The Future of Airports

A Vision of 2040 and 2070

Consolidated Version

White Paper

ENAC Alumni – Airport Think Tank

April 2020

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Contents

Research Team ... 4
Panel Members ... 4
Participating Organizations ... 4
Foreword ... 5
Introduction ... 6
Topic No. 1: The World in 2040 and 2070 ... 7
Topic No. 2: Sustainable Business Models and New Sources of Funding ... 13
Topic No. 3: Smart Airports at the Era of Information Technologies ... 18
Topic No. 4: Security Threats and Unlawful Activities ... 23
Topic No. 5: Enhancing Aviation Safety Under a Growing & More Diverse Traffic ... 29
Topic No. 6: Airside & Airspace Compatibility ... 35
Topic No. 7: Passenger Terminals and Customer Experience ... 40
Topic No. 8: Operational Performance and Resilience ... 44
Topic No. 9: Mobility and Communities ... 50
Topic No. 10: Sustainability and Airport-Citizens ... 54
Topic No. 11: Human Resources and Education ... 61
Appendix 1-1 - Effects of the COVID-19 Crisis on the Aviation Industry ... 64
Appendix 2-1 - Current Examples and Trends on Airport Business Models ... 66
Appendix 4-1 - Selection of Physical Attacks Against Airports ... 67
Appendix 4-2 - Selection of Cyberattacks Against Airports ... 70
Appendix 5-1 - Enhancing Aviation Safety During Airport Construction ... 71
Appendix 6-1 - Comparisons Between Legacy Airliners and Their Successors ... 74
Appendix 6-2 - Aircraft Characteristics for Airport Planning ... 75
Appendix 8-1 - Long-Term Threats to Airport Resilience ... 77
Appendix 9-1 - Existing and Emerging Modes of Transportation to Airports ... 78
Appendix 11-1 - Emerging and Potential Airport Jobs at the 2040 and 2070 Horizons ... 80
Appendix 11-2 - Selected Higher Education Programs in Airport ... 82
Abbreviations ... 83
References ... 87

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Foreword

In February 2019, ENAC Alumni – the alumni association of the National University of Civil Aviation (ENAC) – organized a day of discussion and education on the current and future challenges in air transportation: **The State of the Air ("Les Etats de l'Air")**. This event, held at the headquarter of the French General Directorate for Civil Aviation (DGAC), was part of a broader effort to fulfill some of our primary missions toward our 24,000 members: to maintain their knowledge up to date, to provide them platforms where to express and exchange ideas, and to promote excellence in aviation & space.

In addition to master classes on Airports, Aircraft and Systems, Design & Certification, Airline Operations, Air Traffic Management, Aircraft Maintenance, Pilots & Flight Operations, Safety & Compliance, and Entrepreneurship, **the State of the Air** featured a series of roundtables bringing together key leaders of the industry in the sectors of air transportation, tourism and general aviation who presented their vision of the future.

Following the large success of the State of the Air, and considering the dedication and expertise of our alumni, it has been decided to take the momentum and invite our think tanks to launch projects on the future of aviation. These think tanks reflect the diversity and excellence of our alumni community: air traffic management, airline operations, airports, digital innovation, and sustainable development.

The Airport Think Tank chaired by Gaël Le Bris is one of the most active of our research groups. The Future of Airports is an important study that brings a significant value added to help us foresee future challenges and prepare our industry for the changes to come. The participants of The Future of Airports have provided remarkable work. The output of the working sessions and the research findings are being released as white papers and other practice-ready materials that will be shared and brought to decision makers and leaders of both the public and private sectors worldwide. I am confident that the outcome of this Think Tank will be a huge move forward for the promotion and recognition of the ENAC Alumni.

Marc Houalla, President of ENAC Alumni

Introduction

From March 2019 to April 2020, the Airport Think Tank of ENAC Alumni conducted a research project on the long-term future of the airport industry: "The Future of Airports". The project involved thought aviation leaders from diverse backgrounds and affiliations who looked at the trends and potentially disruptive changes, emerging transformational innovations, their impact on practice and their challenges for air transportation, and the needs in research, education and policies for anticipating and facilitating these changes.

The future of airports cannot be envisioned without considering the future of our societies. At the 2040 and 2070 horizons of our study, we will count more fellow human beings than ever. Overall, we will be wealthier and more educated, and have a longer life expectancy. However, we will all face increased impacts from climate change that will put pressure on resources and communities, and might increase inequalities. We will have different social expectations. How can aviation address these new paradigms and continue to provide mobility?

First and foremost, we shall never forget that safety always comes first. As we are making air transportation increasingly automated and connected, we shall remember that our top priority must be to safeguard life, health, and property, and to promote the public welfare.

Human-induced climate change is the most formidable threat to our civilization. Transportation must become greener if we want to sustain the development of our societies without degrading our well-being and endangering public health at a horizon increasingly visible. Aviation shall keep pioneering green policies.

As aviation professionals, we are on the front line to tackle the fundamental issues arising and still continue to interconnect people and move freight. Aviation shall remain a world of opportunities and "create and preserve friendship and understanding among the nations and peoples of the world" as stated in the Convention of Chicago of 1947.

By 2040 and 2070, it is likely that unforeseeable groundbreaking technological innovations, scientific discoveries, and social and political changes will occur and deeply impact our world. When reading these pages, remember that we conducted our work and prepared these materials with our eyes of 2019.

We are all part of this future, and we can make a difference individually if we make ethical and sustainable decisions. Aviator and writer Antoine de Saint-Exupéry said that when it comes to the future, "it is not about foreseeing it, but about making it possible". Let's make a bright aviation future possible together.

Gaël Le Bris, Chair of the Airport Think Tank of ENAC Alumni

Topic No. 1: The World in 2040 and 2070

A More Populated World: Adding 3 to 6 Billion People by 2070

Per the United Nations, the current human population is more than 7.7 billion. This number will grow around 9 billion in 2040, and then 10.5 billion in 2070. While the demography of the more developed regions will be nearly stagnant and perhaps even starting to shrink by the mid-century, most of the worldwide population growth will occur in Asia and Africa. Africa will observe the highest growth rates and will account for 26% of humankind in 2070. Nigeria, currently with the world's 7th largest population, is projected to surpass the United States and become the third most populated country before 2050.[1]

These trends will dramatically modify the long-term balance of power and the face of the world. They might also change aviation worldwide. While the population will continue growing tremendously over the coming decades, living conditions in the emerging and underdeveloped regions will improve. According to the World Data Lab, half of humanity is now part of the middle class – defined as the households spending between $11 and $110 per day per person on a 2011 purchasing power parity basis.[2]

There is a strong correlation between wealth and air travel demand.[3,4] The global air traffic is expected to sustain a long-term growth to 2040 and beyond.[5] To address this demand, new airports and route networks are needed. The new Istanbul Airport (IST) and Beijing Daxing International Airport (PKX) opened in 2019 and are intended to ultimately accommodate 100 to 200 million passengers per year. Last year, the Civil Aviation Administration of China declared aiming to add 216 airports by 2035.[6]

In the meantime, legacy hubs in North America and Western Europe such as Chicago-O'Hare (ORD), Dallas-Fort Worth (DFW), Paris-Charles de Gaulle (CDG) and London-Heathrow (LHR) will be opening new terminal complexes. Various legacy hubs will reach their maximum capacity sooner rather than later with increasing difficulty for expansion projects due to resistance in financing and environmental concerns. For direct intercontinental flights, they will face the competition of the Middle East airports still strategically located between Asia, Africa, and the Western hemisphere.

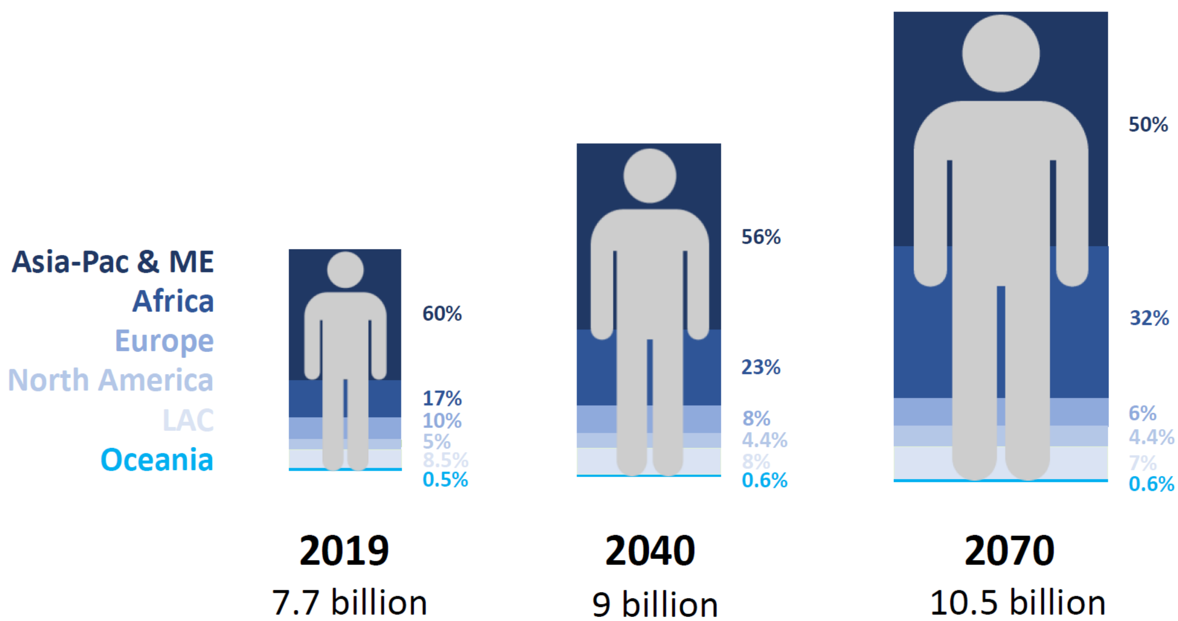

Figure 1-1 - 2019-2070 Evolution of the Worldwide Population

Asia-Pac & ME: Asia, Pacific, and Middle East. LAC: Latin America and Caribbean.

Source: World Population Prospects: The 2019 Revision (Median-Variant Prospect). United Nations, 2019

A Wealthier, More Democratic Society Open to the World

Civil wars are on the rise.[7] They deeply impact the communities and infrastructure, and force populations to move. Conflicts and overall security in several regions severely prevent the development of air service, isolating these countries further and depriving them of economic opportunities.[a]

Paradoxically, our world is becoming freer and more democratic overall – facilitating the emergence of more stable, open and inclusive societies. Since the beginning of the 20th century, the proportion of humans living in democracies have constantly grown. The last colonial administrations were repealed at the end of the years 1970. Interstate conflicts that have ravaged communities all around the world for most of human history are now on the verge of extinction.[8]

Regional integration and inter-regional agreements have been strengthening peace and mutual prosperity, and removed some international barriers to commercial aviation as well. Open sky agreements between countries combined with the liberalization of air transportation nationwide have benefited the industry and the customers by increasing the offer and lowering airfares. After Europe[b], Africa and Southeast Asia are on their way to become the next common aviation markets. The Single African Air Transport Market (SAATM) under the umbrella of the African Union should be operational by 2023. Completion of the ASEAN Single Aviation Market (ASEAN-SAM) is still struggling with opposition from members to grant third, fourth and fifth freedoms of the air to other member states.[9]

