

The smart airport future

A Primer

Airports are facing significant challenges due to increasing passenger numbers, maintaining strict security protocols, achieving environmental sustainability, and embracing technological innovations. The financial impact of airport delays is estimated to cost the global economy \$75.5 billion each year. This primer offers potential solutions enabled by advanced technology and a view into the future of global aviation to meet these challenges.

WHAT'S INSIDE!

- 1 Challenges faced by airports today
- 2 Evolving trends in airports
- 3 Making airports smarter with technology
- 4 Achieving airport sustainability goals
- 5 Smart airports of the future

Executive summary

Airports have never been more indispensable to global commerce, travel, and connection than they are today. They are nodes that enable the most basic functionality of our global economic system. Today, airports are facing significant challenges— to the degree of hampering both their individual utility, and, at a broader scale, our global economy’s most basic capabilities. Many of the most common airport guidelines, rules, and best practices were first established decades ago, in a time when far fewer travelled and customer needs and expectations were quite different from those of today.

Challenges are diverse. They range from managing ever-increasing passenger numbers and maintaining strict security protocols, to achieving environmental sustainability and embracing technological innovations. These complex demands call for inventive and proactive solutions. One of the more pressing issues is the financial impact of airport delays, which are estimated to cost the global economy a staggering \$75.5 billion each year.

This primer offers a comprehensive examination of the principal challenges confronting airports today. It provides both potential solutions— enabled by advanced technology— and a view into the future of global aviation.

We believe that our proposed technology-enabled solutions, integrated end-to-end throughout the airport customer journey, will enable modern airports to “get smart” and meet both the seemingly intractable challenges of today and prepare for those of the years to come.

The smart airport future is here. Buckle up.



The not-so-smart airports of the present





Challenges

Although airports have achieved notable advancements in recent years, countless hurdles remain. While a list of particular and highly-specific hurdles or challenges could be nearly endless, we have identified a few key causes that are at their root.







Root causes include-

- Aging infrastructure
- Soaring air travel demands
- Heightened passenger expectations
- Swift technological progress

To further clarify and identify problems facing today's airports, we've further segmented specific challenges into two key areas: those related to airport operations and those concerning passenger experiences

Challenges			
Operation-related		Passenger-related	
 <p>Capacity & congestion</p>	<ul style="list-style-type: none"> • Overcrowded runways, terminals, and gates, causing delays. • Challenges in managing aircraft and gate assignments during peak travel times. 	 <p>Flight delays</p>	<ul style="list-style-type: none"> • Inconvenience due to unpredictable flight delays and cancellations. • Lack of communication from authorities, leading to missed connecting flights
 <p>Operational efficiency</p>	<ul style="list-style-type: none"> • Inefficient check-in and security screening processes, extending waiting times. • Inefficient baggage transfer processes during connecting flights create delays in baggage delivery 	 <p>Customer experience</p>	<ul style="list-style-type: none"> • Long lines at check-in, security, and immigration counters create negative passenger experience • Inefficient handling of customer complaints leads to negative experience and lack of material improvement

Challenges

Operation-related		Passenger-related	
 <p>Focus on sustainability</p>	<ul style="list-style-type: none"> • GHG emissions from aircraft operations, ground transportation, equipment, and facilities. • Improper disposal of hazardous materials. • Overuse or misuse of water during airport development processes 	 <p>Accessibility & transportation</p>	<ul style="list-style-type: none"> • Inadequate public transportation connections. • Limited parking availability • Inadequate services, assistance, or design to help people with disabilities
 <p>Cargo flow management</p>	<ul style="list-style-type: none"> • Reliance on manual processes for cargo handling increases the likelihood of operational errors. • Inefficient cargo tracking and monitoring systems reduces the visibility of real-time cargo, leading to further errors and/or mismanagement. 	 <p>Baggage loss</p>	<ul style="list-style-type: none"> • Difficulty in locating and retrieving baggage due to inadequate tracking. • Mishandled or lost luggage, causing inconvenience and highly negative customer experience.
 <p>Workforce shortages</p>	<ul style="list-style-type: none"> • Lack of automation that can streamline or manage ground operations • Issues with unruly passengers are more difficult to address due to low industry levels of digital transformation 	 <p>Amenies & facilities</p>	<ul style="list-style-type: none"> • Insufficient Seating and waiting ares, particularly during peak travel periods. • Limited dining and retail options, raising prices and extending wait times.

