Cincinnati/Northern Kentucky International (CVG). Those airports might be the easiest place to conduct a test trial and obtain a cost justification because they're more willing to adopt new technology. Florida airports may also be a suitable location to conduct a test trial because of the significant number of elderly passengers they receive.

Description of Idea

Our proposed airport unmanned self-driving wheelchair (AUSW) design improves many features of manual and existing smart wheelchairs in terms of safety, efficiency, convenience, and suitability. Besides taking inspiration from existing wheelchairs, features are also based on expert inputs and their design feedback. The team developed the AUSW drawing by using computer-aided design (CAD) software. Detailed illustrations of the AUSW and its features are shown in Figures 3 and 4.

Figure 3

Front View of AUSW

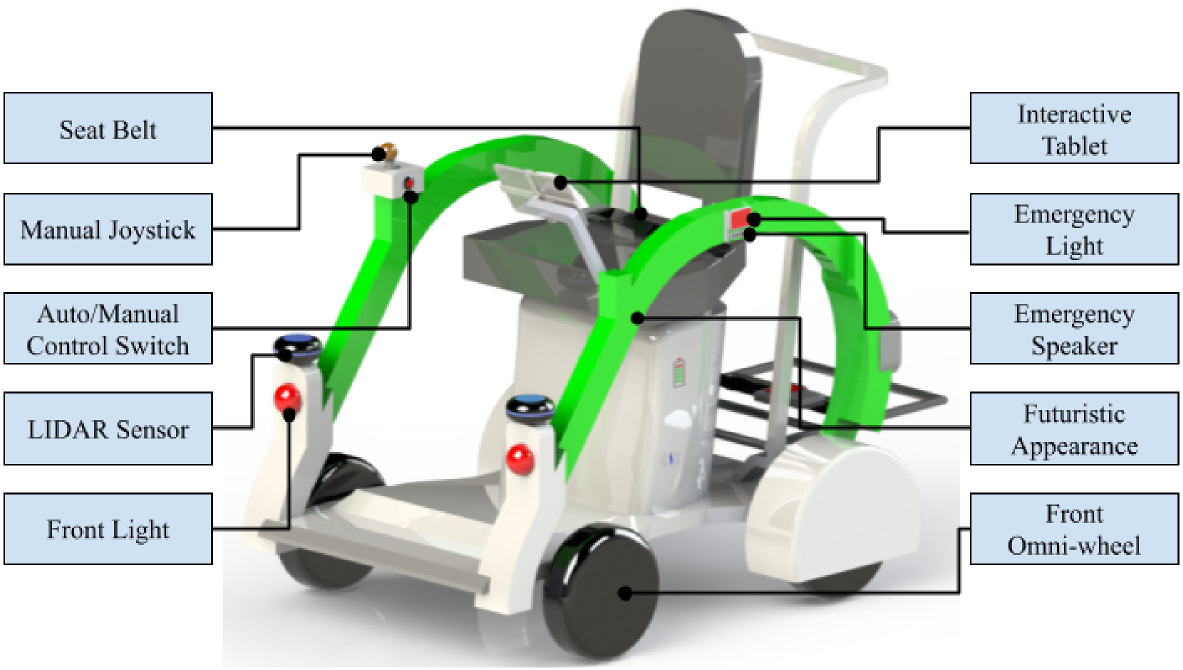


Figure 4

Rear View of AUSW

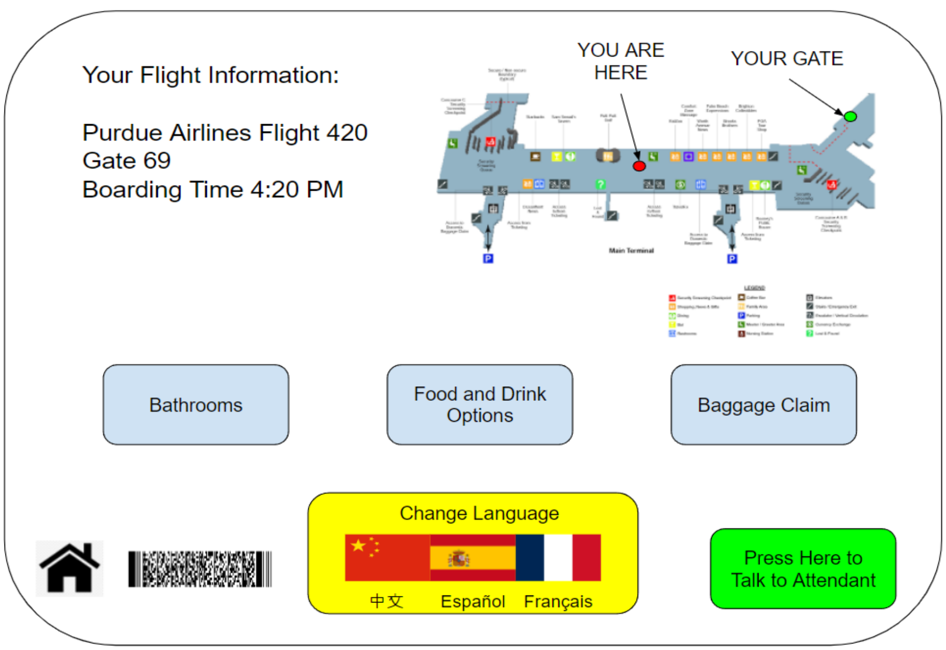
Our literature review found that the elderly typically have lower rates of technological proficiency. Therefore, the interactive tablet is easy to use and flight information may be obtained by scanning QR codes or barcodes. This tablet is equipped with four language options: English, Chinese, Spanish, and French. The interface design is very user-friendly so that the elderly and PRM are not reluctant to use it. If the user needs assistance, the tablet has a virtual face-to-face help feature that directly connects them to command center staff (Figure 5). To promote the autonomy of the wheelchair and account for gate & flight changes, the AUSW will be able to deliver up-to-date information over-the-air to the user. The user can see where they are and where the AUSW will lead them (Figure 6). In general, this tablet acts as the “brain” to self-navigate the AUSW to the passenger's destination.

Figure 5

Virtual Face-to-Face Feature for Passenger Assistance

Figure 6

Tablet Interface Display for Wayfinding



The AUSW is equipped with a LIDAR sensor that acts as input to the autonomous control system. LIDAR is an acronym that stands for Light Detection and Ranging, a technology that employs laser beams to view the environment in 3D, giving computerized systems an accurate depiction of the scanned area. This sensor allows the AUSW to avoid various obstacles and reduces the potential for other passengers to be injured by the wheelchair. Additionally, the front and tail lights will be clearly visible when the AUSW is operating to alert others of its presence.