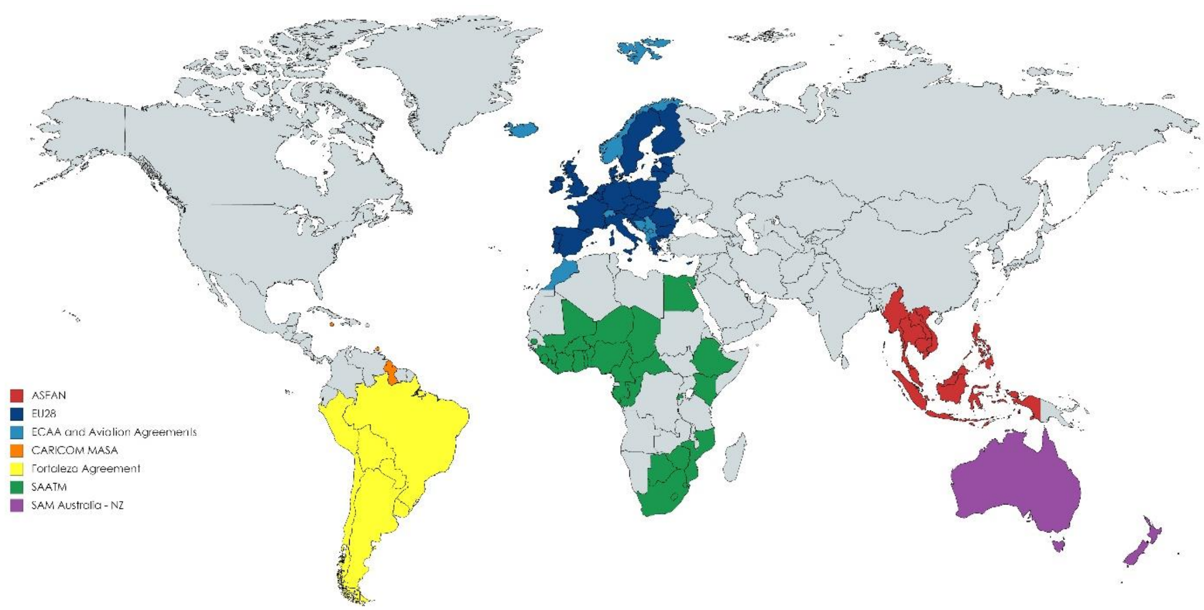

Figure 1-2 - Existing and Emerging Single Aviation Markets

Urban Civilization and Local Communities

The “last frontier” to the competition is the limitations on foreign ownership and control (O&C) of domestic air carriers. In most countries – including the U.S. and E.U., foreign entities cannot control more than 49% of a domestic air carrier. Airlines such as AirAsia and FastJet are getting around current restrictions in Southeast Asia and Africa respectively by creating affiliates under the same branding in different countries, in partnership with local investors, creating a de facto liberalization. In 2019, Brazil

[a] While the U.S. is a top trade partner and origin of foreign tourists for Kenya, further development was limited due to the absence of direct flights. Delta Air Lines briefly operated direct flights before suspending operations over security concerns. Kenya Airways started flying to JFK in 2018.

[b] The European Common Aviation Area (ECAA) allows any airline incorporated in a member state to operate between two airports within the Area – a key to the success of pan-European air carriers such as EasyJet and Ryanair.

repealed limitations on foreign O&C.[10] The same week, Grupo Globalia (Air Europa) applied to operate domestic flights in Brazil.[11] Norwegian Air – already operating domestic flights in neighboring Argentina and international flights to Brazil – has expressed interest. Further liberalization could offer new air service opportunities for countries with weak national air carriers – but also the prospect of further concentration of the offer with mega-mergers between European, North American and Asian air carriers.

About 55% of the worldwide population already lives in urban areas. This percentage will grow to 68% in 2050. In the United States where 82% of the population is already urban today, 11 "megaregions" of higher urban density might appear by 2050[12]. By the end of the century, the 5 most populated metropolitan areas will be in Africa and India each one with over 55 million inhabitants[13] – only one is part of the top 5 today. The growth of megalopolis will create challenges in mobility but also give birth to new aviation megacities. Emerging mobility such as autonomous vehicles, new underground transportation modes, and urban air mobility (UAM) are promising answers to the question of connecting these airports to their metropolitan area. The large footprint of megacities and the congestion on the ground might promote multi-airport systems and secondary airports.

At the same time, smaller and rural communities will still represent a significant population, and some of them might revive or grow with citizens and workers looking for another way of life and a lower cost of living. The dissemination of information and intelligence technologies, autonomous modes of transportation, and new production processes could fill part of the gap in attractivity of these communities with enhancing accessibility to goods and services, and their connection to the world as well. The market share of regional airlines and commuters has grown over the past decade. Local airports will continue to play a vital role in connecting smaller communities and regional hubs to the world. Point-to-point flights between regional cities will also play an important role in the future, complementary to one of the major hubs and helping to economically and socially develop some regions.

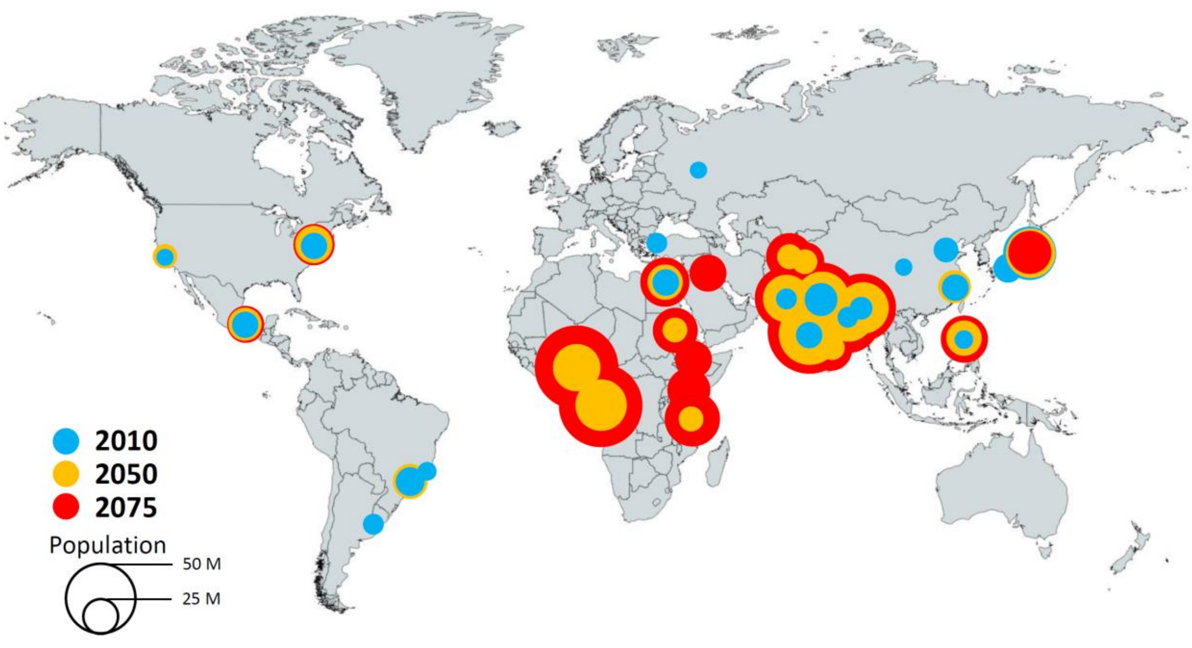

Figure 1-3 - 20 Largest Metropolitan Areas from 2010 to 2075

Source: Hoornweg, D. & Pope, K. Population predictions of the 101 largest cities in the 21st century. Global Cities Institute, 2014

The megacities of the emerging world do not want to be considered as the low-cost manufacture and the landfill of the world anymore. Indonesia, Malaysia, and the Philippines are refusing deliveries of western trash.[14] The P.R. of China has been encouraging economic development in higher technologies. Wages are increasing in developing countries. Carbon taxes on transportation are in discussion. Producing on the other side of the world is not as profitable as it was. At the same time, workers of western nations ask for relocating production and jobs. A growing number of consumers buy locally and call for a circular economy. The *relocalization* of the production of goods and its decentralization to more local sites fostered with a revolution in tooling and industrial processes (e.g. 3D printing) can deeply impact the flows of freight worldwide – including air cargo.

Climate Change

The correlation between human industrial activities and global warming has been widely documented since the years 1960. The Intergovernmental Panel on Climate Change (IPCC) of the United Nations stated in October 2018 that "limiting global warming to 1.5°C would require rapid, far-reaching and unprecedented changes in all aspects of society".[15] Current policies and effective actions all around the world are mostly behind the goals[16] set in 2015 during the United Nations Framework Convention on Climate Change – also known as the Paris Agreement[17]. It is likely that significant impacts on ecosystems, human health, and well-being will occur over the coming decades – some of them are already happening.

While the best warming is the one that we do not generate, airports (and the world) will have to adapt in order to emit less, but also to be more resilient facing the consequences of climate change.[18] Consequences will vary depending on geography and will range from coastal airports more often threatened by flooding hazard to inland facilities impacted by higher temperatures penalizing aircraft payload. Additionally, climate change can already be observed by means of an increase in extreme weather events[19,20] accompanied by disruptive effects for en route and airport turnaround processes. These changes will impact many aspects, if not all, of airport management and operations, increase both capital expenditures and operating costs, and result in more frequent adverse weather conditions.[21]

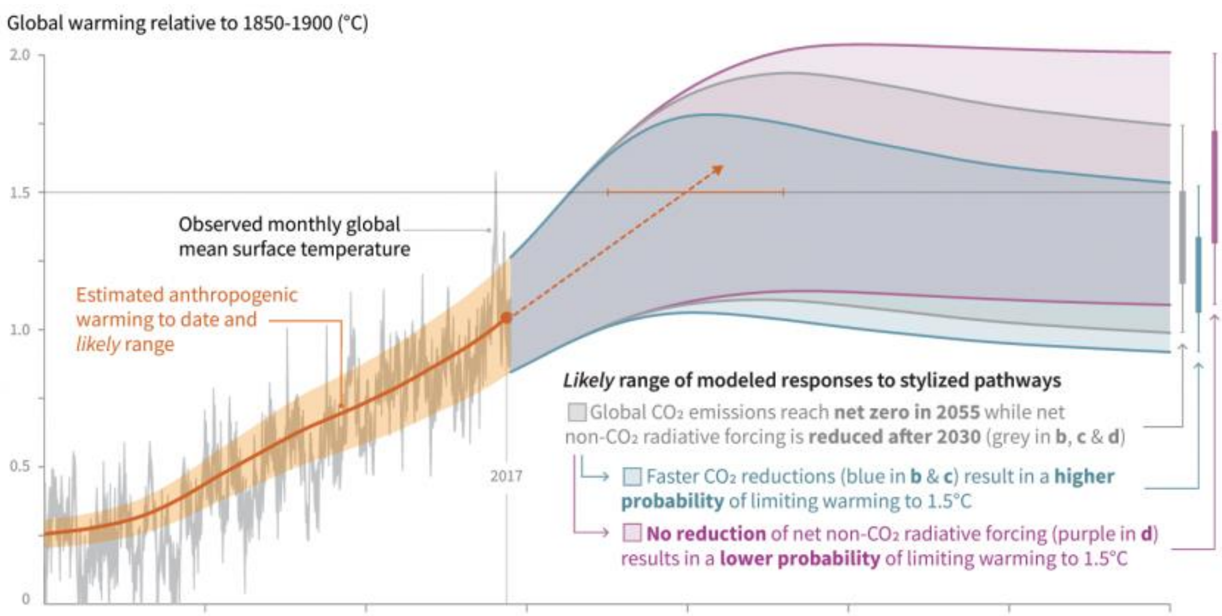

Figure 1-4 - Observed Global Temperature Change and Modeled Responses to Stylized Anthropogenic Emission and Forcing Pathways

Source: Summary for Policymakers, Global Warming of 1.5°C, IPCC, United Nations, 2018

Facing the most challenging threat of human history, airports and the aviation industry in general will continue their unprecedented effort to lower their environmental footprint. Accounting for 2% of greenhouse gas emissions, the aviation industry commits to an average improvement in fuel efficiency of 1.5% per year from 2009 to 2020, to a carbon-neutral growth from 2020[c], and to a reduction in net aviation CO_2 emissions of 50% by 2050 relative to 2005 levels. Today, nearly 50 airports are certified carbon neutral per the ACI World Airport Carbon Accreditation program[22]. Several airports go beyond and have aggressive plans toward more direct carbon emission reduction – sometimes in line with broader local or national policies. In June 2019 at the ACI Europe Annual Congress & General Assembly, the airport trade body unveiled a Resolution formally committing the European airport industry to become net-zero for carbon emissions by 2050, at the latest. Still, a "plane-bashing" movement has developed in Europe supported by lawmakers advocating for banning short-haul flights. Our industry must change, but we shall do more by educating citizens and deciders on what aviation accounts for, what it brings to society, and what it is doing for contributing to the global effort.

Generational Bridge or Generational Gap?