The global travel shift: Current industry and market trends

Fortunately, many airports are either already leveraging new technology or operational initiatives to address a sizeable portion of the challenges listed above, or are currently in the process of implementation. In fact, many current initiatives are progressing rapidly.

We believe that it's a trifecta of emerging technological innovation, evolving customer expectations, and dedicated sustainability goals that are accelerating this sizable industry shift. Evidence abounds- modern airports are increasingly adopting advanced technologies such as biometric identification, AI-enhanced prediction engines, and contactless services to offer experiences that are not only personalized and secure but also highly efficient. In this section, we will provide a brief and highly general overview of current initiatives underway across a wide variety of airport operations categories.

In the following three sections, we will dive into far greater detail into the specifics of currently available technology solutions, their current levels of adoption, and up-and-coming future solutions. Below is the general overview of a wide variety of trends that are currently underway-






- 1 Improved passenger experience:**
Enhancing the passenger experience to attract more travelers and improve their reputation. Optimizing check-in processes, shortening wait times, upgrading seating areas, refreshing signage, and improving access to amenities like restaurants, shops, and Wi-Fi.
- 2 Optimizing capacity and infrastructure:**
Managing and improving airport capacity and infrastructure is particularly important for busier airports experiencing increased passenger traffic.
- 3 Safety and security:**
Safety and security of passengers, employees, and airport facilities. This includes implementing rigorous security measures, adhering to international safety standards, and conducting regular safety drills.
- 4 Regulatory compliance:**
Compliance with numerous aviation and safety regulations set by national and international authorities. Ensuring adherence to these regulations is essential for maintaining operational integrity and public trust.
- 5 Air cargo and logistics optimization:**
For airports that handle significant air cargo volumes, optimizing cargo operations and developing strong logistics capabilities are vital for revenue diversification and attracting cargo carriers.
- 6 Sustainability and environmental impact:**
Airports are increasingly focused on reducing their environmental footprint. This includes adopting eco-friendly practices, investing in renewable energy, using sustainable construction materials, and implementing waste management strategies.

The technological solutions making airports smarter

Technology-based solutions

Some cutting-edge technology solutions are already addressing many core challenges facing the airports of today. Other solutions are expected to be implemented over a longer, or much longer, time horizon. Both technology solutions and time horizons are highlighted in the tables below.

Operations-Related Areas - Technological Innovations

 Capacity & congestion	 Operational efficiency	 Focus on sustainability	 Cargo flow management	 Workforce shortages
AI-based swift & efficient allocation of gates and counters to airlines.	AI-based smart windows for automatic adjustment of natural light.	Real-time passenger flow monitoring for HVAC, climate & light control using IoT.	Driverless vehicles moving cargo.	Robotics and drones for maintenance and cleaning tasks, reducing manual labor.
AI-based improved runway slot adherence.	AI-enabled predictive maintenance of airport assets	Harmful gas detection to improve air quality using IoT.	Luggage count, size, and volume monitoring to predict overhead space overflow using CV.	Smart robots patrolling to track unauthorized people.
Computer vision-enabled passenger movement congestion analysis	Digital Twin for operation optimization.	AI/ML predicting water usage patterns and identifying recyclables.	Cargo condition monitoring using IoT.	AI-powered chatbots and assistants.

○ Current level of adoption / maturity ● Low ● Medium ● High

The technological solutions making airports smarter






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Passenger-related areas technological innovations

	 Flight delays	 Customer experience	 Accessibility & transportation	 Baggage loss	 Amenities & facilities
	Smartphone apps offering personalized go-to-gate reminders.	Smartphone apps enabling virtual queuing.	Parking assistance robots to reduce average parking time.	Reusable RFID tags on baggage for paperless tracking.	QR code and contactless option for order placement and payment..
	Passenger navigation via Augmented Reality (AR).	Walk-through, contactless immigration.	Electric passenger shuttles, catering trucks, etc.	Smart luggage tag to notify passengers of luggage arrival at carousel.	Retina scans, finger-vein scans and facial recognition for lounge access, shopping, etc.
	Biometric authentication for passenger identification, luggage check-in, custom clearance.	Humanoid robots offering passenger assistance / language translation.	Autonomous wheelchairs.	Smart kiosks that track finger movement for check-in, bag drops, etc.	5G connected autonomous robots, vehicles, and mobility equipment to support passengers.

○ Current level of adoption / maturity ● Low ● Medium ● High

Solving for sustainability: A herculean task?

In tandem with accelerating climate change is an accelerating global imperative for innovative and collaborative solutions. Efforts to mitigate detrimental climate impacts on temperature, water resources, and other natural elements are gaining greater momentum.