The AUSW can be operated fully autonomously, manually via a joystick, or be pushed by a person in the back. The user has a switch to change the operating mode. This feature is required by ADA regulations (U.S. Department of Justice, 2014). Furthermore, the user is able to add stops or change the destination, giving them the same flexibility as an able-bodied passenger. Self-navigation features reduce the need for an attendant and help the airline & airport operator reduce costs and utilize those savings for other improvement projects. The ability to avoid human errors will also save litigation costs from passenger injury. The AUSW implements safety features like an emergency stop button & handlebars to reduce the likelihood of injury.

Existing manually pushed wheelchairs have no space for cabin luggage, despite it being very common that passengers bring a carry-on bag. The AUSW is equipped with a retractable luggage rack to reduce the burden of carrying luggage for the elderly and PRM. A ramp and strap are also provided to accommodate those who may not be able to lift their luggage and to secure bags in place.

Independent suspension is added to absorb the resulting impact from uneven or bumpy surfaces and reduce user injury and the possibility of the user bouncing off the wheelchair.

Omni-wheels capable of lateral movement are used as the front wheels of the AUSW, allowing the wheelchair to avoid obstacles in a restricted space. Moreover, the user will need to wear a seatbelt when the AUSW is operating.

We learned from Dr. I. Richmond Nettey that the elderly are sometimes reluctant to use wheelchairs because there is a perceived stigma associated with them that users are frail, impaired, limited, or very old. The stigma can be reduced by improving the appearance of the wheelchair by making it look futuristic, and by giving the user a greater sense of control. The wheelchair must look and feel comfortable, with the addition of a comfortable seat. The seat will be made from recyclable and sustainable polyurethane (PU) foam to decrease the impact on the environment. Polyurethane production produces a very small amount of CO_2 and is recyclable (Kemona & Piotrowska, 2020). This also improves end-of-life sustainability.

