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Innovative Technologies Transforming the Passenger Journey at Airports

From departure to arrival: A comprehensive analysis

Ferrovial Corporate Innovation

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October 2024

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Executive summary

The aviation industry is undergoing a significant transformation driven by innovative technologies that enhance the passenger experience from the moment they arrive at the airport until they board the plane. This white paper explores the most novel and future technologies impacting various stages of the passenger journey, highlighting key advancements in biometric identification, Artificial Intelligence (AI), wayfinding, and smart infrastructure.

Airports are strategically embracing innovative technologies with a focus on three key pillars: enhancing the passenger experience, maximizing non-aeronautical revenue, and improving operational efficiencies to reduce costs. These advancements not only streamline the journey from arrival to boarding but also integrate cutting-edge solutions to elevate service quality, ensure timely operations, increase safety, reduce risks, and create new revenue streams, thereby transforming the overall airport ecosystem.

The overview is approached from the passenger perspective, detailing the different technologies and airport interactions encountered during their journey. Starting with the arriving passenger by car, utilizing smart parking solutions, autonomous shuttles, and integrated ride-hailing/taxi services, the journey proceeds through check-in, bag drop, security, wayfinding, and navigation. The document also covers the in-terminal dwell time, focusing on activities such as shopping, dining, and utilizing airport facilities with a special emphasis on personalization.

Smart parking solutions, for instance, use AI-powered systems to guide drivers to available spots, track parking durations, and facilitate cashless payments, streamlining the passenger parking experience. Autonomous shuttles equipped with advanced sensors and AI algorithms provide a convenient and efficient way for passengers to move between parking areas, terminals, and other facilities. These shuttles enhance the first and last-mile experience by offering reliable and eco-friendly transportation options.

The document also delves into the use of biometric identification technologies, such as facial recognition, iris, and fingerprint scanning, which allow for quick and accurate passenger verification, enhancing security and efficiency. AI-enhanced biometric systems promise dramatic improvements in accuracy, speed, and flexibility, proactively identifying and mitigating potential security threats. These systems streamline the check-in, security, and boarding processes by verifying passenger identities through unique biological traits, reducing the need for physical documents.

Wayfinding and navigation are also critical components of the passenger journey. Innovations like augmented reality (AR) navigation provide real-time directions, flight updates, and other essential information directly on passengers' screens, significantly enhancing the passenger experience. Indoor sensor positioning systems, utilizing a network of sensors such as Bluetooth beacons and Wi-Fi signals, determine the precise location of passengers within the airport, offering accurate navigation and improving operational efficiency.

While centered on the passenger journey, it also opens avenues for further exploration in non-passenger related airport operations, such as landside and airside activities. It is important to note that the spotlight is on the airport from the passenger perspective, excluding the airline experience during the flight and the first and last mile journeys. Certain aspects of the passenger experience might have been omitted due to a lack of identified innovations or opportunities for innovation in those specific areas.

In conclusion, the integration of innovative technologies in airports is revolutionizing the passenger journey, making it more efficient, secure, and enjoyable. By adopting these advancements, airports can significantly enhance service quality, operational efficiency, and overall passenger satisfaction, positioning themselves as leaders in the aviation industry.

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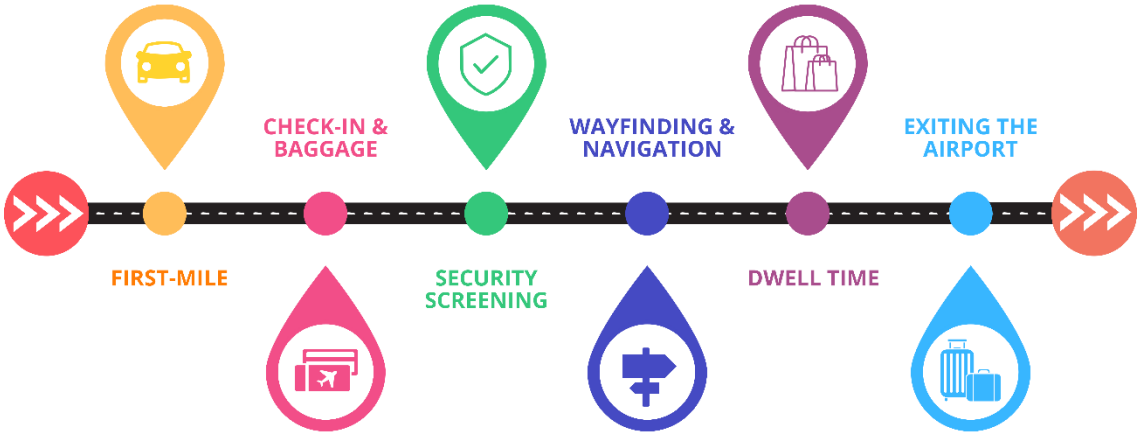
1. Introduction

The aviation industry is undergoing a significant transformation driven by innovative technologies that enhance the passenger experience from the moment they arrive at the airport until they board the plane. This white paper explores the most novel and future technologies impacting various stages of the passenger journey, highlighting key advancements in biometric identification, Artificial Intelligence (AI), wayfinding, and smart infrastructure amongst many others.

More specifically, Airports are strategically embracing innovative technologies with a focus on three key pillars:

- Enhancing the passenger experience
- Maximizing non-aeronautical revenue
- Improving operational efficiencies to reduce costs

These advancements not only streamline the journey from arrival to boarding, but also by integrating cutting-edge solutions, airports can significantly elevate service quality, ensure timely operations, increase safety, reduce risks, and create new revenue streams, thereby transforming the overall airport ecosystem.



This overview has been approached from the passenger perspective and the different technologies and airport interactions they will encounter during their journey. Starting with the **arriving passenger** by car and making use of the car park and autonomous shuttles, the PUDO (pick-up and drop-off) or the integrated ride-hailing solution, the passenger then proceeds to the landside of the terminal to go through **check-in and bag drop**. After going through **security**, it will focus on **wayfinding, navigation and accessibility** including detailed analysis on how do the mobile APP, info kiosks or digital signaling can improve the passenger experience. Next, it focuses on the **dwell time**, which refers to the period a passenger spends within the airport terminal from the moment they complete security checks until they proceed to their boarding gate. This time is crucial as it encompasses various activities such as shopping, dining, and utilizing airport facilities with a special focus on personalization. This is especially important given that efficient management of passenger dwell time can significantly enhance the overall travel experience by providing comfort, convenience, and a range of services that cater to diverse needs. After **disembarking**, the document will follow the passenger airport **egress journey** through the two options that currently exist: Go to border control or simply baggage collection and exit including the last mile options, in this case the promise of the Advanced Air Mobility (AAM).

STAGE	1	2	3	4	5	6
						
	ARRIVAL – FIRST MILE	CHECK-IN & BAGGAGE	SECURITY SCREENING	WAYFINDING & NAVIGATION	DWELL TIME	EXITING – LAST MILE
DESCRIPTION	Initial part of the passenger's journey, starting from their arrival at the airport. It includes various options to get to the terminal, such as parking, autonomous shuttles, and ride-hailing and taxi services.	Processes passengers go through to check in for their flight and drop off their baggage. It includes steps like verifying their identity, checking in, and ensuring their luggage is properly handled and tracked.	Security procedures passengers must go through before entering the terminal. It includes identity verification, screening of carry-on items, and ensuring that passengers do not carry prohibited items.	It focuses on aiding passengers to find their way through the airport. It includes providing directions, flight updates, and other essential information to ensure passengers can navigate the terminal efficiently.	In-Terminal time after clearing security and before boarding the flight. It includes shopping, dining, and other airport facilities, emphasizing providing a comfortable and personalized experience.	Final stages after landing and disembarking their flight. It includes steps like going through border control, collecting baggage, and finding transportation to their final destination.
SOLUTIONS	- Smart Parking Solutions - Autonomous Shuttles - Dynamic Traffic Signal Control - PUDO & Curbside Management - Integrated Ride-hailing/Taxi	- Baggage Tracking - Automated Re-Flighting System - Baggage Handling Automated Systems - Automated Guided Vehicles	- Biometric Identification - Security Pre-booked Timeslots - Self-service Security Screening - 3D Imaging Security Screening	- AR Navigation - Indoor Sensor Positioning - Stress-free Virtual Passenger Guide - Accessibility	- People Flow Monitoring - GenAI-enabled Information Kiosks - Robotic Assistants & Automation - Personalized Retail Experiences - Biometric Payment & Services - VR Lounges - Digital Displays & Multimedia Entertainment - Real-time Announcements	- Border Control - Baggage Collection - Advanced Air Mobility
	LANDSIDE			AIRSIDE		LANDSIDE

While it is centered on the passenger journey itself, it also opens avenues for further exploration in other areas non-passenger related airport operations, such as landside and airside activities. It is important to note that given that the spotlight is put on the airport from the passenger perspective, it excludes the airline experience during the flight and the first and last mile journeys. Now that this has been mentioned, it is also key to remember that there is no intention of remarking on the red line or boundary between the airport and airline responsibilities, hence, some of the solutions might cross that line of ownership indistinctly. Lastly, certain aspects of the passenger experience might have been omitted due to either a lack of identified innovations, an absence of opportunities for innovation in those specific areas or innovations that were innovative in the past but not today such as self-bag drop or self check-in kiosks.