We live longer than ever. Life expectancy is improving worldwide. Fertility rates are decreasing. The population will continue to include a growing number of 60+ members – they will be 2 billion by 2050, healthier and wealthier than their forefathers. It will require societies to think differently, be always more inclusive, and design our world – including transportation – accordingly. Japan leads the way in this domain with a population aging earlier than any other country – more than a third of Japanese are 60-year-old or beyond.

At least half of the generations of passengers of the years 2040 and 2070 are already born. While the 60-year-olds of 2040 grew in a period of relative prosperity and optimism, the 30-to-50-year-olds will have spent their childhood in the post-9/11 era, the Great Depression and the aftermath of the COVID-19 crisis. How will that affect social psychology? Are we going to observe a generational shock?

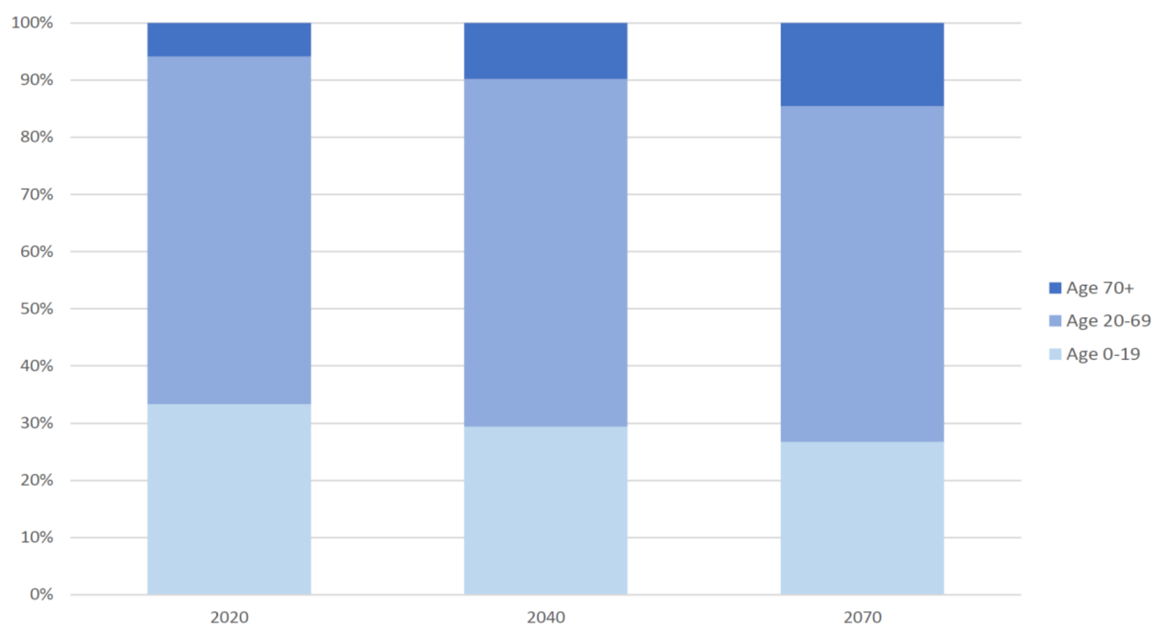

Figure 1-5 - Projection of Age Distribution from 2020 to 2070
Source: World Population Prospects: The 2019 Revision (Median-Variant Prospect). United Nations, 2019

[c] This objective considers compensation mechanisms such as ICAO's Carbon Offsetting & Reduction Scheme for Intl. Aviation (CORSIA).

Children born after 2000 grew up with new technologies. Hyperconnected, the communities of 2040, and furthermore 2070 will not have the same notion of time and space. Adults spend about 6 hours every day in front of an electronic device – half of it on their mobile phones, about the same with a computer. 50 years ago, the news used to take days to reach out to the world and they were dispensed by source considered as authoritative. Acquiring knowledge required to pursue a degree or find a library with adequate books of reference. Paper-based-only bureaucratic processes were taking weeks and months. Information provided by institutional media was curated and verified by professional journalists.

Today, internet users have instant access to more materials than they can ever read in their entire life. Lectures from the best experts are available online for free. At the same time, information is instantaneous – but less often verified. Fake news is spreading – and sometimes spread out on purpose. Waiting in a line is not acceptable anymore. Passengers want immediate achievement of their personal expectations. Full transparency of fares and rules, simplicity and instantaneity of processes, dematerialization, and automation of bureaucracy, no waiting line at all anywhere, personalization of the airport experience at any step are among emerging expectations of passengers that the industry shall satisfy. At the same time, surveys show that 55+ passengers want to keep human interaction in the loop[23].

A Brighter Future Ahead Shall Not Make Us Forget Present Responsibilities and Coming Challenges

Over the decade 2010, oppressed communities showed exceptional resilience and resolution. They do not hesitate anymore to take the streets to topple dictators confiscating democracy. At the same time, in most of the developed and developing world, various movements seem to rebuke the model of liberal democracy built over the 20th century and winner of the Cold War. While 2019 is observing low-unemployment in the Western world, many of its citizens ask for more social justice and transparency, and protest over nation-specific issues as well. They challenge and doubt institutions that promised to deliver freedom and progress for all after the post-Cold War democratization. In a recent survey in South America, less than 25% of respondents declared being satisfied with democracy in their country, and less than 50% of them prefer democracy to other forms of government – the lowest rates since 1995.[24]

Some want a more participatory democracy – or at least a better representation of their aspirations. Others do not want to be the forgotten of the unprecedented improvements our society is experiencing. Some call for more social and environmental justice while others seem to proclaim a new world of individualism. The fear of others competes with those of extinction. While the world is getting better overall, they remind us of all the paradoxes that we need to address at this beginning of the new millennium.

To keep "flying with us" the best experience on Earth and provide to humanity safe, efficient, and reliable air transportation infrastructure, the airport industry and its stakeholders shall adapt to future challenges and address in a sustainable way the expectations of the passengers, the neighbors, and the citizens.

Topic No. 2: Sustainable Business Models and New Sources of Funding

Toward More Independent Airport Operators

During most of the 20th century, airports were planned, built, and operated by central governments as tools of sovereignty, prestige, national defense, and territorial development. Over this period of economic interventionism, airports were entrusted to ministries and National Aviation Authorities (United Kingdom, 1923-1965; Malaysia, 1969-1991), and public agencies (India, 1972-1995) or public companies (Brazil, 1973-Today[d]; France, 1945-2005; United Kingdom, 1965-2006).[e] In the years 1980 to 2010, countries where airport operators were within the same body than the safety oversight functions and the air navigation services organically separated them from the latter (Finland, 1991). In the context of growing ancillary activities and capital expenditure, they were then turned into organizations created for the purpose of operating airports, often with a private corporation status and state-ownership.

This move toward more independence promotes a culture of efficiency and a strategic vision, establishes the autonomy of decision from other national priorities, and enables the airport governance itself to be more independent from political agendas. Also, this change ensures an independent oversight and economic regulation of airports by the governments.

Today, while airport ownership is mostly retained by central or local governments around the world, operations are increasingly transferred to or contracted with airport management entities. In Canada, airports are leased by the Federal government to non-for-profit airport authorities. State-owned private companies operate airports in Northern Europe and Southeast Asia. Public agencies or companies remain still a popular model in Africa, Middle East, and Central Asia. Many of them are changing business model with concessions (Infraero, Brazil), partial privatization of individual airports (GACA, Saudi Arabia), or other Public-Private Partnership (PPP) (Tanzania Aviation Authority).

Because of history and local specificities, some larger public or semi-public entities still manage airport systems. Most of the U.S. airports are managed by city or county departments. The Port Authority of New York and New Jersey (PANYNJ) is a body controlled by two U.S. states – or interstate compact – created for developing and operating vast transportation assets and real estate – including EWR, JFK, and LGA. The Alaska DOT owns and operates a unique state airport system comprised of 239 facilities – the majority of them providing a vital infrastructure to connect remote rural areas.[25] The Departamento Aeroviário do Estado de São Paulo (DAESP) operates about 30 smaller airports within the State of São Paulo, Brazil. Five of them are operated under a PPP (management contract), and the State of São Paulo intends to privatize the remaining facilities in the coming years. Created as a statutory authority in 1994, the Airports Authority of India (AAI) operates 126 airports and still provides CNS and ATM services as well.

Privatization and Global Competition

Airport privatization might be seen as the next step of state-owned corporatization, but can actually take different forms – concessions of the entire airport, Built-Operate-Transfer (BOT) and Design-Build-Operate (DBO) of individual facilities (e.g., passenger terminal), etc. There are privatization projects in virtually all the regions of the world. Public control of airport management is not considered anymore as a necessity for national interests, and private operators are seen as more versatile, cost-efficient, and innovative. Therefore, governments can focus on its role of market regulator and safety/security oversight.

[d] The legacy public operator Infraero still operates airports but has transferred the management of the largest commercial service airports to private joint ventures under Federal long-term concessions. As of 2019, more than 50% of passengers and more than 80% of air cargo fly privately operated airports in Brazil. By the end of 2023, it will be the case of over 90% of passengers & freight.
[e] The United States is a noticeable exception with a transfer of these assets to local governments after World War II.

While separation with NAA can provide better overall governance, privatization is a more radical move out of state-interventionism in transportation with benefits, but also consequences that should not be neglected.

In the United States, few airports are privatized per se: San Juan Luis Muñoz Marín International Airport (SJU) is the only airport successfully transferred to a private operator through the FAA Airport Investment Partnership Program (formerly known as Airport Privatization Pilot Program).[26] Orlando Sanford International (SFB) is operated by a private firm through a joint-venture with the Airport Authority. Branson Airport (BKG) in Missouri is the only privately-owned and developed commercial service airport in the United States. However, U.S. airports are more privatized than it appears. Several terminal buildings have been developed and funded by air carriers and various forms of Public-Private Partnerships (PPP) exist. LaGuardia Gateway Partners (LGP) is redeveloping and will operate the Central Terminal B at LGA under a concession with PANYNJ.

In Europe, where privatization occurred first, former public operators grew into horizontally integrated groups seeking international expansion – AENA Aeropuertos, Changi Group, Fraport, Groupe ADP, Schiphol Group. Hub airports in Asia and the Middle East have relied for decades on expertise from leading western firms to bloom. Today, these organizations are gaining in maturity and experience. They are constituting their own design bureau and project management offices. Will they get full independence from their government – facilitating their entrance to new markets? Will they compete with already well-established groups on concessions abroad?

Ownership of airports themselves is a question because they were originally developed with taxpayer money and because of their massive implications on territorial development and connectivity. Because they benefit and impact first their community, countries have transferred full ownership of smaller airports to local administrations (France, 2005[27]). Groupe ADP, Heathrow Airport Ltd., or Fraport have control over the infrastructure and land. In the United States, the Federal government does not own civilian facilities[f] that were turned to cities and counties after World War II through the Surplus Property Act of 1944. Retaining ownership and signing concessions, Build-Operate-Transfer, or Design-Build-Operate ensure the continuity of operations and facilitate transfer to another firm – a choice that Brazil has made. Canada, where the Federal government owns airports and gives concessions to non-for-profit operators, has been considering "privatizing" (selling) these assets to private operators. Studies were suspended in 2018 with strong opposition from both airports and air carriers. The future will see more diversity in ownership, with local, private, and perhaps at some point foreign ownership.

Table 2-1 - Evolution of Airport Ownership and Management

Yesterday (20th Century)	**Today (2000-2020)**	**Tomorrow? (Toward 2070)**
Airports operated by govt. State-monopolies National assets Policy-driven offer *Airports are public assets operated by Dept. of Defense or Transportation. Offer is largely piloted by govt.*	More airports operated under PPP Little competition between operators Govt. ownership of infrastructure Market-driven offer *Former public airport operators team with investors for finding external growth with concessions.*	PPP and Authorities are the norms Global competition between operators Local, private & foreign ownership Market-driven offer *Open competition between airports. Secondary airports capture more point-to-point markets.*

[f] With very few exceptions such as Atlantic City Intl. Airport (ACY) with most of its land owned by the FAA and leased to the South Jersey Transportation Authority (SJTA).