To increase accessibility convenience, strategic dock placement is extremely important. The team learned from Mr. Mark Young that the elderly and PRM often have to walk a long way at a large airport like DFW, so having wheelchair docks/stations readily available near gates may be essential. Furthermore, since most elderly falls occur between the parking lot and the terminal, having wheelchair docks in those strategic locations is warranted. These docks will feature a wireless charging pad for the AUSW and keep the chair staged organizationally in predetermined locations.

Projected Impacts of Design

The proposed AUSW design can be implemented in airports of any size and throughout areas of the airport, starting from the parking lot, in the terminal, in the passageways, and until the passenger boards the aircraft. The impact would be more significant in large hub airports where passenger traffic is very high and there is a large demand for wheelchairs. AUSW will also be beneficial in reducing passenger travel time at airports that have a relatively high proportion of elderly travelers. The wheelchair's features will reduce elderly anxiety and confusion through the implementation of virtual face-to-face help with command center staff and up-to-date information on gate changes that are directly integrated with the navigation system itself. The AUSW's cutting-edge design will help reduce the stigma that is commonly felt by the elderly and PRM associated with wheelchair usage and turn it into something attractive.

Project Meets ACRP Goals

The proposal meets ACRP goals to improve **airport management and planning** because it addresses the challenge of maximizing airport capability to accommodate the aging passenger demographic. Implementing AUSW improves accessibility and reduces wayfinding and mobility problems for the elderly & PRM. This project is aligned with the issues and proposed suggestions in *ACRP Synthesis 51* (Mein et al., 2014) and *ACRP Research Report 177* (Harding et al., 2017).

The design improvements that have been discussed in the problem-solving approach section will not only improve existing wheelchair safety, efficiency, convenience, and suitability for the user but also will enhance overall airport economic, operational, social, and safety aspects. The advertising space on the AUSW itself can be an additional revenue generator and promote partnerships with other entities.

Finally, this competition has raised awareness of airport issues and encouraged the team to create innovative solutions. Through this competition, the team gained valuable educational experience by addressing existing issues, interacting with experts, formulating the potential solution, assessing risk, analyzing cost and benefit, and designing the solution. Participating in this design competition helped promote the problem-solving skills of team members, essential for current studies but also for pursuing future careers.

Cost-Benefit Analysis

Conducting a cost-benefit analysis to measure tangible costs is required prior to project implementation. This cost analysis comprises two development phases, Alpha & Beta. The Alpha stage is the concept development phase while Beta is a more detailed stage composed of engineering drawings and prototype development. After finalizing the design, the AUSW can be mass-produced and the required project costs by the airport for acquisition, operation, and maintenance are compared with the benefits. The tables below will describe the costs of components in detail.

Projected Cost

In the Alpha stage, graduate students need to understand a considerable number of current issues, improvement necessities, and interact with industry experts. This is so that practicality can be evaluated and various historical data & information can be obtained, such as safety reports, wheelchair operating time, and employee arrangements per wheelchair. With expert input, the team developed a concept design with various improvements, taking inspiration from existing wheelchair technologies. As shown in Table 4, the projected development cost is **$30,308**.

Table 4

AUSW Research & Development (Alpha) - (3 months)

Item	Rate	Multiplier	Quantity (hrs)	Subtotal	Notes
Graduate Student[1]	$21	3 students	300	$18,900	(12 weeks, 25 hrs/week)
Concept Modelling[2]	$50	1 engineer	20	$1,000	Modeling tool
Airport Expert[3]	$35	1 expert	30	$1,050	Safety tests, & resources support
Faculty Advisor[4]	$50	1 advisor	30	$1,500	Project advisor
Subtotal				$22,450	
Overhead cost				$7,858	35% of project cost
Subtotal				**$30,308**	

Notes

1) Graduate student stipend at Purdue University is $20.94/hour, as of 2021-2022.
2) Concept Design: To provide the visual design of the AUSW, the group used modeling tools such as AutoCAD and SolidWorks.
3) Airport Experts: This project required the support of airport experts to conduct safety tests and obtain data resource support.
4) Faculty advisor for comprehensive supervision of this project.

In the Beta section, the team focused on more detailed R&D development such as detailed engineering design (DED) and prototype development. Prototype construction is required to conduct trials to ensure compliance with safety, reliability, and regulatory considerations; this involves acquiring the components required for producing the prototype as well as the labor cost. The second stage is projected to cost **$232,099** can be seen in Table 5.