2. Arrival at the Airport

To start with the passenger journey, the passenger arriving at the airport has different options for their first mile available that also lead to great innovation opportunities: Car park, autonomous shuttles to the terminal, PUDO and integrated ride-hailing/taxi before heading to the terminal landside itself.

2.1 Smart Parking Solutions

AI-powered parking systems guide drivers to available spots, track parking durations, and facilitate cashless payments, streamlining the passenger parking experience.

Parking Slots Tracking

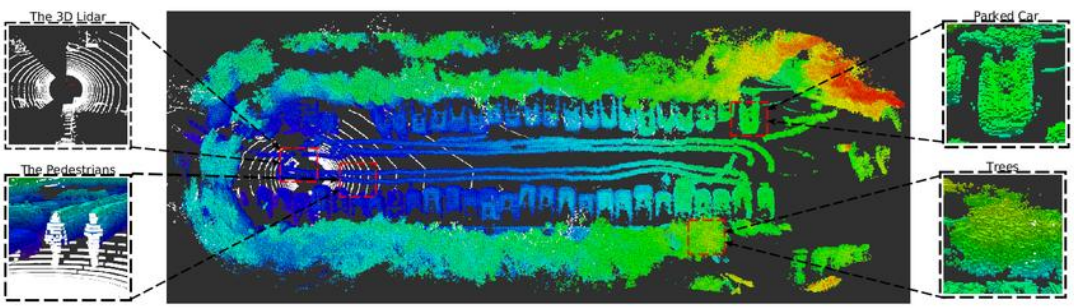
One of the primary challenges for travelers driving to the airport is finding a parking spot. Smart parking solutions are revolutionizing this aspect by integrating advanced technologies such as sensors, cameras, and IoT (Internet of Things) devices to track parking slot availability in real-time. These systems provide live updates to passengers via mobile apps or digital displays, guiding them to the nearest available spot, thereby reducing the time spent searching for parking.

LiDAR (Light Detection and Ranging) technology is being increasingly used in smart parking systems. LiDAR sensors can create detailed 3D maps of parking areas, accurately detecting the presence of vehicles in each slot. This technology not only enhances the accuracy of parking slot tracking but also improves security by monitoring unauthorized access and movements within the parking facility.

Dynamic Pricing

Dynamic pricing models are being adopted to optimize parking space utilization and increase revenue. These models adjust parking fees based on demand, time of day, and duration of stay. For instance, during peak hours, parking rates may be higher, encouraging short-term parking turnover and ensuring availability for more passengers. Conversely, off-peak hours may offer discounted rates to attract more users. This approach not only maximizes the use of parking spaces but also provides flexibility and cost savings for travelers.

San Francisco International Airport (USA) *also employs dynamic pricing and real-time slot tracking. Their system adjusts parking rates based on factors like time of day and occupancy levels, helping to manage congestion and improve the overall parking experience.*



2.2 Autonomous Shuttles

Autonomous shuttles are transforming airport transportation, providing a convenient and efficient way for passengers to move between parking areas, terminals, and other facilities. Equipped with advanced sensors, cameras, and AI algorithms, these self-driving vehicles navigate complex environments, avoid obstacles, and ensure passenger safety.

Autonomous shuttles enhance the first and last-mile experience by offering reliable and eco-friendly transportation options. For instance, Heathrow Airport's ULTra PRT system uses electric pod cars to transport passengers between Terminal 5 and business parking lots, operational since 2011.

The goal is to integrate autonomous shuttles into public traffic, connecting terminals, hotels, car rental facilities, and other services. This integration will provide a seamless travel experience and reduce congestion by offering a reliable alternative to personal vehicles and traditional shuttle services.

Benefits include enhanced accessibility for passengers with disabilities, reduced carbon emissions, and support for airports' sustainability goals. Future advancements may see autonomous shuttles integrated with public transit, operating on an on-demand basis, and offering personalized services through AI and machine learning.

NY JFK Airport (USA) *has introduced a self-driving shuttle service that transports passengers from Parking Lot 9 to the AirTrain. This deployment reduces reliance on traditional shuttle services and helps minimize carbon emissions, aligning with the airport's sustainability objectives.*

2.3 Dynamic Traffic Signal Control

One of the most significant applications of AI in traffic management is dynamic traffic signal control. Traditional traffic signals operate on fixed schedules, which may not always align with real-time traffic conditions. AI-powered systems, on the other hand, can dynamically adjust traffic signal timings based on current traffic flow, reducing wait times and improving traffic efficiency. This technology is particularly useful during peak travel times when traffic volumes are highest.

Charlotte Douglas International Airport in North Carolina (USA) *has implemented an electronic traffic monitoring system designed to prevent gridlock and manage air traffic more efficiently.*

2.4 PUDO and Curbside Management

The use of Pick-Up and Drop-Off (PUDO) and curbside management technologies like traffic cameras and Lidar (Light Detection and Ranging) has significantly improved the efficiency and convenience of airport curbside traffic and passenger flows. These technologies address issues such as inconvenient pick-up locations, safety concerns, prolonged waiting times for drivers, and congestion. By leveraging real-time

data analytics, airports can better understand vehicle and passenger behavior and occupation in designated areas, allowing for a more dynamic and flexible use of the frontage area based on demand ensuring optimal utilization of space.

Additionally, these technologies contribute to better traffic management by preventing bottlenecks and improving overall traffic flow around the airport.

NY Newark Liberty International Airport (USA) *has successfully implemented a flexible curbside management with a new re-design of the curb frontage and pick up lanes increasing passenger loading zones and integrating the use of traffic cameras and Lidar solutions.*

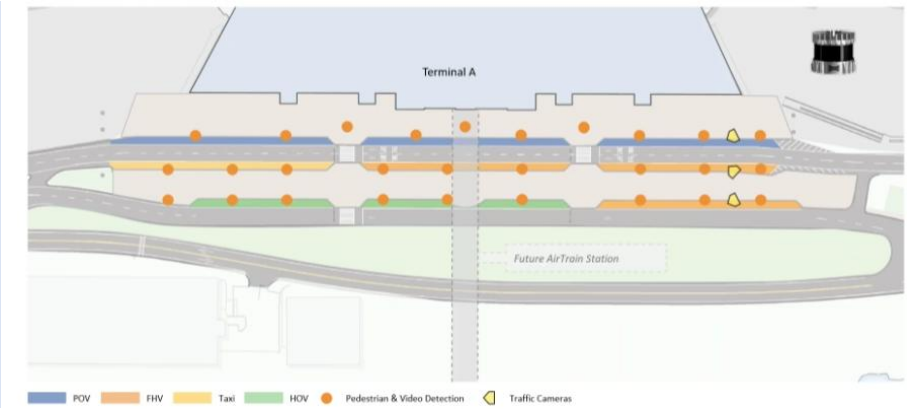
2.5 Integrated Ride-Hailing & Taxi

A groundbreaking innovation in curbside management is the concept of the passenger-driver "perfect match" and "express match" developed by Uber. This approach involves the dynamic and immediate passenger-rider match and assignation of a pick-up area within the curbside, significantly increasing efficiency, reducing congestion and enhancing a safer passenger experience.

A further improvement of this solution would involve using real-time data, advanced algorithms and Lidar (Light Detection and Ranging) technology to assign specific slots at the Pick-Up and Drop-Off (PUDO) area to both driver and rider based on their arrival time, passenger location, and live curbside or parking slot occupancy. When a passenger books a ride through a mobile app, the system calculates the optimal pick-up time and location, ensuring that the vehicle arrives at the designated slot just as the passenger is ready to be picked up.

This precise coordination eliminates the need for vehicles to circle the airport or wait in long queues, minimizing the usage of phone lot, reducing congestion and improving the overall flow of traffic. For passengers, this means shorter wait times and a more streamlined experience.