Economic Viability of Private Operators

Airports compete on larger catchment area over costs, connectivity, and level of service.[28] However, airports are locally monopolistic businesses, even in metropolitan areas served by multiple aviation facilities such as London. Because of their footprint and cost, they cannot fall under the characteristics of a fully demand-driven, oligopolistic market. In other words, a competitor cannot build a new airport nearby another for expanding the offer. Consequently, the central administration provides economic oversight and regulates airport operators by creating an adequate framework. Most of the time, airports agree with their stakeholders under the umbrella of an autonomous regulating body on the airport charges and short-term investments through pluriannual plans or contracts of economic regulation. Profit margin is sometimes a substitute for a cap on airport charges.

Commercial service airports shall be allowed to adequately fund infrastructure maintenance and realistic development through their charges as they can no longer rely on direct public funding. Airport concessions and other PPP shall ensure benefits for both sides, and a fair distribution of profit and financial burden as well. High expectations on infrastructure development not consistent with the actual level of traffic can challenge the financial viability of airports requiring vast capital improvements as shown with the bankruptcy of ABSA, the consortium operating Viracopos International Airport, Brazil, in 2018.

Experience shows that larger airports need to generate an acceptable profit to fund their infrastructure without cash inflows. In Europe, airside facility improvements are mainly funded through aviation facility charges negotiated regularly with the airlines under the umbrella of an independent body for matching 5-year capital improvement programs. Passenger terminal buildings are generally paid with money borrowed to banking institutions or public investment banks such as the European Investment Bank (EIB). PPP can be an option building and operating as well (JFK Terminal 4).

These considerations do not necessarily apply to smaller airports. Their financial equilibrium is more often precarious. While some of them might not appear as profitable, their impact on the local economy and connectivity has to be considered too. Brazil is experimenting with an innovative approach with the privatization of secondary airports through regional packages of individual facilities of different profit prospects. However, several remote aviation facilities provide vital access to the world for air taxi, air ambulance, and subsidized air routes. They will remain public and require direct public funding. They cannot be profitable and are not intended to be.

Supporting Airports Modernization and the Development of National Infrastructure

Several programs exist around the world to ensure airports are safely developed and meet the needs of the nations. Their form and extent depends on the size of the airports and their local specificities. In the United States, the Airport Improvement Program (AIP) finances up to 90% of eligible projects that enhance capacity, safety, or security at airports of national interest. This program is funded by taxes on plane tickets and aviation fuel. In Canada, the Airports Capital Assistance Program (ACAP) specifically assists regional airports in funding their infrastructure. In Switzerland, safety upgrades are eligible for grants from a national transportation fund. In Brazil, mechanisms exist to support smaller airports serving local communities. However, several of these programs show their limits with available funding not meeting the overall need anymore – leading to stricter criteria or tighter policies.

Also, these funds usually exclude terminal facilities from grants. How to rejuvenate and develop this infrastructure without massively increase the debt ratio or involve air carriers? In several countries, public investment banks can lend money at lower interest rates for this purpose as long as the operator is based in the country (BNDES[29], EIB[30]). In the United States, while bonds have been a major source of funding, new strategies emerge. For instance, Paine Field, in the Washington State in the United States has entrusted private interests to develop and operate the new terminal passenger building. In developing countries, regional banks (African Development Bank) or the World Bank can support large infrastructure projects. In every case, airport operators and local governments shall carefully balance the opportunities created by these projects and their level of financial risk to prevent placement under receivership (Ciudad Real Central – CQM, Spain, 2012), waste of taxpayer's money (Castellon), and incapacity of repaying debt (Sri Lanka). Good management, a realistic business model, a resilient strategic vision, and robust business partners are important factors to the long-term success of airports.

Airports are usually safe long-term investments praised by banking institutions, hedge funds, and other investors. Grants are often more controversial and might not always be understood by taxpayers. The U.S. and Canadian examples are interesting, as their national airport funds are based on charges on aviation users only (ticket or aviation fuel). The fundamental principle is that "aviation shall pay for itself". Indeed, direct injection of public money coming from the general budget of a state raises legitimate questions on national priorities – especially when projects are not profitable nor necessarily justified from a social profit perspective. Concessions to private operators of infrastructure developed with public money also raise the question of a fair return on investment to governments.

Governmental support and economic relief might be needed during periods of exceptional calamity. The 2020 COVID-19 pandemic is an example of what a prolonged, forced period of slowdown in air traffic can do to the treasury of airport operators. Airports should be reasonably and momentarily supported through government loans and other mechanisms to ensure that operators without pre-existing conditions of fragility stay afloat, and that necessary investments are conducted in order to maintain the infrastructure and develop the capacity for meeting the future demand and accompany the recovery. Similar considerations should be given to the stakeholders – fixed-base operators, repair shops, ground handling service providers, small businesses, contractors, etc.

Funding Innovation: The Vital Role of Governments and Institutions

Investing in innovation is crucial not only for the industry but for the air transportation ecosystem entirely. Some larger airport operators have the ambition to be leaders in innovation. San Diego (SAN) invites innovators to test their technologies with its Innovation Lab. Groupe ADP has invested in different start-ups (e.g., Safety Line, Innov'ATM) and has various initiatives to promote innovation such as the Airport Startup Day and the Play Your Airport challenge. Avinor is the national coordinator of the electric aircraft roadmap of Norway. ACI and IATA are exploring together the future of airports with NEXTT.

However, the groundbreaking trends and transformational changes that will be explored further in this paper require wider efforts supported by national policies and funding. NextGen in the United States and SESAR in Europe intends to prevent bottlenecks in the airspace at the 2025 horizon. Similar programs of airspace modernization are now following worldwide under the guidance of the ICAO GANP (e.g., Sirius in Brazil). The step beyond will be the rise of automation and will need similar efforts for developing and implementing artificial intelligence and machine learning technologies that can assist further pilots and controllers (e.g. RECAT-3), and even provide decision-making without a human in the loop when needed (e.g. Urban Air Traffic Management). Other topics such as cybersecurity or generational inclusion might need similar initiatives and shall be identified as soon as possible.

During the 2019 TRB Annual Meeting, State Departments of Transportation warned the audience on the lack of skills and means they foresee with emerging challenges such as UAS, cybersecurity, etc. Institutional leadership is much needed, especially with smaller airports and local agencies that cannot have specialized staff and fund research projects. It will require adequate education from universities and a change in agency staffing or outsourcing. Globally, international institutions and especially ICAO, will need to provide guidance and standards to operators. ICAO regional coalitions and global plans will help with implementing these standards and leveling up the less developed countries.

Beyond governmental action, coalitions of airport professionals under the umbrella of aviation institutions have proven themselves as a powerful source of innovation and knowledge. The Transportation Research Board in the United States has produced research studies and practice-ready materials beneficial to the industry beyond the U.S. borders. Regional airport associations are roundtables for sharing expertise between airports of all sizes, and providing support and representation to smaller airports that cannot afford a large staff. The French-Speaking Airport has released innovative recommended practices and practice-ready materials that later became industry standards on topics not covered by the regulations. Specific associations such as NFPA are normative bodies in their domain.

Topic No. 3: Smart Airports at the Era of Information Technologies

Smartphone Applications and Biometrics Enhance Passenger Experience

The information technology revolution in the passenger journey is already here. Passengers are exchanging data with and get personalized information from airlines and airports via their smartphones. From mobile applications, it is already possible to check-in for a flight and get an electronic boarding pass – that once were entirely relying on physical processes at the airport. Several airline applications now offer to perform more complex operations such as purchasing a ticket or changing flight instantly. Transactions can often be confirmed with the fingerprint. Airports too have their own applications. They can send pop-up alerts on flight status and remind the location of the parking spot. They are also supporting the new frequent flyer programs of airport operators – a new trend already available at Paris-Charles de Gaulle (CDG) and Paris-Orly (ORY), London-Heathrow (LHR), San Antonio International (SAT) or Singapore-Changi (SIN). They provide several services – some of them being real-time and georeferenced.

Passengers with their smartphone can interact with their environment when walking in the terminal. Bluetooth « beacons » and NFC tags share personalized commercials and special offers based on location and preferences. Miami International Airport (MIA) has installed more than 400 Bluetooth beacons in the terminal. These connected technologies provide georeferenced information and can facilitate the journey through large hub airports, improving accessibility to travelers with difficulties to find their way. These innovations, along with others such as augmented reality (AR), holograms and robots, are particularly relevant to enhance wayfinding for people with special needs – including a growing number of 60+ travelers. It is also of great help to passengers who do not read foreign languages available on the signage, providing electronic wayfinding in their mother tongue. For instance, the Paris Aéroport application provides contents in French, English, Spanish, Russian, Simplified Chinese, Cantonese, Japanese, Korean, German, Portuguese of Brazil, and Italian as well.

In return, these tools of the Internet of Things (IoT) provides the airport operator and other stakeholders with precious information on passenger flows. It is even possible to do so without a dedicated infrastructure. French startup Smart Flows has developed a flow metering solution based on public Wi-Fi connections and models calibrated depending on local habits.

Exiting the terminal is not the end of the journey for passengers. They use applications from the local transit agencies[g], taxi companies, and Transportation Network Companies (TNC) for the last miles to their destination. Airports are exploring options for connecting their applications to provide a unique portal of services and mobility to and from the airport. Such tools could compare transit times and costs, increasing transparency on price and competitivity between modes. At the 2040 horizon, these same tools might offer travelers the opportunity to pre-order an autonomous or connected vehicle (AV/CV), or an air taxi – the cost and accessibility of Urban Air Mobility (UAM) may be available to a larger public in some metropolitan areas as soon as 2025.

Airports and air carriers have deployed facial recognition to simplify the passenger journey. For instance, Delta Air Lines uses facial recognition devices at Hartsfield-Jackson Atlanta International Airport (ATL) to verify the identity at the gate when boarding international flights instead of scanning boarding pass and checking passports by hand. This expedites the process and minimizes the boarding time. By 2040, biometrics will be available at other steps of the journey from the curbside to the gate. Fingerprints and facial identity might be the future "keys" to your flight. In 2018, SITA presented a suite of solutions for check-in, bag drop-off, and boarding using the same biometric database. In the medium-term horizon,

[g] Transit agencies are implementing "tap-to-pay" solution to pay rides with a smartphone (e.g. Chicago, New York and Portland).

these solutions will reduce waiting times and will increase the automation of control and identification processes, along with other technologies such as the self-service bag drop-off kiosks. These kiosks already equip airports around the world and they might promote decentralized, accessible and easy drop-off services outside of the terminals (e.g. train stations, parking garage, curbside).

Crossing a border without having a passport checked by a border agent is a reality. For instance, the French PARAFE program launched in the years 2000 is available at Paris-Charles de Gaulle (CDG), Paris-Orly (ORY) and Marseille-Provence (MRS). Passengers from the European Union with a biometric passport can present this document at the entrance of a automatic gate, and then confirm their identity with fingerprinting and facial recognition. In the United States, the Global Entry program offers a similar service at 75 international airports – some outside the U.S. For passengers who did not subscribe to Global Entry, Mobile Passport Control (MPC) allows to perform the operations preceding the physical control of passports by an agent of the Customs & Border Patrol (CBP), from a smartphone. Screening is on the verge of significant changes as well. The U.S. Transportation Security Administration (TSA) is working with the industry on developing the next generation of checkpoints with expedited processes for the most trusted travelers (see Topic No. 4 on security).

Information and Intelligence Technologies are Revolutionizing Airport Operations

Building Information Modelling (BIM) is already widely used in terminal design and construction. Airport BIM is coming to the landside and airside for operations purposes as well. Continuing the digitalization of information initiated with Airport Geographical Information Systems (AGIS), ABIM will open a new perspective to asset management and airport operations. As Airport GIS was an important element in the implementation of Pavement Management Systems (PMS), ABIM can enable a new world of collaborative tools and be the vehicle of Asset Management Systems, Integrated Operations Management Systems, etc. that could benefit from the merger of these databases.