Table 5

AUSW Research & Development (Beta) - (4 months)

Item	Rate	Multiplier	Quantity (hrs)	Subtotal	Notes
Graduate Student [1]	$21	3 students	400	$25,200	(16 weeks, 25 hrs/week)
Detail Engineering Design[5]	$100	1 engineer	240	$24,000	R&D drawing (6 weeks, 40 hrs/week)
Physical Prototype Construction[6]	$200	1 unit	480	$96,000	Materials, labor & testing (12 weeks, 40 hrs/week)
ADA Expert[7]	$35	1 expert	35	$1,225	Safety & monitoring prototype test (1 week, 35 hrs/week)
Travel[8]	$500	-		$500	Field survey
Faculty Advisor[4]	$50	1 advisor	400	$20,000	Project advisor (16 weeks, 25 hrs/week)
Intellectual Property Protection[9]	$5,000	-		$5,000	Intent to license the AUSW unit to an existing similar unit manufacturer (if any)
Subtotal				$171,925	
Overhead Cost				$60,174	35% of project cost
Subtotal				**$232,099**	

Notes

5) Developing engineering drawing in regards to technical and ergonomic design.
6) Project materials preparation cost, and evaluating the project's overall performance such as design, implementability, and operability testing.
7) An ADA advisor is required for safety supervision.
8) The team needs to visit the airport for a field survey.
9) The project needs to purchase patents and licenses (if any).

The AUSW technical specification and base electricity cost calculation can be seen in Table 6. The cost of acquisition, operation, and maintenance for the airport during a 10-year period per four units is shown in Table 7. The total cost of the 10-year period is estimated at **$2,220,446**. Several assumptions are made during this calculation:

1. Based on the AUSW technical specification in Table 6, a single unit of AUSW will operate 13,140 miles a year (3 batteries per day x 8 hours x 365 days).
2. The calculation was carried out with consideration per purchase of four AUSW units. Per unit, it is difficult to rationally compare the costs of the number of wheelchair staff working and the rate of reduction in the number of injuries.
3. Considering the size of the airport and its passenger demand, it is more logical to base our calculation on four units.
4. The team assumes that five command staff are needed per day for the AUSW to be operated for 24 hours, 7 days a week. The staff will be divided into 3 shifts with 2 staff in the morning shift, 2 staff in the afternoon shift, and 1 staff in the night shift.

Table 6

AUSW Technical Specification

AUSW Technical Specification		**Electricity Cost Calculation**			
		Rate	**Quantity**	**Subtotal**	**Notes**
Battery capacity	25.2V 10Ah	$0.1029/kWh*	0.252 kWh	$0.0259	Conversion to $/mile: $0.0259/12 miles= **$0.0022 per mile**
Average range	12 miles				
Battery running time	lasts up to 8 hours				
Charging time	5 hours				

*U.S. Energy Information Administration. (n.d.)

Table 7

Airport Acquisition, Operation & Maintenance Cost of Four Units per Year

Item Year 1	Rate	Multiplier	Quantity	Subtotal	Notes
AUSW Cost [10]	$4,500	4 units	-	$18,000	
AUSW Battery[11]	$500	12 units	-	$6,000	Back up battery pack
Initial Airport Operation Training[12]	$750	1 trainer	-	$750	Operation training
Electricity Cost	$0.0022	4 units	13,140 miles	$113.58	See table 5
Insurance[13]	$20	4 units	12 months	$960	Insurance
Preventative Maintenance[14]	$75	4 units	26 weeks	$7,800	Bi-weekly maintenance
Advertisement[15]	$5,000	-	-	$5,000	To promote the wheelchair to elderly & PRM
Command Center Staff[16]	$14	40 hours	365 days	$204,400	5 staff per day, 8 hrs per day
Year 1 Subtotal				$243,024	
Item Recurring Years	**Rate**	**Multiplier**	**Quantity**	**Subtotal**	**Notes**
Electricity Cost	$0.0022	4 units	13,140 miles	$113.58	See table 5
Insurance[13]	$50	4 units	12 months	$2,400	Monthly insurance
Preventative Maintenance[14]	$75	4 units	26 weeks	$7,800	Bi-weekly maintenance
Advertisement[15]	$5,000	-		$5,000	Websites and LED banner
Command Center Staff[16]	$14	40 hours	365 days	$204,400	5 staff per day, 8 hrs per day
Recurring years Subtotal				$219,714	
Year 1 Subtotal				$243,024	
Year 2-10 Subtotal				$1,977,422	
10 Years total cost				**$2,220,446**	