Denver International Airport (USA) *has implemented Uber's ExpressMatch solution to streamline airport pickups. This system dynamically matches riders with drivers waiting at airport-approved curb spaces, significantly reducing wait times and improving overall efficiency.*



3. Smart Baggage Handling

The landscape of baggage handling in airports is undergoing a significant transformation, mainly driven by the development of AI and robotics to enhance efficiency, reliability, and passenger experience. All this combined with the decrease of workforce in these processes, mainly caused by the COVID19.

3.1 Baggage Tracking

Recently, passengers have reported a lack of confidence in luggage handling after checking in and IATA has released the first specific guide for airlines to address this issue. To comply with IATAs Resolution 753 that mandates consistent baggage tracking at multiple points throughout the bag´s journey, one of the most impactful advancements is the integration of advanced technologies such as the Internet of Things (IoT) and Radio-Frequency Identification (RFID). IoT-enabled sensors, RFID tags and modern messaging systems, provide accurate real-time luggage tracking and improve operational efficiencies, reducing the chances of mishandling and loss while enhancing the overall travel experience. The interline luggage transfer remains as one of the main challenges still to be resolved.

Montreal International Airport (Canada) *implemented a Smart Baggage Handling System using RFID tags and IoT technology to track luggage in real-time. This system has significantly reduced the number of mishandled bags and improved overall baggage handling efficiency.*

3.2 Automated Re-Flighting System

In cases of mishandled luggage when the bag has missed the flight, novel systems like the WorldTracer Auto Reflight by SITA, automatically identify the optimal alternative flight routes for checked bags. SITA claims that the extensive use of this automated reflighting system could save the global aviation industry up to $30 million each year in expenses associated with mishandled baggage. This technology is fully compliant with IATA Resolution 755.

Frankfurt Airport (Germany) *employs the Auto Reflight system to streamline baggage handling and reduce delays due to their high passenger volume.*

3.3 Baggage Handling Automated Systems

Robotics also play a crucial role in modern baggage handling systems. The Bagload system is a prime example, where automated robotic loading ensures that bags are efficiently and accurately placed onto conveyors or into containers. This not only speeds up the process but also minimizes the risk of damage to luggage. Similarly, Siemens Logistics has introduced the VarioTip, an automated system for unloading Unit Load Devices (ULDs), which enhances the speed and accuracy of baggage handling. Additionally, Singapore's Changi Airport is at the forefront of innovation, being the first in the world to test autonomous loading and unloading of ULDs using the Auto-Dolly system. Furthermore, the use of data analytics and artificial intelligence (AI) is recently becoming increasingly important in optimizing baggage handling operations.

Changi Airport (Singapore) *is at the forefront of innovation, being the first in the world to test autonomous loading and unloading of ULDs using the Auto-Dolly system. This initiative enhances the speed and accuracy of baggage handling.*

3.4 Automated Guided Vehicles

Automated Guided Vehicles (AGVs) are another notable advancement. These vehicles are designed to transport luggage seamlessly across various points within the airport. For instance, the Fleet Bag system utilizes AGVs to automatically sort and transport individual bags, significantly reducing the time and labor involved in manual handling.

Another innovative technology is the use of Autonomous Vehicles (AVs) to transport luggage directly to the airplane. These AVs are equipped with advanced navigation systems and sensors to ensure safe and efficient movement across the tarmac.

London Stansted Airport (UK) *has integrated Autonomous Vehicles (AVs) into their baggage handling operations, significantly improving the speed and reliability of luggage transport. The enhancement features 180 automated carts, ensuring that bags are prepared for loading in a mere six minutes.*

4. Security Screening

Innovative technological advancements are revolutionizing airport operations, enhancing efficiency, security, and passenger experience. From biometric identification to 3D imaging and AI algorithms, these developments streamline processes and reduce human error, setting new standards for air travel.

4.1 Biometric Identification

The integration of biometric technologies in security screening, such as facial recognition, iris and fingerprint scanning, allows for quick and accurate passenger verification, enhancing security and efficiency. Also, AI-enhanced biometric systems promise a dramatic improvement on accuracy, speed and flexibility of facial recognition while proactively identifying and mitigating potential security threats.

These advancements, championed by industry leaders such as SITA, Idemia, NEC, Clear, Collins Aerospace, and the TSA, continue to push the boundaries of what's possible in air travel. Biometric systems, such as facial recognition, streamline the check-in, security, and boarding processes by verifying passenger identities through unique biological traits. This reduces the need for physical documents,

making the journey faster and more secure. The technology aims to shorten most of the stops passengers have to make along their journey, such as check-in, passport control, payments in the duty-free area, boarding, and accessing the lounge.

Honolulu's Daniel K. Inouye International Airport (USA) *adopted SITA's biometric-enabled SITA Smart Path to support U.S. Customs and Border Protection in fulfilling biometric passenger screening on exit from the U.S.*

One step further towards a globally interoperable standard that encodes the same data in a digitally signed credential verifiable through passive authentication as already done for years with the e-passport is the ICAO Digital Travel Credential (DTC). This mobile/smartphone-enabled solution that pre-verifies and matches the passenger´s e-passport photo with a live facial image taken with their device, allows for a totally seamless and quicker global cross-border passenger processing. A similar approach, the "One ID" concept launched by IATA (International Air Travel Association) in 2018, or the Thales "Fly to Gate" solution, also aims at enhancing the passenger experience through a seamless and contactless journey in the different airport touchpoints maximizing the use of biometrics.

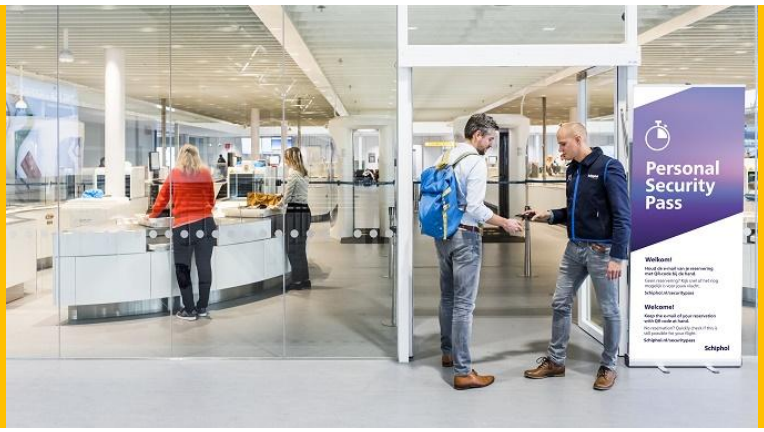
This on-going initiative has been recently demonstrated through pilot projects between the Canada and the Netherlands authorities and also through the European Commission with trials in Finland and Croatia.

4.2 Security pre-booked timeslots

Security pre-booked timeslots are an innovative approach to managing airport security queues, allowing passengers to reserve a specific time for their security screening. This system aims to reduce wait times, enhance passenger convenience, and improve overall airport efficiency.

Passengers can book a time slot for their security check in advance, either online or via a mobile app. Upon arrival at the airport, they proceed to a dedicated lane at their reserved time, ensuring a smoother and more predictable security experience. This system helps to distribute passenger flow more evenly throughout the day, reducing peak-time congestion and minimizing the risk of long queues.

Heathrow Airport (UK) *launched a trial for pre-booked security slots, allowing passengers to reserve their spot ahead of time. This trial, which started in October 2023 and is available at Terminal 3, aims to enhance the passenger experience by providing a more predictable and streamlined security process. The trial is initially open to passengers traveling with American Airlines, Delta Air Lines, Emirates, and Virgin Atlantic, with more airlines expected to join during the trial period.*



4.3 Self-service security screening

An innovative solution that is being currently tested through different prototypes developed under the Department of Homeland Security´s Science and Technology Directorate (DHS S&T) "Screening at Speed Program" is starting to prove a dramatic reduction in wait times and better overall passenger experience through the security process. The solution provides with a video-monitored, multi-step self-service, self-sufficient and self-resolution passenger security screening process that minimizes secondary and manual screening procedures with TSA agents while improving human decision-making. With growing passenger volumes, if successful, this could be a powerful alternative to the obvious solution of incrementing security lanes which is not possible at every airport due to a matter of space to keep passengers flowing and reducing stress.