The last generation of Airfield Ground Lighting (AGL) systems are monitored and driven from control centers that can verify the status of each light individually. The status of aviation pavements (runways and taxiways) during winter conditions can be monitored too with sensors, facilitating the management of snow removal and pavement deicing. By combining pavement monitoring and weather forecast, it is possible to proactively develop strategies anticipating adverse weather conditions hours before they happen – another domain where machine learning (ML) and artificial intelligence (AI) could open new doors. Radars and cameras are already capable of detecting Foreign Object Debris (FOD) on the runways. Using data from the air traffic control radars – and perhaps tomorrow's data sharing with the aircraft, it is possible to deduct the deceleration profile of aircraft on the runway, detect abnormal patterns, and identify loss of adherence on the runway or unsafe flight operations procedures or practices.

In Sweden, air navigation services at Örnsköldsvik Airport (OER) have been provided since 2015 from Sundsvall–Timrå Airport (SDL) – 125 km away – using a Remote Tower (rTWR) system. rTWR works with locally-based sensors, a secure datalink, and a virtual air traffic control environment (virtual reality). Remote Tower Centers (RTC) will increase safety at airports with low-intensity traffic that are or might become non-towered, or with AFIS only (2020-2040). Moreover, the technologies developed for the RTC might bring augmented reality, enhancing air traffic control, increasing safety and resilience at "conventional" towers (during construction works and low-visibility procedures for instance). The next step might be more automated air traffic control. The emergence of Urban Air Traffic Management (UATM) that will advance automation in air traffic management could be a decisive factor in the development of the needed innovations (2040-2070).

Airports manage flows of passengers, aircraft, bags, and vehicles. Their waiting time and outflow are the parameters of its efficiency. From the moment the aircraft is at the gate (In-Block Time) to its pushback (Off-Block Time), the turnaround time (TRT) shall be monitored to ensure the aircraft leaves on time. Ground handling operations involve several functions and different stakeholders that need to be coordinated and supervised. Information technologies radically changed this work. At large airports, coordinators overseeing multiple flights from a control center in communication with field supervisors – increasingly equipped with smartphones or tablets for communicating with operations management solutions. Decision making on a flight does not rely anymore on individual visual information only but is assisted by real-time indicators shared with the stakeholders and providing a broader view on the impact of delayed individual tasks on the performance of the entire flight and of hub operations more generally.

This facilitates the overall management of performance and communication to the Operations Control Center (OCC) of the clients (air carriers). These ground operations control centers tend to be similar in their organizations and equipment – e.g., the Hub Control Centers (HCC) of Air France at Paris-Charles de Gaulle (CDG) and AeroDarat at Kuala Lumpur International Airport (KUL) are comparable. Such organizations require information systems and connection to other stakeholders' systems – especially under Collaborative Decision Making (CDM) agreements or similar integration. The next step in ground handling operations at large hub airports might be the introduction of machine learning and artificial intelligence to perform real-time and post-operations analysis, detect patterns creating delays and providing assistance to decision-making to the coordinators.

Smart Airports Are Connected to the Field and to the World

The need to increase punctuality and minimize the impact of adverse conditions on flight operations led to Airport Collaborative Decision Making (A-CDM). This concept relies on information sharing between the stakeholders of the real-time status of each flight – defined with "milestones" (defined moments on the timeline of a flight). Each stakeholder is responsible for updating specific milestones – for instance, the ground handler with the Target Off-Block Time (TOBT), which is the expected moment the flight will be leaving the gate. A software solution typically consolidates these inputs and delivers takeoff times. With A-CDM, the airport community including the Air Traffic Control, can work with target times that take into consideration the reality of the field instead of theoretical estimates. Reducing uncertainty and increasing transparency make operations more efficient and resilient.

The extension of the Collaborative Decision Making (CDM) concepts to the whole airport is called Total Airport Management (TAM). TAM provides a holistic approach to real-time airport operations, from the curbside to the air. Such a concept is supported by Airport Operations Centers (APOC), integrating the various functions of airport operations (including external stakeholders). It is connected to the entire airport ecosystem – from the crews in the field to the regional ACC as needed. APOC can be seen as a center of anticipation, supervision and decision bringing together all the stakeholders of airport operations – including air carriers, airport operators, air navigation service providers, apron management service providers, ground handlers, transit agencies, law enforcement, and immigration forces, etc.

Together, they monitor flows and capacities in real-time, plan and anticipate for the next days, and react to prevent adverse conditions to turn into a crisis. In their task, they are assisted by imagery provided by CCTV, and data gathered by sensors in the field. More important, they shall rely on agents in the field – sensors cannot address operational issues alone. The acting staff should be connected to their supervisors under the authority of the Airport Operations Manager. A-CDM and APOC empower the Airport Operations Manager and his team as they lower the monitoring workload, assist decision making with key performance indicators, and provide them with powerful C4I (Command, Control, Communications, Computers, and Intelligence) tools to manage the airport proactively with a comprehensive view of its operations, instead of reactively with a focus on one specific issue. A-CDM and APOC implementation are objectives of the ICAO 2016-2030 Global Air Navigation Plan (GANP).

At a broader scale, the System Wide Information Management (SWIM) that is being implemented in North America and Europe will provide unified platforms and standards for information-sharing in order to provide a single point of access to ATFM data. SWIM will provide an information-centric system to support ATM modernization programs such as NextGen and SESAR. As part of ICAO's GANP, it will enable and facilitate a worldwide exchange of real-time information, and connection to a new wide range of applications and users. Today, the Air Navigation Service Providers (ANSP) in Europe (Eurocontrol), the United States (FAA), Brazil (DECEA), and the United Arab Emirates (GCAA) already exchange flight data in real-time – prefiguring worldwide exchanges at the 2040 horizon.

Deep Automation and Blockchain Could Drive a Second IT Revolution

The collection and treatment of such volumes of data require adequate standards and infrastructure for supporting their transfer and storage. Most commercial airports now have data centers. They will be fed by the Internet of Things (and ultimately the Internet of Everything) supported by 5G infrastructure – and its next iterations. The data themselves have limited value for the airports and their stakeholders. Investing in big data should serve a purpose – and will depend upon the value added that could be extracted from these data. Emerging means and processes to analyze data are dramatically expanding the horizon of possibilities. Machine learning and artificial intelligence can extract patterns and trends from Airport Operations Data Bases (AODB) and other stakeholders- or function-specific database for planning, situational awareness, or decision-making purpose. Deep learning using artificial neural networks (ANN) and deep automation will be the next step and could assist, supplement, and even replace human analysis and decision-making in domains such as operational resource management and asset management. These intelligence technologies could provide analytics and direct assistance to decision-making with "what if" scenarios – a move from current practices similar to recent changes from reactive management mainly based on a visual assessment to a proactive organization basing decisions on indicators providing a broader vision of the field. Blockchain is another emerging technology based on cryptography that can help with securing the exchanges of information and facilitating approval/validation processes ("contracts") in a wide range of activities such as construction (document reviews, field inspections), operations (ground handling contracts, TOBT updates, aircraft recovery agreements) and regulation (airport certification, security clearances).

The airport industry is aware of the potential of information and intelligence technologies. The larger airports can and want to be at the front edge of this new revolution. San Diego, MWAA, and Groupe ADP have different strategies ranging from innovation challenges to intrapreneurial labs and even direct investments into startups.[31] In the long run, these technologies will be accessible to regional airports, and even general aviation airports with scalable solutions tailored for simpler facilities and lower traffic. Meanwhile, there is a risk for local governments, smaller airports, and the least developed regions of the world to stay behind. The industry shall work on closing the gap on information technologies as their dissemination will make the whole air transportation system more resilient. In the short-term, it is possible to be a connected airport for a fistful of hundred U.S. dollars. In 2015, the Executive Director of Tupelo Regional Airport (TUP) presented at the TRB Annual Meeting low-cost connected airport systems developed in-house and using the GSM network to send NOTAMs and pilot information by text messages to the pilot community, and messages on the status of emergency generators and fire suppression systems to the airport management.

As airports rely increasingly on information systems and data exchange, they become more vulnerable to any disruptions. Upon transitioning to new systems for supporting their operations, airports shall develop IT resilience and contingency plans for business continuity when they are down. They are also exposed to cyber-criminality and cyberterrorism. They shall consider their cybersecurity aspects. Data gathering and exchange through open or poorly protected networks create new opportunities for criminal organizations, individual hackers, and State-sponsored groups with hostile intentions to penetrate databases and endanger the integrity of networks and systems. Cybersecurity is now a hot topic worldwide in aviation. During the last Air Navigation Conference (ANC) of ICAO, nearly all the papers discussed included elements of cybersecurity.

Topic No. 4: Security Threats and Unlawful Activities

Existing Patterns of Terror Will Remain the Main Threat of Tomorrow

In 2017, then U.S. TSA Administrator Peter V. Nuffenger declared that “there is a spectacular nature to attacking aviation. First of all, it says something about you as a terrorist group if you are able to get through all the systems designed to prevent damage. But it also has a huge psychological impact and a very large economic impact”. This was true in 2017 and will still be applicable in 2040 and 2070.

The most common patterns have remained unchanged since the years 1970. Bombing the check-in counters or baggage claim and attacks with firearms by armed groups in the public area of passenger terminals have been used on multiple occasions. These modes of action maximize damages, casualties, and mediatic impact while they are difficult to prevent unless these efforts are identified prior to their action via intelligence and police investigation.

Early checkpoints filtering the access to the airport landside greatly perturb the flow of passengers, greeters, and workers without addressing the threat as they create bottlenecks that provide an easy target to terrorists. They are not relevant countermeasures. Vigilance from the airport community and awareness of passengers form the first natural barrier. Canine patrols specially trained for detecting explosives are an efficient deterrent inside the terminals at the most exposed airports as long as both the dog and the handler are adequately trained and comply with standard operating procedures.[h] The next evolution could be walk-through sensors at the entrances of terminal facilities. Microwave radars with machine learning are already in use at some casinos and banks. Strategically located at terminal accesses, they might constitute an early warning system for detecting weapons and explosives without slowing downflows.

In the years 2000, radicalized individuals started increasingly ramming cars into the public. Used for the first time against an airport in 2007 in Glasgow (GLA), it has then been involved in multiple non-airport mass murders such as in Nice, France in 2016. The most efficient strategy is the protection of the terminal curbside with reinforced bollards or blocks. Current bollards are typically able to stop 1.5 to 7-ton vehicles (midsize cars to medium trucks) at 50-80 km/h (30-50 mph).[32] Systems capable of stopping heavier trucks exist too.

While they are not an airport-specific phenomenon, active shooters are an emerging threat at airports. The first mass shooting by an active shooter at an airport occurred in January 2017 at Fort Lauderdale-Hollywood International Airport, Florida (FLL). They are perpetrated by mentally unstable or radicalized individuals (FLL, schizophrenia; ORY, under influence with suspicion of radicalization). These are the most difficult to detect as they are committed by motivated individuals who can stay “under the radars” of counter-terrorism and law enforcement until they commit their crimes.

The Risk-Based Approach is the Future

Airports shall never again be the access door to aircraft for terror organizations. The 1994 hijacking of the Algiers-Paris flight AFR 8969 by the Armed Islamic Group (GIA) can be seen as a prelude of the September 11 attacks seven years later. In the period immediately following 9/11, the countries the most targeted by jihadist groups and their followers took exceptional measures to prevent aircraft hijacking and bombing. Adjusted multiple times afterwards, these standards provide an efficient security

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[h] As long as both the dog and the handler are adequately trained and follow standard operating procedures. Research in the U.S. demonstrated that inadequate training or non-standard practices deeply degrade the performance of canine patrols.

net today. The number of hijacking from departing countries where they are implemented has plunged, and the aviation community is now better prepared to counter in-flight attempts.

As in aviation safety, the Reason's model applies in security. Adding layers of different measures and policies reduces the likelihood of an attack to be successful. Because terrorists – unlike safety issues – adapt to countermeasures and innovate as well, these security layers shall be versatile and evolutive. While they are already not the same from a region to another depending on local activities and global targeting of terrorists, they might not use the same layers from airport to airport in the future – depending on the reality of the threat. This risk-based approach is now promoted by ICAO. Per the Global Aviation Security Plan (GASeP) roadmap[33], nations should conduct their own security risk assessment, elaborate a national security plan from this assessment, and then refine locally and implement at the airports. We are moving toward a similar framework than in safety, with an international framework, national safety objectives, and certifications based on local specificities.