Notes
10) Projected cost based on current smart wheelchairs.
11) Backup battery for 24 hours operation.
12) Operation, maintenance, and initial safety training for staff.
13) Insurance plan for an unexpected accident, considering a golf cart accident at Miami International Airport (Matter, 2021).
14) Estimated labor ($25) and spare parts ($50) cost.
15) To promote ease of mobility and wayfinding to the elderly and PRM at the airport.
16) Based on the U.S. Bureau of Labor Statistics (2021), Indianapolis customer service average wage is estimated at $14.54/hour.

Tangible Benefits

As described in Table 8, implementation of the AUSW will reduce the number of labor hours as compared to traditionally manually operated wheelchairs. There are four tangible benefits of operating the AUSW as shown in Table 9. If four AUSWs reduce the probability of wheelchair injury rate by 10% in 10 years, the airport could expect to save $9,550 per year as a prevention benefit. This figure is based on the value of serious injury at $955,000 as mentioned on the ACRP website (Byers, 2016). The AUSW has advertising space that can be sold to brands and partners to advertise their products, so it will become an additional revenue generator for the airport. Moreover, since the airport will be more inclusive and accessible to all people, the team expects there will be an increase in demand to increase revenue in terms of landing fees and gate fees. The benefit of operating the AUSW for 10 years is shown in Table 9.

Table 8

Labor Hours Reduction due to AUSW Implementation

Assumption: **Before** implementing AUSW	
Command Center Staff	
5 Morning Shift	8 hours
5 Afternoon Shift	8 hours
3 Night Shift	8 hours
13 Staff per day	104 hours per day
Total	37,960 hours per year

23,360 hours reduction / year

Assumption: **After** implementing AUSW	
Command Center Staff	
2 Morning Shift	8 hours
2 Afternoon Shift	8 hours
1 Night Shift	8 hours
5 Staff per day	40 hours per day
Total	14,600 hours per year

Table 9

Benefit to the Airport due to AUSW Implementation

Item (1 year)	Rate	Multiplier	Quantity	Subtotal	Note
Reduces Wheelchair Injury Rate by 10% in 10 year	$9,550	-	-	$9,550	Estimated by $955,000 x 0.1 divided by 10 years
Staff Salary before AUSW	$14	104 hours	365 days	$531,440	13 staff per day, 8 hrs per day
Sells Advertising Space	$5,000	4	12	$240,000	$5000 per 4 weeks (revenue generator)
Other Benefits	$5,000	-	-	$5,000	Estimation of more gate fees, landing fees, etc.
Yearly subtotal benefit				$785,990	
10 Year total benefit				$7,859,900	

The summary of the cost-benefit calculation for 10 years of operations is shown in Table 10. The benefit of operating the AUSW is estimated at **$7,859,900,** while the projected cost is **$2,220,446.** Therefore, the benefit/cost ratio is **3.54**, which means that there is a net benefit to AUSW implementation.

Table 10

Benefit/Cost Ratio

10 Year total benefit	**$7,859,900**
10 Year total cost	**$2,220,446**
Benefit/cost ratio	**3.54**

Intangible Benefits

This project has some intangible benefits, which are difficult to measure quantitatively but are crucial in evaluating the social equality responsibility of human life. In general, as this project contributes to improving airport operation, we expect to enhance the travel experience for the elderly and PRM. The AUSW will reduce the hurdle for people who may not have been fond of or are reluctant to use air transportation. More intangible benefits are described in the "Sustainability Assessment" section.

Sustainability Assessment

Sustainable Development

The topic of sustainability has gained much prominence within the past few decades, as people began to realize that there are certain costs in human activities. It became increasingly necessary to study the impacts of these activities on the environment. In 1987, the Brundtland Report coined the term "sustainable development" as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987, p. 41). The aviation industry has been on the frontlines of sustainable development and has set numerous goals, like reducing greenhouse gas emissions & increasing the use of sustainable aviation fuels (SAF). These goals and programs are the results of government organizations, the International Civil Aviation Organization (ICAO), Air Transport

Action Group (ATAG), and the wider aviation community. The international air transport industry has set a goal to "continuously improve CO_2 efficiency by an average of 1.5 percent per annum from 2009 until 2020, to achieve carbon-neutral growth from 2020, and to reduce its carbon emissions by 50 percent by 2050 compared to 2005 levels" (ICAO, 2019, p. 2).