Las Vegas Harry Reid International Airport (USA) *has been the first airport to deploy a TSA-compliant self-service security screening prototype in collaboration with the DHS S&T. This prototype developed by Vanderlande is the first to pass all laboratory testing with the TSA and combines their own Automated Screening Lane carry-on bag conveyance system and new equipment from other manufacturers.*

4.4 3D Imaging Security Screening

3D imaging technology, primarily based on computed tomography (CT), represents a significant advancement in airport security screening. Unlike traditional 2D X-ray scanners, which produce flat images, 3D imaging provides a volumetric view of baggage contents. This allows security personnel to rotate and examine items from multiple angles, significantly enhancing the accuracy of threat detection.

The technology works by taking multiple X-ray images from different angles around the object. These images are then reconstructed into a 3D model using advanced algorithms. This detailed model enables the identification of complex threats that might be missed by 2D scanners. Additionally, 3D imaging systems are equipped with sophisticated software that can automatically detect explosives and other prohibited items, reducing the reliance on manual inspections.

One of the key benefits of 3D imaging technology is its ability to streamline the security process. Passengers no longer need to remove liquids and electronic devices from their carry-on baggage, as the detailed 3D images allow for thorough inspection without unpacking. This not only speeds up the screening process but also enhances passenger convenience and reduces the likelihood of human error.

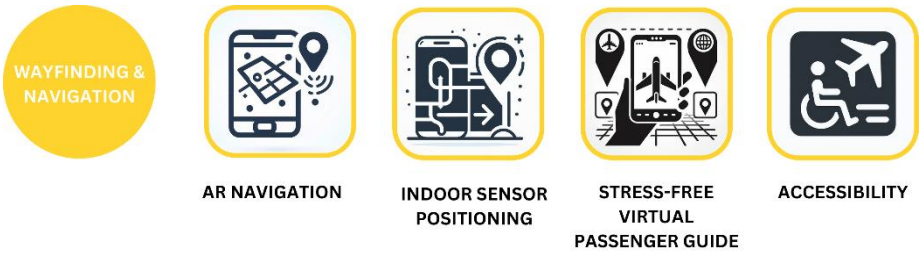
Munich Airport (Germany) *has partnered with Smiths Detection to implement 60 advanced 3D cabin bag scanners. These CT scanners provide high-resolution images of baggage, allowing security to inspect items from multiple angles, enhancing threat detection and reducing manual inspections. Passengers can keep liquids and electronic devices in their bags, speeding up the screening process and enhancing convenience.*

Generative AI algorithms improve the accuracy and efficiency of security screening processes by analyzing vast amounts of data and identifying potential threats. This technology enhances the overall safety and security of air travel and can be directly implemented in conventional X-Ray scanners. Leveraging deep learning algorithms and AI that enable automatic recognition of prohibited items, it helps to relieve the burden on airport security staff. Passenger flow management is also improved through AI algorithms that analyze movement patterns and predict congestion points, helping airport authorities manage passenger flow more efficiently, thereby reducing wait times.

Schiphol Airport (Netherlands) *is implementing AI technology to enhance inspection of carry-on bags and automate security screening while improving operational efficiencies (Project Dartmouth: Pangiam & Google). It is approached in an agnostic open environment so any security technology such as Computed Tomography (CT) scanners and any airport security checkpoint can benefit from it.*

5. Wayfinding and Navigation

Effective wayfinding and navigation are vital for improving the passenger experience in airports, making their journey smoother and encouraging more spending in non-aeronautical areas. Innovations like eye-tracking technologies allow airports to understand how passengers navigate terminals using existing wayfinding signage. With advanced technologies, airports can now offer more efficient and user-friendly navigation solutions.



5.1 Augmented Reality (AR) Navigation

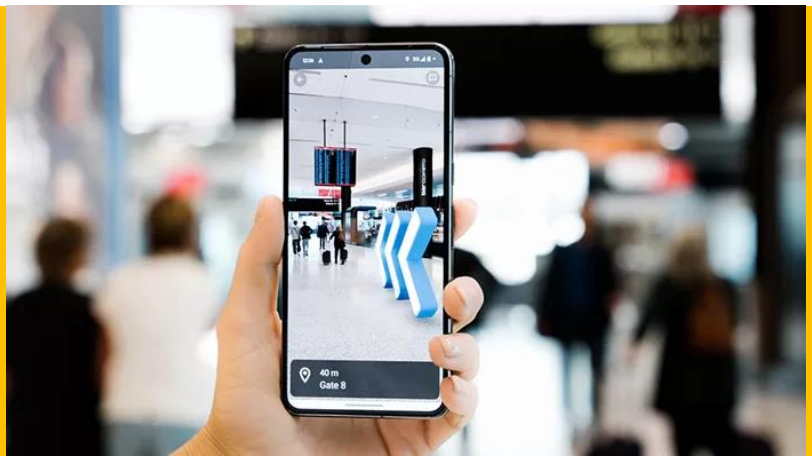
AR technology overlays digital information onto the user's view through smartphones or AR glasses. In airports, this innovation provides real-time directions, flight updates, and other essential information directly on passengers' screens. This significantly enhances the passenger experience by reducing the stress of navigating large, complex airport environments. It also improves efficiency by allowing

passengers to move more quickly, reducing congestion and delays, and increases engagement by offering additional information about airport amenities, promotions, and services.

The benefits of AR navigation are manifold. It provides a seamless and intuitive way for passengers to find their way around, which is particularly useful in large and complex terminals. By displaying real-time information such as gate changes, flight delays, and security wait times, AR helps passengers make informed decisions and reduces anxiety. Additionally, AR can support multiple languages, making it easier for non-native speakers to navigate unfamiliar environments, which is particularly beneficial in international hubs. AR can also offer additional information about airport amenities, promotions, and services, increasing passenger engagement and satisfaction.

However, there are some challenges to consider. The implementation of AR technology requires significant investment in both hardware and software. Passengers need to have compatible devices, such as smartphones or AR glasses, which may not be universally available. There are also privacy concerns related to the collection and use of location data. Despite these challenges, the potential developments in AR technology are promising. Future advancements could include more sophisticated AR glasses that are lightweight and affordable, as well as improved integration with other airport systems for a more cohesive experience.

London Gatwick Airport (UK), *has implemented an AR navigation app that overlays directions and information on the user's smartphone screen. This app guides passengers to gates, baggage carousels, and check-in counters, significantly reducing the stress associated with navigating a large airport. The app also provides real-time updates on flight statuses and other essential information, enhancing the overall passenger experience.*



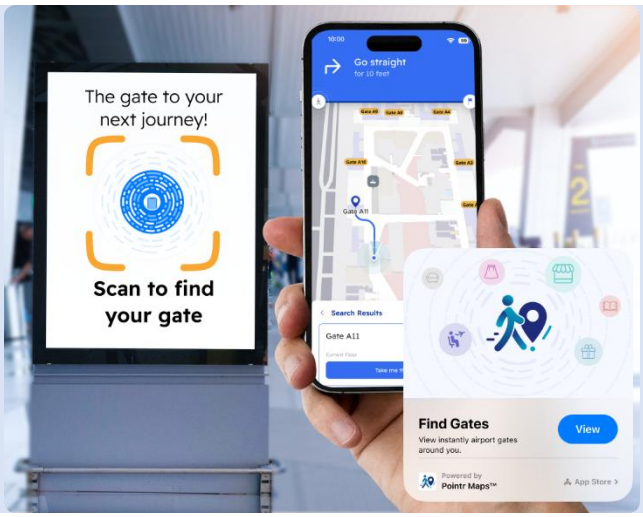
5.2 Indoor Sensor Positioning

Utilizing a network of sensors, such as Bluetooth beacons, Wi-Fi signals, and inertial measurement units, indoor sensor positioning systems determine the precise location of passengers within the airport. This technology offers accurate navigation by providing precise location data, helping passengers find their way quickly. It enhances operational efficiency by improving resource allocation and management through tracking passenger flow and congestion points and improves safety by assisting in emergency situations with accurate location data for passengers and staff.

The benefits of indoor sensor positioning are significant. It provides real-time, accurate location data that can be used to guide passengers through the airport, reducing confusion and improving the overall travel experience. This technology can also help airports manage resources more effectively by identifying congestion points and optimizing staff deployment. Additionally, in emergency situations, accurate location data can be crucial for ensuring passenger safety and coordinating responses.

However, there are also challenges associated with indoor sensor positioning. The accuracy of the system can be affected by physical obstructions and interference from other electronic devices. The initial setup and maintenance of the sensor network can be costly and complex. Privacy concerns also arise from the tracking of passengers' movements within the airport. Despite these challenges, the future of indoor sensor positioning looks bright. Potential developments include the integration of AI and machine learning to predict passenger movements and optimize navigation routes, as well as the use of more advanced sensors that can provide even greater accuracy and reliability.