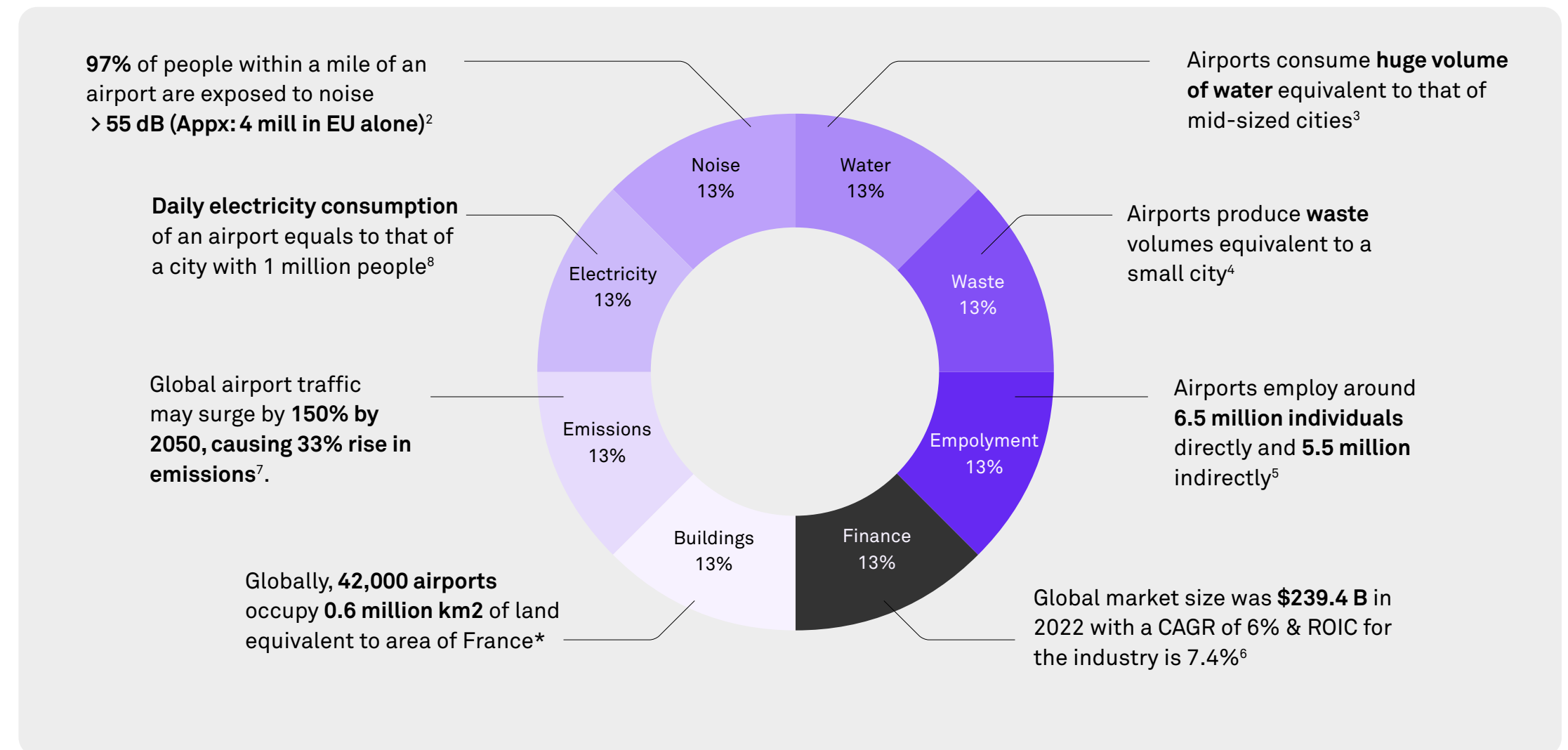
The aviation sector is responsible for approximately 2 - 3% of human-induced carbon emissions, with airports contributing around 2% of this figure.

Although this may seem relatively modest, airports do exert a notable environmental impact through their operations and infrastructure.

The graphic on the right illustrates some of these environmental effects in greater detail—

As the graphic illustrates, airports generate sizeable negative environmental impacts on their communities.

Fortunately, many have recently adopted a set of sustainability goals. New technology now enables airports to embrace various action items far more proactively. Consequently, many sustainability goals that may have once seemed unrealistic are now



becoming not only possible, but even a lived reality in certain circumstances. Sustainability goals that were once believed to require “herculean” efforts, are now far more accessible.