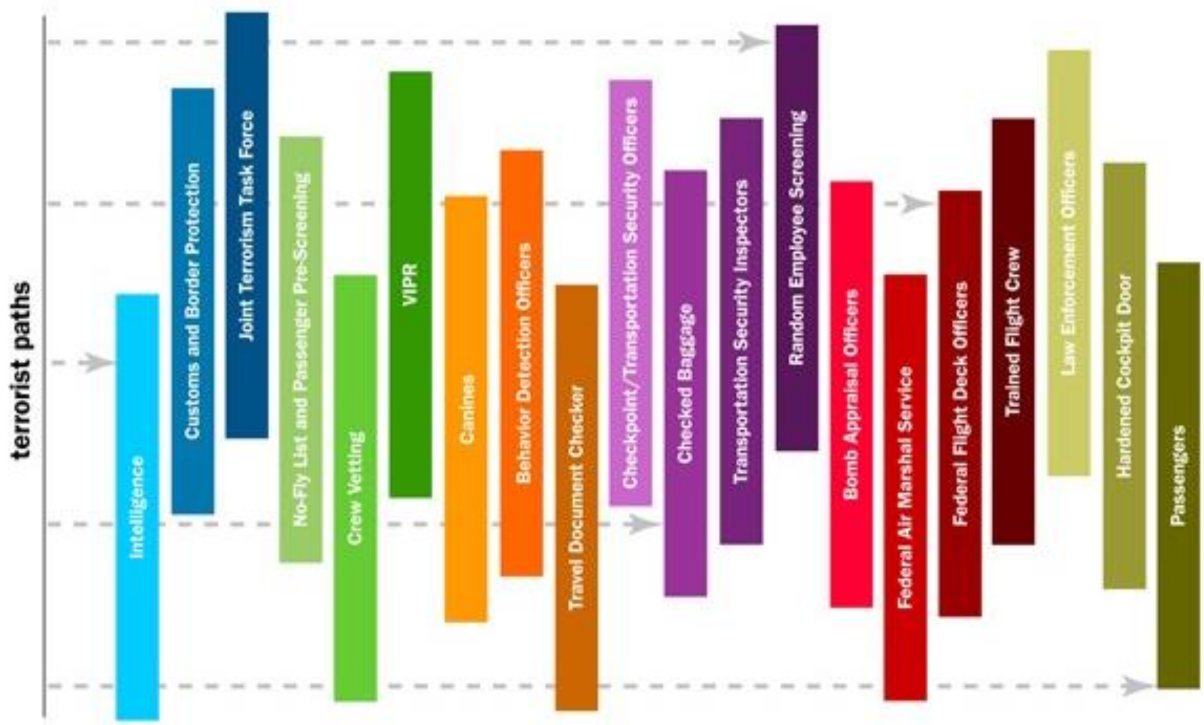

Figure 4-1 - Layered Security Approach in the United States
Source: U.S. Transportation Security Administration

While the post-9/11 measures intended to implement the same restrictive standards at all airports, it is now time – nearly two decades after the September 11 attacks – to reassess the threat and revise standards meet to future, long-term challenges. In the United States, the Transportation Security Administration (TSA) is designing the checkpoints of the future. TSA is considering introducing more pre-clearance levels to its Pre-Check program. Processes would range from the existing full-screening methods for the non-cleared passengers to a sensor-based walk-through concept with shoes and bag closed. Identification control could be expedited via biometrics. The goal of switching from a "100% screening" approach to smart and adaptive concept of operations is to increase capacity, lower operating costs, and reduce intrusion into the passenger journey.

Emerging Threats Require New, Specific Approach

Man-Portable Air-Defense Systems (MANPAD) have been used sporadically against civil aviation since the years 1970. Radical movements continue seeking their acquisition. Recently, the proliferation of limited but consistent stockpiles of these systems happened consecutively the 2003 war in Iraq and the 2011 Libyan civil war. These systems can be stored for long periods of time (up to 20 years) and reactivate them. Today, several hundreds of MANPAD units might be under the control of militias and terrorist groups. More than 50 strikes against civilian aircraft have been perpetrated, with about 30 of them accounting for about 1,000 fatalities. Since 2000, at least three civilian aircraft have been targeted in Eastern Africa and the Middle East. Such threats have cost these airports a delay in the development of air services. A 2005 study from RAND Corporation evaluated the potential economic damage beyond 16 billion USD if an attack was conducted in the United States. While airports are not currently equipped with active counter-measures, some airlines have decided to equip aircraft flying exposed destinations with flares (Arkia, El Al). As anti-surface-to-air missile (SAM) defensive lasers are being developed, the most exposed airports could be equipped with such systems in the future.

A Body Cavity Bomb (BCB) or Surgically Implanted Improvised Explosive Device (SIIED) was detonated at least once in a tentative assassination of a member of the Saudi nobility in 2009. BCBs are detectable by canine patrols and explosive trace detectors, but they are not by current body scanners. SIIED are not detectable by current systems unless the bomb holder takes an X-ray. However, because of the logistics required for implanting the device and limited blast yield, such weapons are primarily anti-personal bombs rather than massive destruction weapons. The target of the 2009 aggression was only lightly injured. However, this threat should not be underestimated.

After 9/11, western governments feared that extremist Islamic groups might have access to radioactive and fissile materials and try to manufacture nuclear devices or “dirty bombs”. While it seems that Al-Qaeda did explore such an option, it has not been established that any terrorist groups have ever secured significant quantities or even pursued the acquisition of materials – even ISIS that was in possession of exceptional means. They are expensive to procure, complex to manipulate, and require specific expertise to turn into an actual weapon.

As it is of bioterrorism. However, recent progress in bioengineering raises the question of easier access to these technologies and knowledge in the short-term. CRISPR genome editing was the AAAS 2015 Breakthrough of the Year. Compared to previous methods, it allows a highly efficient and selective editing of genomes. Could terrorist organizations, rogue governments or mentally unstable but skilled individuals[i] create and spread enhanced diseases? Air transportation is a major vector of contagious disease and can contribute to creating a pandemic within weeks specifically by displacing subjects across borders (SARS, 2002-2003; COVID-19, 2019-2020). Spreading at the airport is as much as a concern than in any other public place. Some airports have designed their ventilation systems in anticipation of a potential pandemic to minimize transmission, filter the air of the airport with hospital-grade filters, and renew the air of the terminal. Emerging post-COVID-19 procedures may also make aviation more resilient to this threat.

Small Unmanned Aerial Systems (sUAS) are opening a new world of cost-efficient solutions in several domains. They are also available to the general public with very affordable pricing (US$50-US$200). Multiple airports, mainly in Europe and North America, have reported drone seeing and encounters that have endangered or perturbated air operations. In 2019, London airports faced characterized, repeated incursions of sUAS that were obviously intentional. While the objective might have been to disturb flight operations rather than constituting a real threat to aircraft integrity, these flights are still violating safety

[i] In 2001, anthrax spores were disseminated by letters. The attacks, killed 5 people and infected 17 others, was perpetrated by a researcher seeking to revive interest in his anthrax vaccine program.

regulations and are a threat against flight safety. The potential damage of an encounter between an aircraft and a small UAS is comparable, for the aircraft, to a collision with a large bird.[j] Commercial aircraft are by design able to survive such collisions, while general aviation aircraft and helicopters are more vulnerable and can be lost consecutively to bird strikes.

Technologies have recently been developed for countering sUAS incursions. They typically consist of portable GPS jammer or "canon" sending an electromagnetic impulse (EMI) to the drone that will make it fall or be forced to land. Recent efforts in research and development have focused on automated detection and identification as well. Systems have been tested or in the process of being tested at airports in the United States, the United Kingdom, France, and Israel. At the 2025 horizon, automated or semi-automated sUAS counter-measures might be part of the typical security equipment of hub airports with operators at the Airport Operations Center.

As discussed in the previous chapter, intelligent airports and connected passengers are a growing target for cyberterrorism. According to the 2019 Threat Intelligence Index, transportation currently accounts for 13% of cyberattacks. Airport public Wi-Fi is regularly the target of cyber hackers seeking personal information or cyber-ransoming of travelers. Sensitive airport systems require hardening regarding the evolution of the cyberthreat to prevent intrusions. Security systems themselves are exposed as they become increasingly connected. In this domain, a collaboration between the stakeholders of information technologies is vital beyond aviation. Initiative for sharing experience and responses are important. Locally, Computer Security Incident Response Teams (CSIRT) can organize exercises to raise awareness and stress-test systems and procedures – including at non-hub airports. But cybersecurity is neither a local or industry-specific issue, and broader initiatives are needed as well. We can mention the ATT&CK initiative of MITRE corp. with an online library and an annual conference.

Table 4-1 - Long-Term Threats to Airport Security

Threats	Recent Events	Long-term global risk	Prevention & Mitigation at Airports
Active shooter	FLL	High	Airport community awareness
Terminal bombing	BRU, ISL	High	Airport community awareness Canine patrols Sensors (future)
Cyberterrorism	Various	High	Hardening sensitive systems Best practices
Firearm attacks in terminals	KDH, KHI	High	Airport community awareness Sensors (future)
Hijacking airliners	9/11, ALG-MRS	High	Airport community awareness Screening process
Vehicles ramming into public	GLA	High	Bollards and other reinforced obstacles
Hijacking GA aircraft	N/A	Low	GA community awareness Airport watch programs
MANPADs	MGQ, BGW	Low	Laser defense (future)
UAS	LHR, LGW	Medium	Active counter-measures
Bioterrorism	None	Unknown	Ventilation systems

[j] In most countries, sUAS regulations were designed based on the weight and density of drones.

Security Education and Stakeholders Outreach are Vital

Education and training of the greater airport community are vital for raising awareness on security threats. Airport professionals are on the front line and are the best people for identifying suspicious activities and recognizing threats. Facing shooters, every second count, and the action of each individual can save lives. An open gate can be the sign of an intrusion into the aircraft operating area. Recent events show that a lot can still be done in this domain. A widely disseminated awareness culture is also of a significantly helps in detecting and containing non-terrorist, non-criminal security offenses such as accidental intrusions that can degenerate into serious safety threats.

Security awareness should not be limited to a yearly recurrent session for badge holders. Joint training between the different stakeholders of the same area of the airport should be implemented. This outreach should include all the stakeholders potentially exposed to or able to provide early warning against terrorism and active shooters. Taxicab drivers in London now receive training for identifying and reporting suspicious customers, following the Brussels attacks. At least one large hub airport in Europe involves spotters in delivering them authorization, and in return constituting a small community active along the airport perimeter that can report suspicious activities and “fake” photographers.

While the potential use of General Aviation aircraft has been mentioned as a threat after 9/11, the reality of the field shows that such a tactic is not cost-efficient and effective. It requires a logistics involving pilot training and highly-explosive device preparation when these aircraft are slow and with a limited payload. The 2009 tentative suicide strikes by the Tamil Tigers (LTTE) using light aircraft demonstrates the difficulty of this modus operandum. Moreover, there is now a better security awareness of the general aviation community after 9/11, reducing the likelihood of a light aircraft being hijacked without being reported.

The Good, The Bad and The Ugly

The threat assessment that is the basis of the risk-based approach shall be revised periodically and triggered by alerts from the intelligence community, security events, or geopolitical evolutions. For instance, international terrorism threat is variable and is highly dependent on the results of the global war against terror and local actions for dismantling groups. As this paper is being finalized, terrorist attacks worldwide are dramatically decreasing with ISIS losing ground in Syria and Iraq. As long as poverty, violence, and political instability plague certain parts of the world, new “ISIS” could and will rise.

New movements and motives might also appear. After the “Golden Age” of nationalist and political terrorism in 1970-1980, jihadism took the lead in the years 2000. In 2014, Iraq and Nigeria accounted for more terrorist violence than the rest of the world. This peak of terror is dramatically decreasing with ISIS and its affiliates losing physical control over territories. Between 2013 and 2018, the majority of attacks in North America and Western Europe were carried out by individuals with far-right, white nationalist or anti-Muslim motives. Mass shootings in Norway and Christchurch by isolated but mutually inspired far-right extremists should raise concerns over potential white supremacist aggressions at airports – in particular when they welcome a diverse population of passengers such as pilgrims flying for the Hajj. On the longer term, eco-and social-terrorism could revive on the frustration of the most radical factions of green activism and radical anarchism. Aviation is increasingly in the spotlight and denounced by some for its impact on the environment. In 1982, an eco-terrorist group fired an anti-tank rocket at the construction of the Superphenix nuclear powerplant in France. Between 1978 and 1995, anarchist terrorist “Unabomber” had targeted persons and entities involved with technologies, including airlines – and at least one commercial flight.