Houston's George Bush Intercontinental Airport *and* ***William P. Hobby Airport (USA)*** *have implemented Pointr's advanced indoor positioning solutions. These systems use Bluetooth beacons and Wi-Fi signals to provide accurate location data, enabling turn-by-turn wayfinding technology that offers interactive maps and real-time navigation directly from the airport's website. This technology enhances passenger navigation and improves overall airport efficiency by providing precise location data and tracking passenger flow.*



5.3 Stress-free virtual passenger guide

In order to calm passenger' stress in the days leading up to travel so that they arrive in a more relaxed state, some airports are facilitating access to virtual guides. These pre-trip planning "digital twins" help passengers to better understand what they should expect at each stage of the journey, view and experience the journey before they even get there and assist with wayfinding. This can be especially useful to relieve stress during connections at large airports, but also include other use cases such as security, check-in, ground transportation and all the way to the gate.

London Heathrow Airport (UK) *Terminal 2 launched a virtual tour in their website to help passengers prepare for their airport journey and their departing flight. This is accessible on all devices including smartphones and tablets and allow to comfortably explore the airport from home.*

5.4 Accessibility

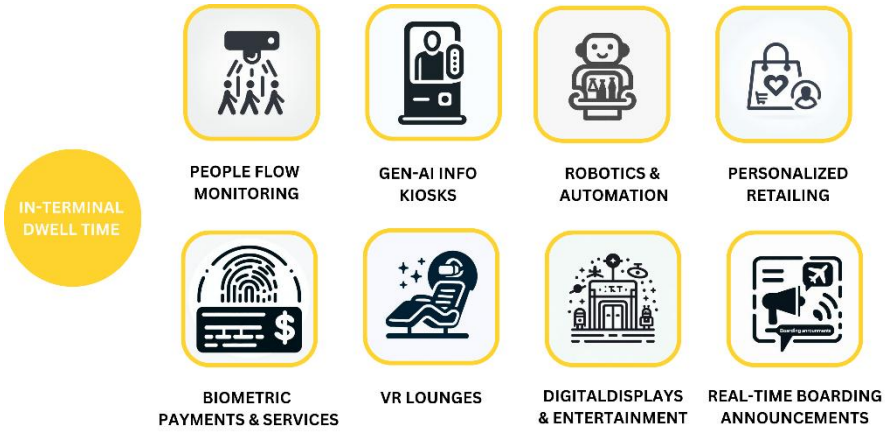
Airports are adopting various technologies to ensure all passengers, including those with disabilities, can navigate comfortably and independently. This approach creates an inclusive environment by ensuring that all passengers, regardless of their abilities, can navigate the airport independently. It enhances the passenger experience by reducing anxiety and stress for passengers with disabilities by providing tailored assistance and ensures compliance with regulations by helping airports meet accessibility standards and regulations, improving their reputation and customer satisfaction. Companies such as Wheelshare or Whill, are at the forefront of PRM (Person with Reduced Mobility) airport mobility through automated self-

service wheelchairs that enhances the passenger experience by providing with freedom, confidence and independence.

Miami International Airport (USA) introduced ten new autonomous power chairs to assist passengers with limited mobility. These autonomous wheelchairs enhance accessibility and modernize the customer experience by providing greater independence and ease of movement for passengers with mobility challenges.

6. In-Terminal Dwell Time

The time that passengers spend at the terminal after security and before boarding the plane, also called "Dwell Time", provides a great opportunity to deploy high impact and advanced technologies that enhance airport operations and passenger experiences, including people flow monitoring, generative AI-enabled information kiosks, robotic assistants, and personalized retail experiences.



6.1 People Flow Monitoring

People Flow Monitoring (PFM) in airport terminals has become increasingly essential, showcasing significant enhancements in operational efficiency, passenger experience, and security. With the surge in passenger volumes, the necessity for advanced systems to manage and optimize the flow of people has become critical. PFM technologies collaborate to detect, track, and manage passenger movements throughout the airport. These systems provide real-time data on passenger density, queue lengths, and wait times. Intelligent video analytics further augment this data by identifying patterns and predicting congestion points. Depending on the technologies implemented, various KPIs and functionalities can be developed to enhance terminal processes.

3D Cameras

3D cameras utilize stereoscopic vision or structured light to capture depth information, creating a three-dimensional representation of the environment. These cameras offer high accuracy, providing detailed depth information and precise tracking of individual movements. They are versatile, functioning effectively in various lighting conditions and environments, and capable of capturing complex behaviors and interactions. However, they raise privacy concerns due to the identifiable images they capture and can be expensive to install and maintain. The complexity of these systems also requires sophisticated software for data processing and analysis. Key performance indicators (KPIs) tracked by 3D cameras include passenger count, dwell time, movement patterns, and queue lengths.

WiFi/Bluetooth (BT) Tracking

WiFi and Bluetooth tracking use signals from passengers' mobile devices to monitor their movement and location within the airport. This technology is cost-effective and non-intrusive, as it does not require physical infrastructure changes. It can cover large areas using existing network infrastructure. However, it is less precise compared to 3D cameras and LiDAR, and relies on passengers having WiFi/Bluetooth enabled on their devices, which may raise privacy issues. KPIs tracked by WiFi/Bluetooth include passenger flow, device count, dwell time, and zone occupancy.

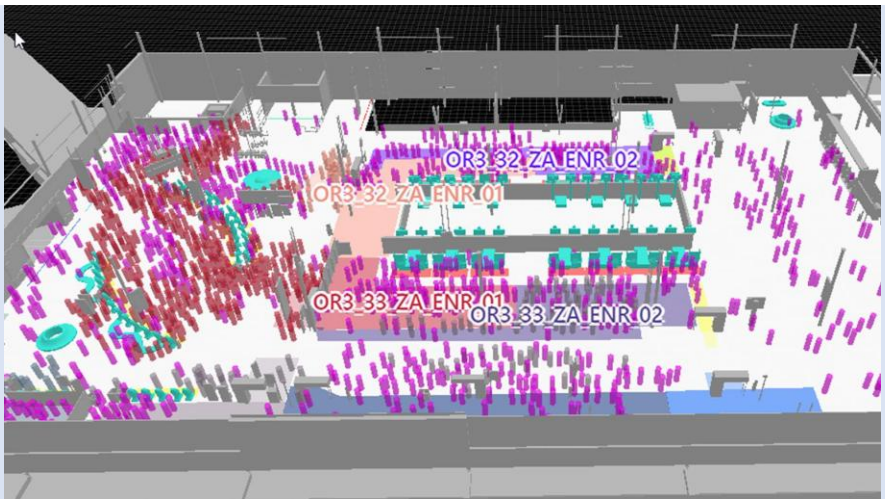
LiDAR (Light Detection and Ranging)

LiDAR uses laser pulses to create high-resolution 3D maps of the environment. It provides high precision, accurate 3D mapping, and can handle complex environments. LiDAR is privacy-friendly as it does not capture identifiable images, preserving privacy. It is scalable, suitable for large areas, and can be integrated with other systems. However, it requires a higher initial investment compared to other technologies. The complexity of LiDAR systems also requires specialized knowledge for installation and maintenance. KPIs tracked by LiDAR include passenger density, flow rates, queue lengths, and space utilization. Additionally, LiDAR can track individual passengers throughout their entire journey, enabling assessments of dwell time and correlations between different processes and locations, such as advertisement effectiveness and resource efficiency.

Role of AI and Machine Learning

AI and machine learning algorithms play a crucial role in processing the vast amounts of data collected by PFM technologies. These algorithms can forecast passenger flow, optimize resource allocation, and simulate different scenarios to improve planning and response strategies. For instance, AI can predict peak times at security checkpoints and suggest staffing adjustments to minimize wait times, thereby enhancing the overall passenger experience.

Paris Charles de Gaulle Airport (France) *has adopted Outsight's LiDAR technology to manage and optimize passenger flow. This advanced system uses LiDAR sensors to capture high-resolution 3D data, which is then processed to track passenger movements and predict potential congestion points. The technology provides real-time monitoring of passenger density and queue lengths, allowing the airport to adjust staffing levels and manage congestion more effectively. The implementation of Outsight's LiDAR technology has significantly enhanced the airport's ability to manage passenger flow, reduce wait times, and improve the overall passenger experience. This system also ensures privacy by not capturing identifiable images, making it a privacy-friendly solution for monitoring large crowds.*



6.2 Gen AI-enabled Information Kiosks

Generative AI is revolutionizing airport services through AI-enabled information kiosks. These kiosks enhance the passenger experience by providing real-time, personalized assistance. Integrated with airport systems, they offer up-to-the-minute details on flight statuses, check-in information, gate changes, and security wait times, ensuring passengers are informed and can plan accordingly. Additionally, and on the non-aeronautical revenue line, kiosks can facilitate additional transactions such as adding fast track, lounge access, purchasing retail items or ordering F&B or a TNC (ride-hailing) ride.