Environmental impacts of airports: A statistical overview

Several new technological solutions enabling airports' sustainable transition are discussed below—

- 1 Energy Efficiency and Renewable Energy:**
Action 1: Use advanced analytics to identify patterns in energy usage and implement targeted energy-saving measures.
Action 2: Integrate renewable energy sources into the airport's power grid and utilize AI to optimize their usage.
- 2 Waste Management and Recycling:**
Action 1: Implement waste sorting robots or AI-powered waste sorting systems to enhance recycling efficiency.
Action 2: Use data analytics to identify waste generation hotspots and target waste reduction efforts accordingly.
- 3 Water Conservation:**
Action 1: Use AI to predict water demand patterns and optimize water supply accordingly.
- 4 Carbon Emissions Reduction:**
Action 1: Implement AI-driven air traffic management systems to optimize flight routes and reduce fuel consumption.
Action 2: Use big data analytics to optimize

airport operations, reducing energy usage and emissions.

- 5 Sustainable Construction and Design:**
Action 1: Utilize AI-powered simulations to optimize airport layout and minimize energy consumption.
- 6 Stakeholder Engagement and Education:**
Action 1: Implement AI-powered chatbots and virtual assistants to provide passengers with sustainability-related information and tips.
Action 2: Utilize virtual reality (VR) and augmented reality (AR) experiences to educate airport staff and visitors on sustainability practices.
- 7 Sustainable Transportation Options:**
Action 1: Develop AI-driven algorithms for managing transportation services to and from the airport, optimizing routes and schedules.
Action 2: Utilize IoT technology to monitor public transportation usage and optimize services based on demand.

Beyond the previously highlighted action items, airports can adopt numerous additional measures to further enhance their operations and passenger

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experiences. By embracing the concept of “smart airports,” they can integrate advanced technologies to streamline various processes throughout the entire journey, from check-in to boarding and beyond. Beyond the above action items, airports can adopt a wide range of additional strategies to further elevate their operations and enrich passenger experiences. Key stakeholders simply choosing to adopt the “smart airport” mindset, regularly seeking to leverage advanced technologies to optimize airport processes throughout the entire customer journey, will likely uncover untold additional opportunities for sustainable technology implementations. This mindset will be crucial to further refinement and optimized implementation.

The global travel evolution: Upcoming industry and market trends

Most smart airport innovations are incremental in nature. They concern daily challenges that new solutions partially alleviate or ameliorate rather than completely solve.

Smart airports offer subtle yet significant improvements at every stage and service of the customer journey.