These goals promote four general areas - economic vitality, operational efficiency, natural resources, and social sustainability (EONS model). This model was found on the Sustainability Aviation Guidance Association (SAGA) website and provides a way for airport operators to holistically assess sustainability (SAGA, n.d.). Using the EONS model, a sustainability analysis was conducted on our proposed AUSW solution and evaluated the benefits and drawbacks based on each section of the EONS model. We expect to see the largest sustainability improvements in economic vitality and social responsibility by helping the airport bring in increased revenue, passenger flow, and improving convenience. Table 11 below shows a more detailed description of the design's sustainable impacts.

Table 11

Sustainability Aspects of AUSW Implementation

EONS Section	Design's Sustainable Impacts	Positive (+) or Negative (-) Effects on Airport Sustainability
Economic Vitality	Better airport reputation, leading to increase in potential passenger throughput	(+)
	Increased opportunities for savings to be put into other projects benefitting the airport, its users, and the surrounding community due to decreased airport expenditures - litigation costs, insurance costs, & personnel salaries	(+)
	Increased revenue gain from gate fees and concessions income due to increase in transiting passengers	(+)
	Increased business opportunities and partnerships resulting from increased revenue income	(+)
Operational Efficiency	Increased airport terminal congestion	(-)
	Reduction in travel time for elderly and PRM due to increased speed	(+)
	Increased airport order through dedicated staging & charging areas	(+)
	Elimination of language barriers for international elderly passengers	(+)
Natural Resources	Wheelchair foam seat made from recyclable & sustainable materials, like Polyurethane (PU)	(+)
	Wheelchair can be charged by sustainable sources to reduce environmental impact, like wind & solar	(+)
	Three life-limited batteries are required per wheelchair, increasing electronic waste	(-)
Social Responsibility	Reduction in passenger injury and death due to safety devices and self-navigating abilities	(+)
	Accessibility inequality will be reduced between the elderly, PRM, and able-bodied persons	(+)
	Reduction in stress, confusion, and anxiety for the elderly and PRM while at the airport	(+)
	Increased convenience resulting from features like luggage rack and the ability to modify routing	(+)

United Nations Sustainable Development Goals (SDGs)

Developed in 2015, Sustainable Development Goals (SDGs) are a set of 17 global goals set by the United Nations (UN) to promote “peace and prosperity for people and the planet, now and into the future” (United Nations Development Programme, 2022; United Nations, n.d., para.

1). Our team's proposal corresponds to three of these goals - SDGs 9, 10, & 11. By implementing this AUSW, the greater air transportation system will be safer, more inclusive, sustainable, and accessible for all. Table 12 below defines the SDGs met and their associated targets.

Table 12

Sustainable Development Goals due to AUSW implementation

Sustainable Development Goal (SDG)	Targets Met	How?
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	9.1 - Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all (United Nations, n.d.)	9.1 - Despite being targeted to the elderly and PRM, our solution is a free accomodation available to all to help minimize the travel barrier at airports, reduce injury, and improve convenience
10 REDUCED INEQUALITIES	10.2 - By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status; 10.3 - Ensure equal opportunity and reduce inequalities of outcome, including by eliminating discriminatory laws, policies and practices and	10.2 - Having easy access to air transportation allows those elderly and disabled to travel, promoting tourism, social, and economic inclusion (Air Transport Action Group, 2005.); 10.3 - Our wheelchair reduces accessibility inequalities and practices present in
11 SUSTAINABLE CITIES AND COMMUNITIES	11.2 - By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons (United Nations, n.d.)	11.2 - Our wheelchair helps older persons and those with disabilities to safely access aviation & the wider transportation system where it was previously inaccessible to them

Note. UN SDGs and symbols are from the United Nations (n.d.).

Conclusion

Our proposed project - Airport Unmanned Self-Driving Wheelchair (AUSW) aims to meet the **Airport Management and Planning** challenge. The main key goals of our project are to improve airport safety, optimize airport operation costs, and maximize elderly & PRM airport accessibility. Our AUSW was developed in CAD modeling programs by reviewing the benefits and drawbacks of current technologies and implementing feedback from industry experts. Additional focus was put into implementing safety features that were considered in the safety analysis.