These kiosks reduce reliance on human staff, allowing personnel to focus on more complex tasks, thereby optimizing resource allocation. For instance, routine questions and directions are managed by kiosks, freeing up human resources for critical issues.

Personalization is a significant benefit, as kiosks tailor responses based on individual passenger needs and even recognize the passenger if they are a recurrent user during that day. This enhances the journey, making it more pleasant and stress-free. Additionally, integrating with biometric systems improves security by verifying passenger identities quickly and efficiently. Additionally, a highly useful feature is their connected web app, extending kiosk functionalities to passengers' personal devices, ensuring continuous support for instance, for wayfinding functionalities.

Dallas Fort Worth International Airport (USA) *leads in integrating Gen AI with the "Digital Iris," a digital concierge created by Soul Machines. This hyper-realistic AI persona provides real-time flight statuses, restaurant options, and other services using IBM's Watson Assistant. Since its launch, Digital Iris has managed thousands of conversations, enhancing the passenger experience with a touchless, voice-controlled interface that mimics human interaction.*

6.3 Robotic Assistants and Automation

Robotic assistants help passengers with tasks like carrying luggage, providing directions, and delivering food and beverages ("snackbot"). These robots reduce wait times at checkpoints, improve overall satisfaction, and feature advanced AI for efficient task management, despite high deployment costs and integration challenges.

Retail and food delivery robots offer contactless services, enhancing the passenger experience and reducing the need for human staff. However, they face challenges in navigating crowded airport environments and ensuring timely deliveries. Usually, these robots are programmed so if a person crosses its path withing 20cm, it will stop automatically to ensure a safe navigation and once the battery is low, it will autonomously drive to its designated charging station.

Personal assistant robots are being introduced in airport lounges and check-in areas to provide a VIP touch. Equipped with AI and onboard projectors, these robots offer personalized assistance and entertainment but require significant investment and must handle complex tasks effectively. One of the leaders in this area is Allresto Munich Airport who apart from deploying a "snackbot" is looking at future developments like automated kitchens for autonomous freshly cooked meals deliveries and telemetry-powered coffee machines.

Autonomous technology is being used to future-proof airport operations. Schiphol Group aims for a fully autonomous airside operation by 2050, and Avinor is exploring ways to automate the last mile of the baggage handling process through an innovation partnership with Vanderlande.

Incheon International Airport (South Korea) deployed autonomous robotic assistants to help passengers with carrying luggage and providing directions. These robots have enhanced passenger convenience and reduced wait times at various checkpoints.

6.4 Personalized Retail Experiences

The integration of personalized retail experiences in airports is transforming the way passengers' shop and dine, making their time at the airport more enjoyable and engaging. By leveraging artificial intelligence (AI) and data analytics, airports can offer tailored recommendations and special offers, enhancing the overall travel experience and boosting commercial revenue.

This technology can track passenger preferences, travel history, and real-time location to provide relevant suggestions. For example, if a passenger frequently purchases coffee, the AI system can send a discount coupon for a nearby café as they pass by.

Personalized retail experiences make shopping and dining at airports more convenient and enjoyable. By receiving tailored recommendations and special offers, passengers can discover new products and services that match their preferences, making their time at the airport more pleasant.

Airports can benefit commercially from personalized retail experiences by increasing passenger spend. Tailored offers and recommendations encourage passengers to make more purchases, boosting sales for airport retailers and food and beverage outlets. Additionally, personalized marketing campaigns can attract more passengers to specific stores and restaurants, driving foot traffic and increasing revenue.

AI-driven personalized retail solutions can also improve operational efficiency at airports. By analyzing passenger data, airports can optimize store layouts, manage inventory more effectively, and tailor marketing strategies to meet passenger needs. This can lead to better resource allocation and more efficient operations, ultimately enhancing the overall airport experience.

Los Angeles World Airports (LAWA) *has brought a new level of personalization to digital retail and food and beverage (F&B) ordering at LAX. In partnership with Airport Dimensions, Servy, and Unibail-Rodamco-Westfield, LAWA has implemented systems that analyze passenger data to offer tailored recommendations and special offers. This approach not only enhances the passenger experience but also drives sales and increases spend at the airport.*

6.5 Biometric Payments and Services

Biometric payment systems allow passengers to make purchases using their fingerprints or facial recognition, providing a convenient and secure alternative to traditional payment methods. This technology can be used for a variety of transactions, including purchasing food and beverages, shopping at duty-free stores, and accessing premium services such as lounge access eliminating the need for physical membership cards or boarding passes while enhancing security and providing a more convenient and touchless experience for travelers.

For example, some airports have implemented biometric payment systems at their retail outlets, allowing passengers to pay for their purchases with a simple fingerprint scan. This not only speeds up the transaction process but also reduces the need for physical contact, making it a safer option in the context of health concerns such as the COVID-19 pandemic.

In addition to lounge access, biometric technology is being used to offer personalized entertainment options. Some airports have introduced biometric systems that allow passengers to access entertainment services, such as VR lounges, using their biometric data. This ensures a smooth and hassle-free experience, as passengers can enjoy these services without the need for additional verification steps.

Delta Sky Club members who have signed up for CLEAR's biometric service can use their fingerprints to enter all 50 US Delta Sky Club lounges. A fingerprint recognition-based boarding process has also been trialed for domestic flights at ***Reagan Washington National Airport (USA).***

6.6 Virtual Reality (VR) Lounges

The integration of Virtual Reality (VR) technology in airport lounges is part of a broader trend towards enhancing the overall travel experience. By offering cutting-edge entertainment options, airports can reduce the stress and boredom often associated with waiting times. This not only improves passenger satisfaction but also encourages travelers to spend more time (and potentially money) in the airport, benefiting the airport's commercial operations.

VR lounges offer immersive experiences for passengers to relax and entertain themselves while waiting for their flights. Airports are often associated with long waiting times, which can be stressful and boring for travelers. By providing VR entertainment, airports can offer a unique and engaging way for passengers to pass the time. This can significantly reduce the perceived waiting time and improve overall passenger satisfaction.

They can offer a variety of experiences that cater to different interests. For instance, passengers can take virtual tours of popular travel destinations, watch movies in a 3D cinema, or play interactive games. These immersive experiences can help passengers relax and unwind before their flights, making their time at the airport more enjoyable.

The integration of VR technology in airport lounges is made possible by advancements in VR hardware and software. Modern VR headsets are more comfortable and user-friendly, making them suitable for use in public spaces like airport lounges. Companies like Inflight VR, Abegant and Skylights are at the forefront of this technological revolution, providing VR systems specifically designed for the air travel industry.

Italy Rome's Fiumicino Airport *partnered with Inflight VR to provide VR entertainment in their lounges. Passengers can use VR headsets to enjoy immersive experiences, including virtual travel and 3D cinema, enhancing their waiting time at the airport.*

6.7 Integrated Digital Displays and Multimedia Entertainment

With a focus on improving the passenger experience, creating a sense of place and a memorable/unique experience at the airport, different architecturally integrated large-scale multimedia technologies are being more and more deployed at airports around the world. To achieve that "wow" effect, different factors must be considered such as the location, the local idiosyncrasy/culture, light conditions, visibility from different angles... Not only that, but some other aspects more related to understanding the passenger behavior that help to adjust the length of playing time or creating a playlist of fresh content that dynamically adapts to different screen aspect ratios and updated according to different seasons and festivities.

There are clear operational benefits too, from guiding travelers through the terminal (wayfinding) to creating a more effective, exciting retail environment. In this line, a new trend that is gaining traction is the use of transparent display s which are designed to blend seamlessly into the surrounding room when not in use. These technologies aim at passenger engagement by making the line between content and reality virtually indistinguishable. This can also be integrated with traditional airport systems to show flight information to passengers though the use of Multi Use Flight Information Displays (MUFIDS).