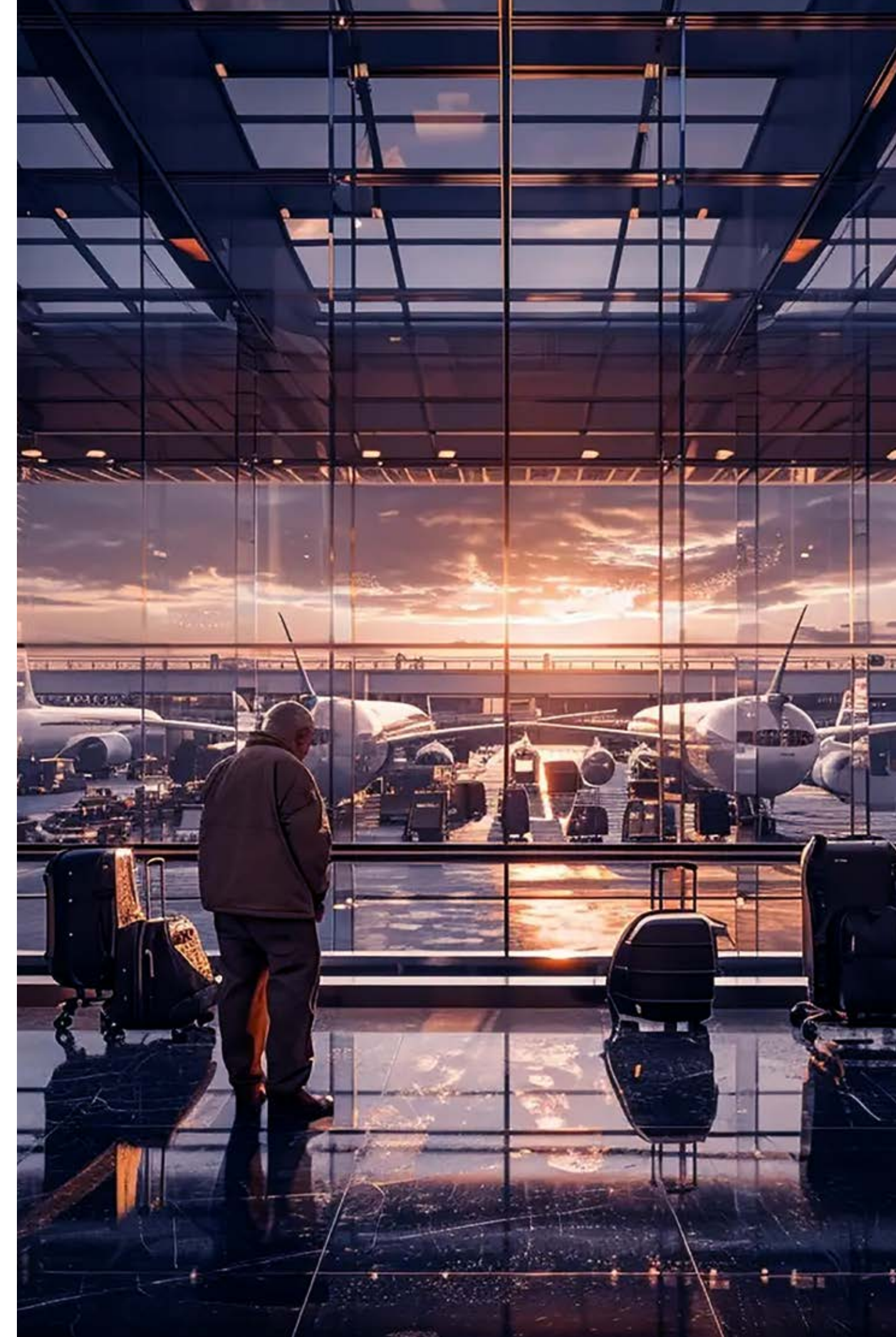
An airport digital twin can provide grounds for major airport optimization, strategic operation, and disruption training and management, serving as one major gathering point of all information flows.

Enhanced baggage tracking, streamlined passenger check-in, more efficient disruption management, and centralized data gathering for insightful analytics are all examples of smart airport innovations.

While each development on its own may seem marginal, the cumulative impact of each element of an integrated smart airport system creates a vastly enhanced airport experience. Smart airports may visually seem nearly identical to traditional airports, but their functionality and usability are truly evolved.

Smart airports are a textbook case study of where the whole truly is greater than the sum of the parts. Further, it seems to be true that some of these technological advancements, while contributing to incremental improvements, also may one day lay the groundwork for a radical overhaul of the entire airport experience.

Below is a summary of the most rapidly evolving technologies that may impact airports, affecting digital, operations, and transportation:



Digital.

Most foundational changes are currently in the areas of data and cloud, converting airport digital back-end or front-end capabilities from a set of disjointed services into integrated entities offering personalized customer interactions.

Private networks – Connectivity and IoT^{5,7}: Connecting all airport devices, from top to bottom, into one integrated network simplifies maintenance, improves observability, and opens the door to multiple point-optimizations of the customer experience.

Metaverse, digital twin⁶: An airport digital twin can provide grounds for major airport optimization, strategic operation, and disruption training and management, serving as one major gathering point of all information flows. In a combination with Metaverse, it may help customers with trip planning, navigation, and access to airport services and retail.

Operations.

Existing operational challenges drive airports to implement “point solutions”, each solely focused on solving a separate component of a given challenge. Current solutions do not disrupt the airport operations and they

target to make some elements of it smoother, faster, cheaper, smarter, or more pleasurable to the customer.

Dynamic resource management⁴: The insights from IoT and Digital Twin allow to optimize the use of airport resources and staff, adjust in anticipation of predicted passenger traffic, track and handle luggage, and minimize impact of various disruptions.

Dynamic sustainability management: Sustainability of the airports involves multiple technologies, from the top – staff optimization, airport climate control, and low-waste maintenance, to the bottom – rainwater recycling, paperless bathrooms, and energy saving bulbs. An elephant in the room⁴ here is the current commitment across the industry to reach net zero carbon emissions by 2050, what presses high requirements on the aircraft technology and fuel and requires changes in airport operations and infrastructure.

Streamlined customer journey^{6,7}: Focused on improving customer convenience. Innovations include automated check-in, information and navigation kiosks, mobile passport control, and rapid scanners for liquid and shoes.