State-sponsored cyberterrorism is a growing threat too. Over the past decade, mass cyberattacks with a strong suspicion of State-sponsorship have skyrocketed. Statewide power or internet outages have occurred in Estonia (2007) and Ukraine (2015). Dictators and rogue factions could go further and try to attempt to destroy the integrity of air transportation. Moreover, viruses targeting specific information system infrastructure could get out of control and contaminate critical networks and systems (e.g., Stuxnet, 2010).

Active shooters and suicidal individuals rejecting our society might be a major threat of the future – not only for aviation. Contemporary urban societies that aim at connecting many have created deep isolation of some. Suicides have been historically high within the youngest members of the community in Japan, while attacks with knives against school pupils have multiplied these past two years in P. R. of China. The United States struggles with mass shootings. Mental illness is growing by the number and can be exacerbated in countries and "cultures" of tight social control with a lack of solidarity. This pandemic is not yet fully recognized by governments, and is susceptible to creating new Unabombers and active shooters.

Criminality Must Be Fought Too

While these activities are not necessarily a direct threat against aviation security, criminality at airports exist as these facilities are doors to the world and large communities where goods and people live and transit. While Central America, Southern, and Southeast Asia are major centers of production for drugs, products are changing and their flows as well. Central Africa is now a major hub for drug trafficking. Criminal organizations are adaptive and seize short term opportunities, with for instance, a dramatic increase of smuggling from Venezuela as the political and economic structure of the country is falling apart. The current strategy against smuggling – a blend of police intelligence, canine patrols, profiling, and selected in-depth inspections of passengers and freight – might continue to be the most efficient.

According to the U.S. State Department, 600,000 to 800,000 people are trafficked across international borders every year, of which 80% are female and half are children. While there are no aviation-specific figures available, the use of air transportation for trafficking people worldwide is documented with long-term records.[34] In 2016, the U.S. Congress made mandatory for air carriers to provide human trafficking awareness training to the cabin crews. Other countries have or are working on introducing similar legislation. Several airports have programs of human trafficking awareness, including to the public.

Some specific larcenies and scams such as fake taxis might target airports because of travelers and more specifically foreign tourists carrying valuables making them easy targets. However, strategies and best practices exist to prevent them. The organization of taxi pickups, the rise of app-based transactions, and broader information of passengers make it harder for fake taxis to proliferate. At Paris-CDG, driver unions have organized red-vest squads of volunteers to provide orientation to passengers exiting the sterile area and looking for taxis. At several commercial airports, pickup is extremely regulated, limited to licensed operators with specifically labeled vehicles, and ride fares to downtown or business districts are fixed or caped.

Topic No. 5: Enhancing Aviation Safety Under a Growing & More Diverse Traffic

Cooperation Can Build a Collective Expertise in Safety and Fast-Track Enhancements

Generally speaking, the number of fatalities per revenue passenger kilometers (RPK) has decreased quasi-continuously since the years 1970.[35] However, this function has a logarithm-like shape – which means that it is becoming increasingly difficult with our current conception of safety to reduce fatalities as we are improving safety overall. This calls for a revolution in aviation safety as we are at the threshold of several groundbreaking changes. Also, RPK does not consider general aviation. While the number of accidents has decreased as well for these activities, they have its specificities – such as a peak of fatalities around 200 hours of experience[36]. Finally, we should not consider fatalities only in a comprehensive risk-based approach. Incidents of lower criticality can be the precursors of fatal occurrences, and aviation safety shall prevent injuries and damages to aviation assets as well.

Over the second half of the 20th century, standards in airfield design were mainly conservative and prescriptive. The progress of the overall knowledge in flight control and airport engineering bolstered by the need for accommodating larger aircraft at existing infrastructure showed these standards were often overestimating risks and sometimes underestimating them. These efforts fostered a mutual understanding of the stakeholders of airfield design and certification – airport operators, aircraft manufacturers, and civil aviation authorities. More importantly, this created a momentum in safety and regulations that enabled the emergence and rise of the risk-based approach. This new vision of risks led to the redefinition of several airfield design criteria and standards in the 7th and 8th editions of Annex 14.

We have already developed most of the infrastructure enhancements possible for ensuring aviation safety at airports. “Hardware” design standards have reached an exceptional maturity. Mitigations were developed for addressing the most impactful deviations to these standards. Arresting systems[37,38] provide since the late years 1990, a solution to airports lacking space for a standard Runway End Safety Areas (RESA). More competition on this market is coming, meaning that innovation and lower prices are coming. A cost-efficient solution could make the case for equipping general aviation airports. Another improvement of international standards could be a better protection of people and assets on the ground against the fall of an aircraft in the vicinity of runways.[39] To date, only the United States requires airport operators to freeze the land beyond the RESA – up to 810 m beyond the runway extremities for this purpose. These areas are called Runway Protection Zones (RPZ)[40,41].

Safety Management System (SMS) is a systemic and systematic vision of safety that was adopted by the ICAO in 2004.[42] While some countries are still in the process of implementing it at airports, it is now a well-accepted international standard that has significantly contributed to the advancement of operational safety – including on the traffic and non-movement areas with the inclusion of ramp safety and ground handling. SMS has helped to bring together the stakeholders of airport operations at individual airports to build a joint ambition in aviation safety. Industry working groups[k] and forums[l] with an emphasis on safety have tremendously helped airports sharing best practices and advancing safety. The Transportation Research Board (TRB) and its Airport Cooperative Research Program (ACRP)[43] in the United States have produced a considerable amount of research studies, synthesis on practices, and guidance materials that have helped practitioners around the world. Groups of airport operators have led

[k] Such as the Technical, Operations & Safety Committee (TOSC) of ACI Europe, the Infrastructure Workgroup of The French-Speaking Airports (UAF&FA), and the Airport Construction Advisory Council (ACAC) of the Federal Aviation Administration (FAA).
[l] Recent national and regional events include the AAAE/FAA Airfield Safety, Sign Systems and Maintenance Management Workshop (United States), Eurocontrol Airport Surface Risk Safety Forum 2020 (Belgium), 2017 DSAC Symposium on Runway Construction Safety (France), and 2019 ANAC Fórum Técnico de Obras (Brazil).

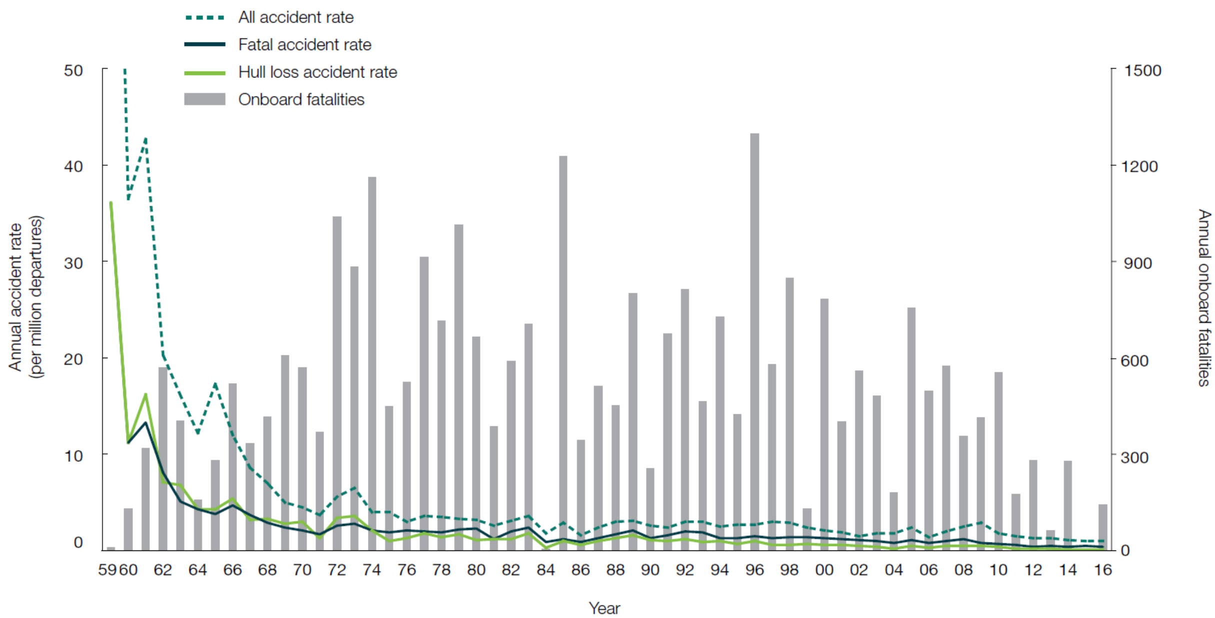

Figure 5-1 - Accident Rates and Onboard Fatalities by Year for Commercial Jet Aviation
Source: Boeing, 2017

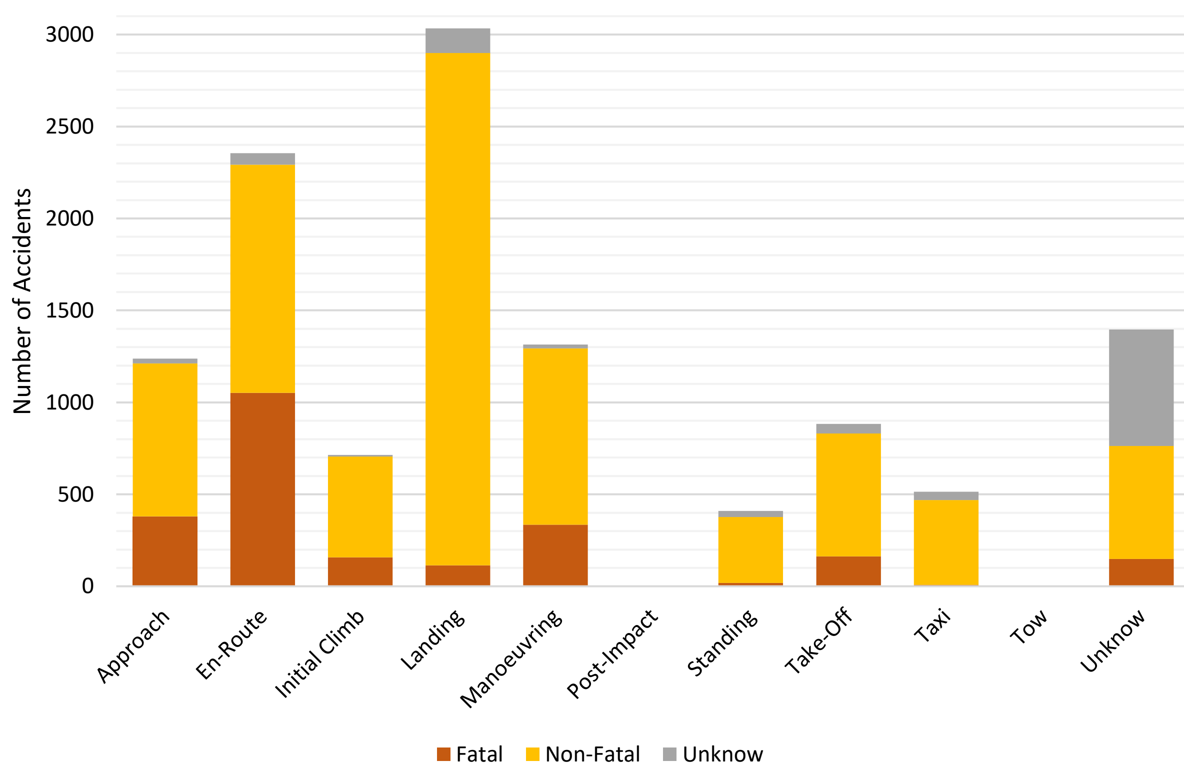

Figure 5-2 - Accidents per Phase of Flight from 2008 to 2020
Source: ICAO iSTARS API Data Service, April 2020

the way and addressed together significant operational safety challenges – some of their answers have become standards.