Orlando International Airport (USA) *embraced audio visual multimedia into the design from the very beginning at Terminal C. They installed two large-format experiential media environment s(EME). Windows on Orlando which allows passengers to enjoy the 1:1 scale view of for instance a cattle drive in the sunset or a Kennedy Space Center launch, and Moment Vault which offers interactive engagement in settings such as underwater or Mars.*

6.8 Real-Time Announcements

AI-driven systems provide real-time boarding announcements and updates, ensuring passengers are well-informed and can board their flights promptly. These technologies use AI to generate synthetic speech with digital fragments of real voices to make the announcements as human as possible.

For example, an alternative to the traditional hearing loop also known as Frequency Induction Loop Systems (AFILS) is PA stream from Avia Box, a multi-language technology that improves real-time announcements and notifications sending them directly to mobile phone devices which is key in especially noisy environments. Additionally, it also addresses those disable and hearing-impaired passengers and improves their experience removing the need for special aids use and extending the uses to receiving security alerts or retail and food & beverage offers while improving passenger flows around the airport and during boarding.

Amsterdam Airport Schiphol (Netherlands), *is using PAstream to deliver real-time passenger announcements directly to mobile devices, enhancing accessibility and communication for passengers with disabilities and health condition.*

Passenger Information

There is a challenge that remains to be addressed and resolved and it's concerning the consistency across the different flight information sources. On the endeavor to "own" the passenger, airlines and airports are constantly competing for instance, on who sends the notifications to the passenger. Usually this happens simultaneously but not always in a consistent way. In some cases, the FIDS (Flight Information Displays) might indicate that the flight is boarding while the passenger might have received a notification in its airline app that the flight is delayed.

Being the airline the single source of truth on what flight information is concerned, the airlines use this as an advantage towards differentiating themselves and directly impacting the passenger journey. This is an area of development that must keep the passenger experience as apriority to make sure information is delivered at the right rime, its consistent and ultimately avoiding any kind of confusion.

7. Exiting the Airport

Finally, once the passenger has disembarked, additional innovative advancements and technological developments aim to enhance the passenger experience and streamline airport operations. More specifically, border control biometric identification, baggage collection systems, and the integration of Advanced Air Mobility (AAM).

7.1 Border control

The U.S. Customs and Border Protection (CBP) has significantly expanded the use of biometric technology at airports to enhance security and streamline the entry process for international travelers. This initiative, known as Simplified Arrival, employs facial recognition technology to automate the manual document checks traditionally required for admission into the United States. By comparing live images of travelers

with their passport or visa photos, CBP can quickly and accurately verify identities, reducing the need for physical touchpoints and expediting the entry process.

The implementation of facial biometrics at all international airports in the U.S. marks a critical milestone in the biometric Entry/Exit program. This technology not only enhances security by preventing impostors from entering the country but also improves the overall travel experience by making it more efficient and touchless. Since its deployment, CBP has processed millions of travelers using this technology, significantly reducing wait times and enhancing the accuracy of identity verification.

Currently, the Global Entry Touchless Portals have significantly reduced the physical touchpoints of arriving passengers and expedited processing. Looking ahead, innovations such as "biometrics on the go", “non-stationary biometrics” or “in-motion biometric identification” are set to further revolutionize the travel experience, particularly for Global Entry passengers. This concept involves the use of mobile biometric technology that allows travelers to be verified without stopping at a kiosk. Instead, biometric data can be captured as passengers move through the passport control area, providing a seamless and uninterrupted travel experience. This advancement is expected to enhance the efficiency of the Global Entry program, making it even more convenient for frequent international travelers while maintaining high security standards.

*At **Hartsfield-Jackson Atlanta International Airport (USA)**, the Transportation Security Administration (TSA) has been piloting in-motion biometric identification at security checkpoints. This technology allows passengers to be identified as they walk through the checkpoint without needing to stop.*

7.2 Baggage collection

Once the passenger has completed the passport control after landing and is heading to exiting the airport, there is still some space for innovation at the baggage collection hall. These innovations are specifically aimed at improving the passenger experience by making the baggage collection process smoother, faster, and less stressful for passengers:

Automated Baggage Delivery

Automated baggage delivery systems are transforming the baggage claim experience by delivering luggage directly to passengers at designated points within the collection area. This innovation significantly reduces congestion around carousels and speeds up the baggage retrieval process. These automated systems utilize cutting-edge technology to sort and transport baggage accurately and swiftly, ensuring it reaches the correct collection point without delays. By reducing the need for manual intervention, these systems also decrease the risk of errors, making the process more reliable. Overall, automated baggage delivery systems contribute to a smoother, faster, and more stress-free experience for travelers.

London Stansted Airport (UK) has upgraded its baggage handling system with 2.4 km of advanced conveyor belts and 180 automated carts. This system ensures efficient and quick delivery of baggage to passengers, minimizing wait times and enhancing overall satisfaction.

Enhanced Communication Systems

Enhanced communication systems in baggage collection halls are designed to keep passengers informed and reduce stress. Digital displays and mobile notifications provide real-time updates on the status of luggage, including which carousel it will arrive on and estimated wait times. This transparency helps passengers plan their time better and reduces anxiety about lost or delayed baggage.

Dubai International Airport (UAE) has implemented advanced digital displays and mobile notification systems to keep passengers updated on their baggage status. These systems use real-time data to inform passengers about the exact location of their luggage and any potential delays. By providing timely and accurate information, these communication systems improve the overall passenger experience, making the baggage collection process more efficient and less stressful.

Baggage Claim Robots

Baggage claim robots are an innovative solution designed to assist passengers in locating and retrieving their luggage efficiently. These robots are equipped with advanced technologies such as cameras, barcode scanners, and AI algorithms to identify and track baggage. They can scan baggage tags and guide passengers to their luggage, making the process more streamlined and less stressful.

By leveraging these robots, airports can enhance the overall passenger experience, making baggage collection quicker, more efficient, and user-friendly. This technology represents a significant step forward in modernizing airport services and improving customer satisfaction.

Krasnodar International Airport (Russia) is planning to implement robots to automate the baggage picking and loading process. These robots will help passengers by scanning their baggage tags and directing them to the correct carousel or even bringing the luggage directly to them. This reduces the time passengers spend searching for their bags and minimizes congestion around the carousels.

Improved Carousel Design

Innovations in carousel design are significantly enhancing the efficiency and experience of baggage collection. Modern carousels are designed to handle larger volumes of luggage more effectively, reducing

wait times and congestion. Multi-level carousels and automated sorting systems distribute luggage more evenly, ensuring that bags are delivered to passengers quickly and accurately.

These improvements in carousel design not only streamline the baggage collection process but also enhance the overall passenger experience by reducing stress and wait times. This makes the journey through the airport more pleasant and efficient for travelers.

Beijing Daxing International Airport (China) *features advanced carousel designs that improve the efficiency of baggage distribution. The airport's innovative layout includes multi-level carousels that can handle a high volume of luggage, reducing crowding and speeding up the collection process. Automated sorting systems further enhance this efficiency by ensuring that luggage is correctly routed and delivered to the appropriate carousel.*

7.3 Advanced Air Mobility (AAM)

Once the passenger has exited the terminal, some of the different options for last mile have already been covered. An innovative and disruptive approach for last mile (and first mile) that is closer to becoming a reality is analyzed next. In this regard, every airport is looking at how AAM might be integrated into their operations without major disruptions or impact in their already congested airspace.

While the whole world is expecting the electric vertical take-off and landing (eVTOL) aircraft certification as the crucial milestone for the industry to finally kick off by 2025, many manufacturers are already preparing the production facilities to satisfy the many aircraft pre-orders signed with different operators and airlines. In the meantime, some other large and small infrastructure companies are in the process of developing the facilities and ground infrastructure necessary for eVTOLs to take off and land, also known as "Vertiports". These must be developed to meet the ICAO Annex 14 "Requirements for aerodrome design and operations" and follow the existing FAA EB-105 – "Vertiport Design" recommendations in the USA and the EASA PTS-VPT-DSN "Prototype Technical Specifications" in EU. Still, it is expected that initial operations and during the operational testing period, existing landing infrastructure such as heliports or FBOs will be leveraged. This is where the question arises, what about airports? And indeed, it is an obvious use case.

There are different use cases for airports that can be leveraged, some of them are already being analyzed by airline operators such as Delta Airlines with eVTOL manufacturer Joby Aviation or United Airlines with Archer. The overall idea is that a passenger books a ticket for a seat on an eVTOL that will take them from their origin to the departure airport and then from the arrival airport to their destination. On the one side, there could be the option where a passenger books a standalone ticket (from the same airline or not) or book it as part of the whole journey including the airline flight (from the same airline). The most immediate benefit for the airline is the fast and seamless passenger feeding to the airport. Additionally, this can be as part of a Business or Premium Economy ticket or simply as an add on, which might also include other premium services such as fast track security screening or access to lounges.