The cost-benefit analysis provides implementation justification and is a crucial step in evaluating the feasibility of implementation. Each cost-benefit element was calculated based on the latest expenditure data and published average costs. The projected benefit/cost ratio was calculated to be **3.54** over a 10-year operation forecast. To evaluate the sustainability impacts of our proposal, a sustainability assessment was completed using the EONS model. Additionally, the AUSW meets three of the 17 UN SDGs - Goals 9, 10, and 11. The results show that our proposal not only increases accessibility for the elderly and PRM, but also will contribute to developing airport infrastructure - done so in a manner that reduces economic, operational, environmental, and social impacts.

Appendix A - Contact Information

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Appendix B - University Description

Purdue University Description

"Purdue University is a vast laboratory for discovery. The university is known not only for science, technology, engineering, and math programs, but also for our imagination, ingenuity, and innovation. It's a place where those who seek an education come to make their ideas real — especially when those transformative discoveries lead to scientific, technological, social, or humanitarian impact.

Founded in 1869 in West Lafayette, Indiana, the university proudly serves its state as well as the nation and the world. Academically, Purdue's role as a major research institution is supported by top-ranking disciplines in pharmacy, business, engineering, and agriculture. All 50 states and 130 countries are represented" (Purdue Polytechnic Institute, n.d., para. 1-2).

School of Aviation & Transportation Technology Description

"Purdue University's School of Aviation and Transportation Technology, one of six departments and schools in the Purdue Polytechnic Institute, is recognized worldwide as a leader in aviation education. All seven of Purdue's Aviation and Transportation Technology undergraduate majors are world-class educational programs. The mission of the School of Aviation and Transportation Technology is to prepare the next generation of leaders and change agents for the transportation sector. The School of Aviation and Transportation Technology will be the recognized global leader in aviation technology education through excellence in faculty, students, curricula, laboratories, and mutually beneficial partnerships" (Purdue Polytechnic Institute, n.d., para. 3).

Appendix C - Description of Industry Contacts

Mr. Alan Gonzalez - Mr. Gonzalez now works as the Landside Manager for Dallas/Fort-Worth International Airport (DFW). Previously, he has served as the Guest Transportation Assistant Manager, as well as the Ground Transportation Supervisor. He has obtained a Bachelor of Business Administration degree from The University of Texas at El Paso and a Master of Science in Aviation & Aerospace Management from Purdue University. Mr. Gonzalez is Safety Management Systems certified from AAAE.

Ms. Junghye Lee - Ms. Junghye Lee formerly worked for Korea Airports Corporation as a Deputy General Manager of the ESG Management Department. She has led projects improving PRM service at Korean airports. She has a Bachelor of Science degree in Air Transport from Korea Aerospace University. Currently, she is pursuing a Master of Science degree in Aviation & Aerospace Management from Purdue University.

Dr. I. Richmond Nettey - Dr. Nettey is a Professor of Aeronautics in the College of Aeronautics and Engineering at Kent State University. He is President of the Safety Division of the Association of Technology Management and Applied Engineering (ATMAE) and Chairman of the Transportation Research Board's Standing Technical Committee on Airport Terminals and Ground Access (AV050) at the National Academy of Sciences, Engineering, and Medicine (NASEM). Previously, he served as President of the University Aviation Association (UAA) and as the Associate Dean and Senior Academic Program Director of Aeronautics at Kent State University. Dr. Nettey has also served as an Airport Management Consultant for the Houston Airport System, Federal Aviation Administration (FAA), and the Department of Homeland Security (DHS).

Mr. John van Woensel - He is currently serving as the National Aviation Planning Manager & Vice-President for Williams Sale Partnership (WSP). Prior to working at WSP, he has also served as the Director of Airport Planning & Implementation Planning at C2HM HILL, as well as a Senior Project Manager at Landrum & Brown.

Mr. Mark W. Young - Mr. Young is a Board Member for DFW International Airport and is serving as a Senior Risk Analyst, where he works with Enterprise Risk Management. He is also the airport's ADA coordinator. He has a Bachelor of Science Degree in Business Administration & Marketing from West Texas A&M University.

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?