Retail personalization⁶: Implementation of new technologies and business models to personalize

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the airport retail experience. Trends include personalized pricing, biometric payment, all-you-can-fly subscription services, grab-and-go and just-walk-out technologies, as well as robotic delivery, recommendations, and navigation.

Enabling innovation: The Covid-19 pandemic awakened the industry to its need for innovation. Airports have



Walking to distant gates, between gates, and from gates increases overall travel times, exhausts customers, and hinders them from enjoying retail or recreational areas

since begun to engage startups and scaleups. The exponential growth of the [FTE Digital, Innovation & Startup Hub](#) demonstrates this trend, which we expect to further accelerate in 2023 and beyond.

Transportation.

While innovations mentioned above can all dramatically improve the airport customer experience, an airport's primary value proposition remains end-to-end customer transportation. This naturally includes transportation to and from airport, within the airport, and between different airports. The airport industry is designed around this purpose, considering all limitations of various airport locations, passenger transportation needs, and airplane docking requirements.

Transport to-and-from airports⁶: Airport distance from major city centers encourages experimentation with Urban Air Mobility models, with air taxi-service provided for popular or heavily frequented locations.

Transport within airports^{5,8}: With increasing airport sizes, walking speed becomes a significant hindrance to airport efficiency. Walking to distant gates, between gates, and from gates increases overall travel times, exhausts customers, and hinders them from enjoying retail or recreational areas. Self-driving

passenger vehicles are an appealing solution. Other experimentation is also taking place.

Transport between airports⁵: Advanced air mobility concepts that entail the use of unmanned aircrafts for short flights are currently in development. This may both ameliorate air crew limitations and significantly reduce the price of short-range aircraft service.

The global travel revolution: A futuristic rethinking, from first principles

If smart airports are considered as a the whole resulting from a sum of incremental improvements across all aspects of airport services and and operations, then “future airports” may be understood as an ultimate destination point for smart airport improvements.

Airports may cross the line from smart to future when the many incremental changes have eventually accumulated into major disruptive rethinking of airport design, operation, and customer experience. One may consider this process as a kind of incremental revolution.

Let’s now consider all the major steps of the passenger journey, with an eye to first principles— should each be not just improved – but rethought, entirely?

1 Travel to airport.

Airports are often far from populated areas. Travel to the airport may be costly, long, subject to traffic and scheduling risks, and stressful due to enforced flight schedules.