Given the limited capacity of the eVTOL it is expected that passengers bring with them carry-on luggage and a personal item, in case they need to bring larger or more pieces of luggage other solution might be in place such as pre-check in at home with ground transportation delivery. This also opens the opportunity for cargo operations including leveraging existing infrastructure for small parcel deliveries, mid-sized specialized goods transport, and large bulk goods shipments. Airports can anticipate increased aircraft movements and must integrate these operations seamlessly into current systems to enhance capacity and maintain safety. These developments will accommodate diverse operational needs and ensure that airports can support the growing demand for advanced drone-based logistics and cargo services.

The airport can own and control the vertiport, giving select AAM operators exclusive access. Alternatively, it might lease the facility to a firm like an FBO for passenger facilitation and ground handling. Another

option is leasing space to an AAM operator to develop their own vertiport and infrastructure within the airport perimeter.

The idea sounds just perfect and undoubtedly will improve the passenger journey however, some challenges are still to be resolved:

- First, **fly where people want to fly and within a reasonable price point**. To do so, vertiports need to be developed based on a demand-driven business plan that understands what the passenger wants and how much are they willing to pay. Initially, as with any novel product introduction into the market, price is expected to be high and reachable for a few, but the medium and long-term plan is to democratize this with scalability making the price per mile closer to a traditional ride hailing or taxi service and making it more accessible to the wider clientele. In this line, airlines feeding their airport hubs might have an important role on providing with bundle offers and options to promote the new industry as a more convenient alternative for people connecting at an airport.
- Another challenge to face is **community acceptance and adoption**. This is not a major issue for airports where the background noise of nearby highways, aircraft taxi, take-off and landing is already there, but it might be an issue for those urban locations specially with residential areas nearby. That is why most eVTOL manufacturers are focusing on reducing their noise impact to make it almost unnoticeable during cruise flight. Early engagement with the affected communities and the local governmental offices to explain and educate them on what Advanced Air Mobility is, its perceived noise and visual pollution impact and how are they working on mitigate it.
- **Charging infrastructure** and power supply harmonization and interoperability. Two standards have arisen as the main connectors for most of the eVTOL charging plugs: CCS1 (USA and Canada)/CCS2 (Europe) and the newly created Joby Aviation´s Global Electric Aviation Charging System (GEACS). The demand for energy at each of the vertiports with high turnarounds of eVTOLs coming in and out and requiring fast charging, it is expected to be rather high. Leaving alternative and less mature power sources aside for now such as hydrogen, electricity and Li-ion batteries for energy storage has remained as the most relevant energy source across the AAM manufacturers market to rely on. Airports will need to facilitate access to those power networks and ensure that this service is provided unstoppably.
- **Integration with the airport operations and the TSA/CBP controls** specially for international flights. One of the outstanding questions is if the vertiport at the airport should be on the airside like the rest of the planes, in the executive flights are or alternatively, in the landside like the rest of the ground transportation mobility options. These different use cases create different scenarios with different implications that in some cases must be regulation compliant and addressed early.
- **Integration into the local low-altitude airspace** and Air Traffic Management (ATM) especially when the industry starts to scale up. Initially, all eVTOLs will be piloted and operate under the current Visual Flight Rules (VFR) recommendations and regulations. Once the industry starts to scale up and in order to sustain the growing volume of operations, it might make sense to move towards autonomy by removing the pilot from the aircraft after a remotely piloted transition phase. This is when the on-going developments and tests specially in Europe on Unmanned Traffic Management (UTM) will gain comes into place and have a lead role to ensure the safe operations.

To conclude, a key example on the AAM developments and possibly one of the first use cases in the USA is New York City and its connection to its five local airports in the different boroughs. Traditionally, passengers have been relying on ground transportation like subway, taxi/ride hailing or shuttles which take them from 45min-1.5h to get for instance to JFK airport at a cost of $65-75 per trip. There are alternative air services connecting the different heliports in Manhattan with the five airports by helicopter

provided by operators like Blade, at a price point that can be as much as $195 for a 5min trip which makes it much more expensive but definitely more convenient.

Given all this, AAM might have the solution (and the opportunity) to fill the gap in between the two ends of the transportation options for passengers to get to/from the airport. In this line, recently Joby Aviation made flight demonstrations at the JRB heliport in the south east of Manhattan while Skyports (vertiport developer start-up with different living labs across the world and building the first operational vertiport in Dubai) and Groupe ADP have been awarded not only the operation of JRB for the next 5 years but also the electrification to transform it in the first operating vertiport in the Big Apple.

8. Conclusion

The aviation industry is at the cusp of a technological revolution that promises to transform the passenger journey from start to finish. This document has explored the myriad ways in which innovative technologies are being integrated into airport operations to enhance efficiency, security, and passenger satisfaction. From biometric identification and AI-driven solutions to smart infrastructure and advanced wayfinding systems, these advancements are setting new standards for air travel.

One of the key takeaways is the strategic focus on three main pillars: enhancing the passenger experience, maximizing non-aeronautical revenue, and improving operational efficiencies to reduce costs.

The integration of breakthrough technologies in airports is dramatically transforming the aviation landscape, setting new benchmarks for efficiency, security, and passenger satisfaction. The advent of generative AI-powered virtual assistants, which provide real-time information and personalized assistance, is revolutionizing the way passengers navigate through airports.

One of the most significant benefits of embracing novel technologies is the ability to maximize non-aero revenue. Advanced data analytics and AI-driven insights enable airports to tailor their commercial offerings, thereby increasing retail and concession sales. By understanding passenger preferences and behaviors, airports can create targeted marketing strategies that drive higher engagement and spending.

Operational efficiency is another critical area where technology is making a substantial impact. AI algorithms analyze passenger movement patterns, predict congestion points, and optimize passenger flow management. This results in reduced wait times and a more seamless travel experience. Enhanced security screening processes, powered by generative AI algorithms, improve the accuracy and efficiency of threat detection, ensuring the safety of air travel.

Sustainability is a cornerstone of modern airport operations. The adoption of innovative technologies contributes to more sustainable practices by optimizing resource usage and reducing environmental impact. For instance, predictive maintenance reduces unnecessary equipment usage and prolongs the lifespan of assets, while AI-driven energy management systems optimize power consumption. Additionally, sustainable practices are increasingly becoming a priority for passengers, who seek environmentally responsible travel options.

Collaboration with start-ups plays a pivotal role in driving innovation within the airport ecosystem. Start-ups bring fresh perspectives and cutting-edge solutions that can address emerging challenges and opportunities. By fostering partnerships with start-ups, airports can accelerate the adoption of new technologies and stay ahead of the curve in an ever-evolving industry.

Future Outlook

Looking ahead, the future of air travel will be shaped by the continuous evolution of these technologies and the emergence of new innovations. One of the significant challenges that airports will face is understanding and addressing the travel preferences and behaviors of new and younger generations. These travelers are more tech-savvy and expect seamless, digital-first experiences. Airports will need to invest in technologies that cater to these expectations, such as mobile apps for real-time updates, virtual assistants for customer support, and personalized services based on data analytics.

Another critical aspect is the importance of reducing overall stress and queues at airports. While significant progress has been made in streamlining processes, there is still much work to be done. Airports will need to continue investing in technologies that enhance efficiency and reduce bottlenecks. For example, the use of AI and machine learning to predict passenger flow and optimize resource allocation can help manage congestion and improve the overall travel experience. Additionally, the implementation of pre-booked security timeslots and self-service security screening can further reduce wait times and enhance passenger convenience.

Furthermore, the future of air travel will also be influenced by the need to create more inclusive and accessible environments for all passengers. Technologies such as augmented reality navigation and indoor sensor positioning can help passengers with disabilities navigate airports more easily and independently. By ensuring that all passengers, regardless of their abilities, can have a stress-free and enjoyable travel experience, airports can improve customer satisfaction and meet regulatory requirements.

In conclusion, the integration of innovative technologies in airports is revolutionizing the passenger journey, making it more efficient, secure, and enjoyable. However, the journey towards a fully optimized and seamless travel experience is ongoing. Airports must continue to invest in and adopt new technologies to stay ahead of the curve and meet the evolving needs of passengers. By doing so, they can enhance service quality, operational efficiency, and overall passenger satisfaction, positioning themselves as leaders in the aviation industry.

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