   This competition provided a meaningful learning experience for the team. Working on this proposal allowed us to see what was out there that tried to solve this exact problem and analyze their benefits and drawbacks. Furthermore, we were able to experience firsthand how difficult coming up with a viable and feasible solution really is. It takes a lot of effort and there is a lot of thought and consideration involved, ranging from financial to technical aspects, as well as our stakeholders' needs. Being able to work on this topic gave us good insight into the problems that the elderly and PRM face every day.

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

   The challenge in devising our proposal comes from the fact that our solution tries to resolve multiple elderly and PRM issues, instead of focusing on just a specific one. Additionally, our problem itself is very broad and is typically resolved using multiple solutions. Therefore, our proposal required immense amounts of time and work. We overcame this by focusing on the core issues we learned from our literature review, review of current solutions, and our expert interviews. We also had to acknowledge the fact that our proposal will not be perfect, nor is it a one-size-fits-all solution.

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

To develop our hypothesis, we first researched problems that the elderly and PRM faced. Afterward, we evaluated current solutions to see their benefits and drawbacks. From our analysis, we obtained a general idea of what our idea should look like and understood the design requirements. We decided to take inspiration from existing wheelchairs and develop our own design. Finally, with the help of experts, our group was able to extensively consider additional facets of our design and implementation requirements.

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

   Our interaction with industry experts was appropriate, meaningful, and useful. Our interviews allowed us to consider stakeholder needs, cost, implementation considerations, and design features. The experts that we interviewed were able to bring about different perspectives because they had different backgrounds. We tailored the questions we asked to their specialties. For example, we asked financial-related questions to Mr. Mark Young and more stakeholder-related questions to Mr. Alan Gonzalez. Together, our expert interviews gave us a lot of insight. They also brought up some very useful points that we have not previously considered. Overall, our interaction with industry experts reflected very real issues currently faced by the industry.

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?

   From this experience, our group learned about the immense amount of effort and consideration it takes to develop a viable solution to a large issue. We also learned about different thinking processes, developing a cost-benefit analysis, and creating a safety risk assessment. This project helped us develop skills and knowledge for successful workforce entry because a lot of what we learned is transferable. Airlines and airports are constantly looking for ways to improve operational safety while reducing costs. Risk evaluation and efficiency optimization skills can be applied to many industry operators.

Faculty

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

   For this class, the educational experience provided by this competition is an opportunity for student teams to respond to a Request for Proposals (RFP) with a proposal to design a specific airport improvement that will respond to one of the challenge areas and increase sustainability in four dimensions: economic, operational, environmental, and social, and to connect their design proposal to one or more UN Sustainable Development Goals. One thing that I encourage is to have small (3-4 students) teams made up of a diverse mix of cultural, social, and/or disciplines. In this way, the teams are practicing skills that are used in industry (proposing ideas for improvement on paper and in presentations, developing justifications to move the idea forward, collecting ideas and deciding on implementation, and working in teams made up of a varied group of people). One of the unique values of this experience is for the team members to interact with experts. It is valuable because the airport operators and industry experts volunteer their time and share their experiences with these students. Due to this sharing, the teams make changes to the design or implementation, and gain experience in obtaining and listening to feedback.

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

   Yes. This competition is one option in a one-semester graduate-level course in sustainability. The other option is to prepare a manuscript for publication in an academic journal. Thankfully, this team chose the competition.

3. What challenges did the students face and overcome?

   The first challenge was to figure out how they would improve upon the many wayfinding and mobility options that have been implemented in airports. They also looked at chairs for malls, stores, trains, and hospitals before coming up with their design. The team discovered for themselves that it is not just a chair by itself; instead, the chair is part of a transportation system within the larger system of the airport. The chair must interface with existing systems, and may need special fixtures and signage added. The team quickly found out that mobility issues are not specific to one age group, and that self-esteem is an important factor in the design to be accepted and used. Therefore, the team designed a chair to be attractive, have enhanced autonomy, be able to plan and display the wayfinding steps, and have immediate and kind assistance.

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

   Definitely. We do this project within one semester. It is a challenge for the teams to develop as a team and become productive in that short 8-week time span between project teaming and project delivery. This team will be able to hit the ground running in their first jobs in their airport careers. These three gentlemen have shown me that even though they come from three countries and from diverse backgrounds, they can quickly become productive and effective.

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

   Keep updating the challenge areas to include existing project ideas and newer technologies.

Appendix F - Reference List

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