Does it have to be this way? No

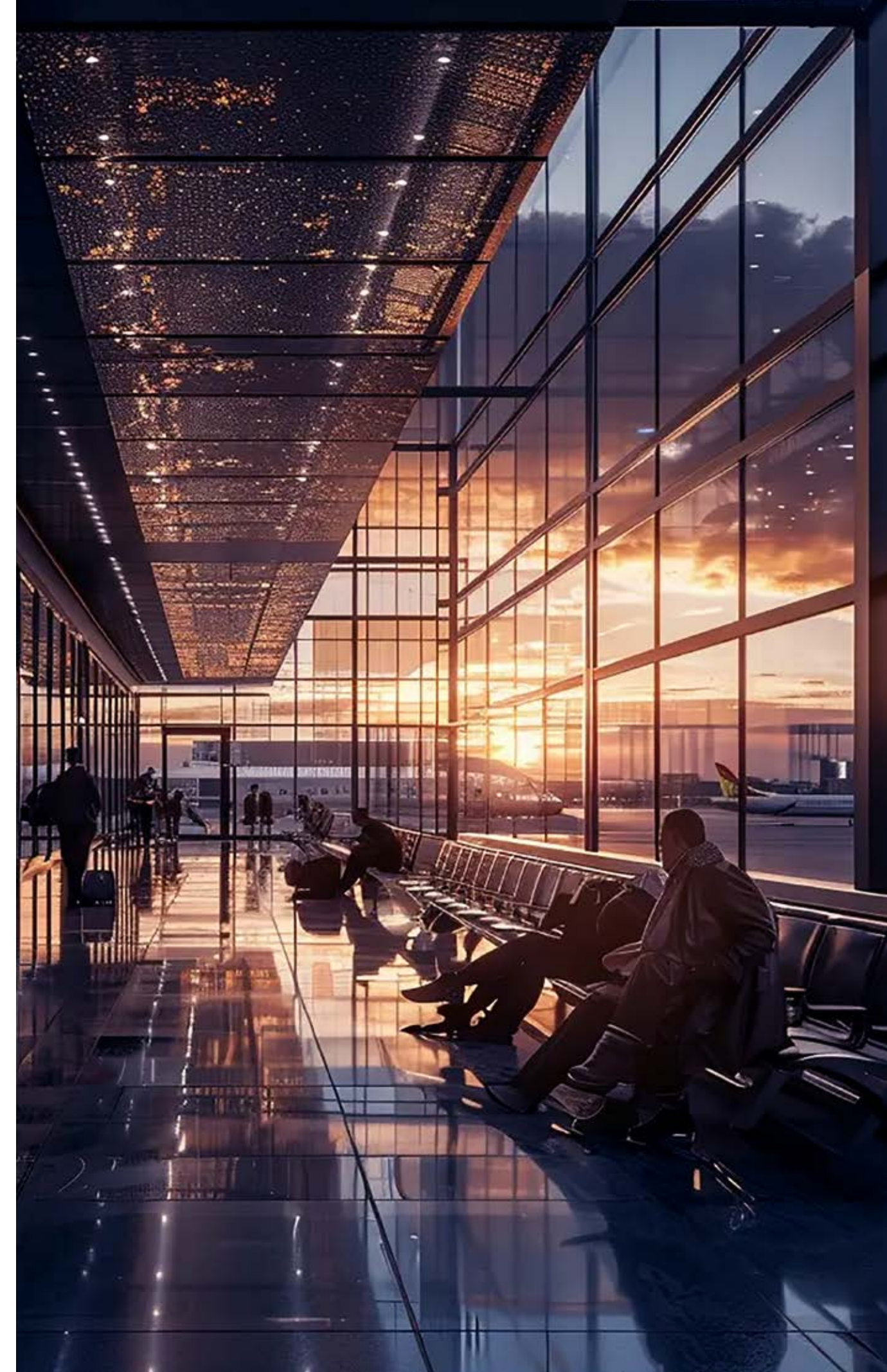
Rapid transportation, synchronized with airport services, is the solution. An autonomous vehicle can pick up the passenger at any reasonable location and escort them to a rapid airport shuttle line. The trip could be automatically tracked by airport services from the point of pick up, so that the passenger is aware that she is traveling on schedule from the very first moment she leaves her point of departure. Further, airport services will ensure that she is registered in the system and her flight is not going to be missed. Autonomous air taxi may be an option for less convenient locations.

2 Check-in and document check.

Check-in currently requires early arrival, searching for the correct airline counter, standing in lengthy lines, and showing documents to airline staff.

Does it have to be this way? No

Passengers can be automatically checked-in once they entered an airport-synchronized





Luggage drop-off is one of the more aggravating travel limitations, requiring passengers to arrive at the airport 40 minutes earlier than they may otherwise. Further, size and weight restrictions can be onerous.

autonomous vehicle. Customer biometrics can be sufficient for registration and thus no even documents would be required. For international travel, passports could be scanned inside the vehicle or also linked to biometrics.

3 **Luggage drop-off.**

Luggage drop-off is one of the more aggravating travel limitations, requiring passengers to arrive at the airport 40 minutes earlier than they may otherwise. Further, size and weight restrictions can be onerous.

Does it have to be this way? No

With autonomous vehicle service, passengers could drop their luggage off in advance. When the passenger arrives to the airport, it may already be checked and on the plane. An additional optimized luggage handling system may further reduce the time of handling the luggage, from the current standard of 40 minutes to one of 20 minutes or less.

3 **Security.**

Currently, airport security requires waiting in long lines, undressing and unpacking, dressing and re-packing, and planning for multiple item restrictions on the flight. It also can create

unpredictable delays that can jeopardize the passenger's ability to catch their flight.

Does it have to be this way? No

Optimized and upgraded scanners combined with AI can boost the speed of security check, remove lines, reduce or eliminate the need to undress and unpack, and even allow for many of the items on the non-allowed list. Further, biometrics and digital identity can provide enough passenger information to bypass most passengers from extensive screening.

4 **Waiting in the airport.**

Currently, non-flexible flight schedules require passengers arrive on time. This requires passengers to plan for unpredictable risks that usually results in them arriving to the airport well-in-advance, prolonging travel time and limiting quality time. As departure gates and quality entertainment areas are often remotely separated, and traveling to the gate and boarding is can be a lengthy process, often times time spent in the airport is not high quality.

Does it have to be this way? No

Optimization of the previous steps allows the passenger to arrive to their flight with a much

lower likelihood of missing the flight. Further optimization of travel to the gate, boarding, and system of passenger tracking – can otherwise allow passengers to safely enjoy improved airport retail and recreation services, knowing that they are going to be notified in advance and the flight is not going to be missed.

5 Way to the gate.

Currently, getting to the gate may require a long walk of a noticeable and unpredictable length. This causes most passengers to prefer to walk to their gate before enjoying any quality retail or entertainment time.

Does it have to be this way? **No**

An autonomous vehicle can safely and predictably deliver the passenger straight to the gate. There is no need to leave entertainment area long before the flight. Further, autonomous vehicles can deliver retail goods to passengers who arrived at to the gate in advance.

6 Boarding.

Currently, boarding takes from 20 to 30 minutes of unpleasant standing in line to the gate, adding on average around 30 minutes to travel time.

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Does it have to be this way? **No**

Automatic pre-sorting of the passengers based on the seating in combination with automated biometrics can reduce this time in half. Utilizing more than one entrance to the airplane may reduce this time further and consequently reduce the time an airplane needs to occupy a given gate.

7 Transferring flights.

Today, flight transfers between gates require long walks, passing through extra layers of security, an occasional travel to a different terminal, and further walking to a new gate. Consequently, any layover that is less than an hour becomes a source of stress for passengers.

Does it have to be this way? **No**

An autonomous vehicle can safely and predictably deliver passengers straight to the gate. For the delayed incoming flight, an autonomous vehicle could already wait for the transferring passenger to deliver them straight to their next flight. Transfer can be fast, reliable, and pleasurable.

8 Plane exit delays.

Sometimes, planes arrive at a destination—and for whatever reason, is delayed from allowing passengers to exit through the gate. Another version of this situation may involve a lengthy or delayed exit of each passenger from the plane.



Autonomous vehicles can also allow for easier airplane unloading from any position on the airfield, perhaps even without a gate. Incorporating more exits and entrances to the plane may also speed up the process.

Does it have to be this way? ❌ No

Faster boarding processes, optimized airport operations, and improved airport design may decrease the possibility of gate-access delays. Autonomous vehicles can also allow for easier airplane unloading from any position on the airfield, perhaps even without a gate. Incorporating more exits and entrances to the plane may also speed up the process.

9 Border control / Luggage pick-up.

Arrival also consists of several hassles. Walking to customs, baggage claim, and finding ground transportation are among them.

Does it have to be this way? ❌ No

Biometric, digital identity, and remote communication technologies can enable us to pass through border control and submit declarations while being on the flight. Pre-sorted luggage that satisfies international green corridor requirements can even be delivered directly to the passenger after the flight. They can reunite at the airport fast shuttle, where the passenger is directly transported from the gate or landing position .

10 From airport to the destination place.

The destination airport may again be remote from

populated areas. Travel to the destination location may also be costly and lengthy, further exhausting already-tired customers.

Does it have to be this way? ❌ No

Instead, an airport autonomous vehicle can pick up the customer and escort them to a fast airport train shuttle line. Another autonomous vehicle can even wait for the passenger to arrive at the passenger's chosen shuttle destination, to meet the customer and transport them to either their final destination or another reasonable location. Delayed luggage bags can be delivered via another automated vehicle system, similar or identical to the bag pick-up system. An autonomous air-taxi could be an option for inconvenient locations.

Conclusion

The Smart Airport Future represents a remarkable convergence of cutting-edge technologies, innovative design, and a steadfast commitment to enhancing the overall passenger experience.

As the broader aviation industry continues to evolve, airports are poised to both enable further industry evolution and evolve in lockstep with the broader industry. Innovation is often symbiotic— airport evolution may be supported by innovations in automation, for example, which will then enable airports to provide better services that can enable customers to spend more time on their own creative or innovative projects, feeding back into the broader system.

Regardless of broader innovation implications, smart airports are positioned to revolutionize travel and connectivity. By seamlessly integrating IoT devices, AI-powered analytics, biometric systems, touchless solutions, and other emerging technologies, smart airports and future airports will lead to the development of an ecosystem that prioritizes efficiency, security, and hyper-personalized services.

However, this movement's commitment to sustainability is also critical. An implementation of eco-friendly initiatives and sustainable practices will further reinforce industry dedication to environmental responsibility and contribute to a greener and more resilient future.

Airport industry leaders will benefit from understanding and embracing this transformative smart airport concept— one that is paramount to effective competition within the rapidly evolving aviation landscape.



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