Paving the Way to the Future of Airport and Aviation Safety

The next frontier to improve safety standards is made of real-time systems and data. Data sharing and real-time analysis of these data will increase both operational performance and safety. For example, the lack of safety data available have prevented airport safety risk analyses from being as quantitative and comprehensive as they should be, and National Aviation Authorities to get a detailed vision of safety issues – a condition for designing an efficient State Safety Programme (SSP). A more systematic reporting of accidents and incidents, and the centralization of these data, start helping airports and agencies to get this vision and utilize data to improve safety in complement of lessons learned directly from the field.

Sensors available can now provide an estimate of the surface condition of runways. Radars and visual systems detecting Foreign Object Debris (FOD) are coming on the market and could tackle an issue that is still not fully addressed[m]. Autonomous Runway Incursion Warning System (ARIWS)[44] such as the Runway Status Light (RWSL)[45] provides visual information on runway occupancy to the crew, preventing runway collisions. Simpler technologies of runway incursion prevention on the ground are being developed in the United States through the Runway Incursion Reduction Program (RIRP).

The next step may not be based of ground equipment. The future of airside safety also resides in cockpit equipment such as Runway Incursion Prevention Systems (RIPS), aircraft-ground data exchange, and the use of big data. Several cockpits already navigate airfields with the assistance of dynamic digital aerodrome charts. With inflight updates, these charts could include the latest aeronautical information published by airports, provide enhanced guidance information during taxiing, and raise awareness and generate alerts on airfield safety issues such as runway incursions and wingspan restrictions.

Runway adherence is an essential information for preventing runway excursions, and triggering runway deicing and snow removal.[46] Airbus[47] and Boeing[48] both developed onboard Runway Overrun Awareness and Alerting System (ROAAS) (resp. ROPS and SAAFER). Next, these systems could exchange their assessment of the friction coefficient with other aircraft and the ground, providing a real-time, reliable, and aircraft-centered measurement of this value in a complement of the estimate derived from heterogeneous methods currently in use around the world.[49,50] Combined with Artificial Intelligence, this information could assist airports in their decision-making for continuing operations under rainstorm or winter conditions, triggering rubber removal and winter operations, and for enhancing airline procedures and individual pilot safety performance.

The revival of Urban and Rural Air Mobilities (UAM/RAM) with a new generation of vehicles (eVTOL) raises questions in airside/airspace safety. The experience in UAM over cities such as São Paulo, Brazil demonstrates that it can be safe with today's helicopters and specific procedures and practices. However, the extension of the domain of operations to IMC, the introduction of new players and vehicles, and the coexistence of piloted, remotely piloted and fully automated vehicles in the lower airspace call for new concepts of operations and standards. The ongoing research efforts in Urban Air Traffic Management (UATM) aim at addressing these issues and allow a safe and efficient deployment of UAM.

Concepts and technologies developed for UATM and Remote Tower Centers (RTCs) could contribute to the improvement of safety at "conventional" ATC facilities. At the 2040 and 2070 horizons, the stakeholders of real-time airfield and airspace operations will have more tools assisting them in the

[m] After the crash of Concorde at Paris-CDG in July 2000, standards and practices on runway inspections were tightened. However, the possibility of a FOD on the runway between two inspections mostly relies on pilot vigilance and reporting.

decision-making tasks and providing predictive scenarios during adverse conditions. At some point, the complexity of some concepts of operations might take part of the human decision out of the loop. This transition towards more automation in critical tasks and safety nets will require a careful assessment of the potential adverse impacts, and contingency plans in case these systems fail.

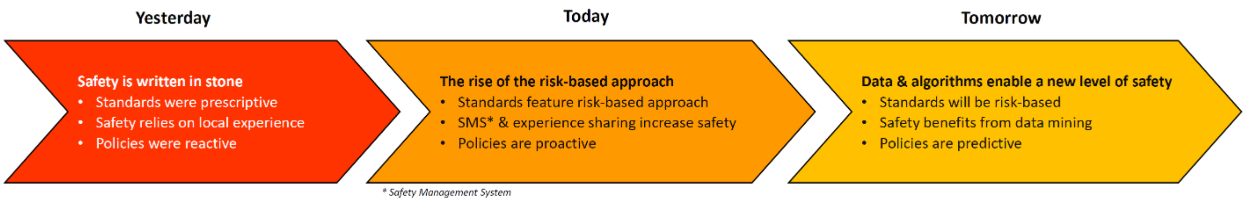

Figure 5-3 - Long-Term Trends in Aviation Safety

The Aviation Community in the Emerging World Must Improve its Safety Culture

According to IATA[51], the P.R. of China will overpass the United States and become the world's largest aviation market around 2025. Thailand should make the top 10 by 2030. By 2040, India and Indonesia should be among the 5 largest markets. In the meantime, Africa will be the fastest-growing region with a CAGR of 4.6%. Latin American and Caribbean (LAC) will follow closely with a CAGR of 3.6%. As air traffic should dramatically increase in the newly industrialized and developing world over the coming decades, it is crucial that the less safe countries keep up with the rest of the world. Their unprecedented growth is synonymous with an urgent and large need for aviation professionals. In an industry where experience and mentoring can make a difference in the field, an afflux of young professionals on critical positions of all the components of the local air transportation system can threaten safety.

It is vital to acknowledge that the level of safety is not the same throughout the world. Airports and oversight authorities shall work at closing the gap on ICAO standards. They should be inspired by the recommended practices as well to champion safety. Moreover, they shall become aware of their local specificities and gaps, and work on addressing them timely. The ICAO Global Aviation Safety Plan (GASP) is calling for such effort worldwide. The previous plan fell short in bringing all states up to the target on effective oversight implementation by 2017.[52,53] The ongoing plan aims at getting each country to define and implement a State Safety Program (SSP).[54] It is expected that the next period to the 2028 horizon focuses on implementing advanced safety oversight systems, including predictive risk management – a step that the most advanced countries have already achieved.

As of today, the Universal Safety Oversight Audit Programme (USOAP)[n] reveals that the average global effective implementation of ICAO's standards and recommended practices (SARP) with regard to aerodromes is of 62.29%. Considering the items at stake, this is a poor performance – and it is one of the lowest implementation rates of all the USOAP domains. Airports and the other stakeholders of flight operations need strong National Aviation Authorities to support national industries and ensure the safety of the overall air transportation ecosystem. In the less performant regions, a safety revolution is urgently needed to safeguard passengers and aviation assets. Beyond compliance with ICAO standards on oversight, each segment of the air transportation system shall comply with international standards and best practices, and a safety culture shall develop inside the aviation community, from the field to the executive management and governments. As these countries are at the threshold of unprecedented growths of air transportation, it is now that their governments must realize the imperative need for safety and pave the way to a bright and safe future for their aviation and airport industry.

[n] USOAP audits focus on validating a State's capability of performing safety oversight of its industry.

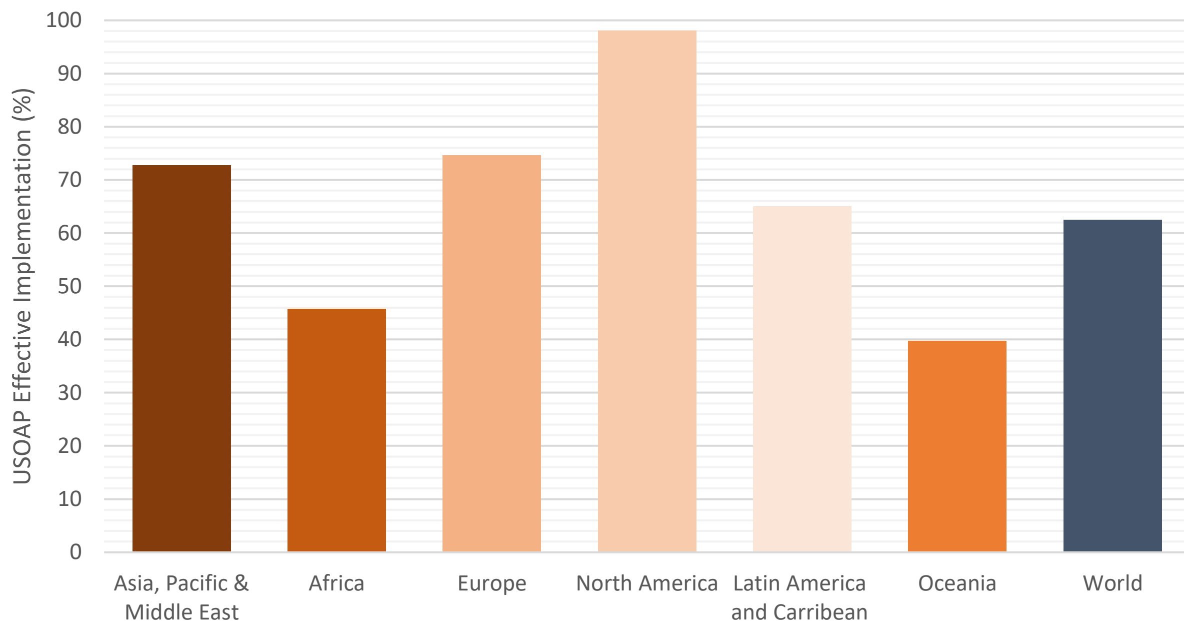

Figure 5-4 - USAOP Effective Implementation on Aerodrome and Ground Aids
Source: ICAO iSTARS API Data Service, April 2020

Achieving this requires specific progress in the funding, governance, and continuous improvement of aviation safety.[55] First, governments shall provide the National Aviation Authorities (NAA) with adequate financial means and workforce, organic and effective independence, and a strong commitment to “safety first”. The partial delegation of monitoring and certification to the operators cannot be a solution to organic deficiencies of the NAA. Then, major deviations to airport standards shall be removed. Airport operators cannot be expected to undertake alone all corrective actions. Grading runway strips, creating Runway End Safety Areas (RESA), removing obstacles and moving habitations, installing airside fencing, procuring rescue and firefighting (RFF) apparatus, and wildlife mitigation equipment might call in some cases for governmental coordination and public funding.[o] Adequate land use planning and strict enforcement of good sense rules shall prevent the errors of the past to be repeated. In some cases, international institutions such as the World Bank, ICAO, and other assistance mechanisms can provide funding to infrastructure projects and studies. The support of the ICAO is also offered as part of the No Country Left behind (NCLB) initiative.

Beyond the needs in infrastructure and equipment (“hardware”), a strong airport safety culture shall emerge within the airport staff and among the stakeholders (“software”). It should take into consideration the human and organizational aspects of safety. It shall be supported by the top management, embraced by the field, enable bottom-up reporting, be transverse throughout the airport organization, include the stakeholders as well. It means providing adequate means and training to the acting staff, and ultimately implementing Safety Management Systems (SMS). It also means fostering a safety culture based on transparency, non-punitive reporting, lessons learned and risk management.

A great deal can be achieved with cooperation within the airport community in each country, with the National Aviation Authority, and through international cooperation as well. Making the information accessible to the industry is a must-do, and while internet accessibility is now widespread in the whole

[o] This is applicable to developed countries as well. In the United States, RESA and arresting beds were implemented with the help of the Airport Improvement Program (AIP) and coordinated by the FAA through the Runway Safety Program.

world, too many countries – including among the developed nations – do not provide a great extent to safety regulation and practices on their website. We call for sharing accident and incident databases with the industry to make this knowledge available to the practitioners and facilitate the lessons learned process. National or local symposiums and safety task forces or action teams can help tackle the top priorities. Learning from others, gathering external lessons learned, and implementing best practices is a way to fast-track safety enhancement. High-level regional meetings at the governmental or industry levels are not enough and do not address alone the safety challenges ahead. Direct cooperation between airports, workshop between field operations teams, transnational collaborative work on specific issues, and dissemination of industry best practices may provide the complement to fill the gap.

Topic No. 6: Airside & Airspace Compatibility

Diversity is in the Air

The fleet of aircraft in the field and in the air will become more diverse over the coming decades. The lower airspace might get busier in the coming 5 to 10 years. Urban and Rural (or Regional) Air Mobility (UAM/RAM) promises a new era of mobility with new vehicles that should be safer, cheaper, quieter and greener than today's helicopters. Upon getting clearance from the regulators, they might enable an increase in capacity on intra- and perhaps inter-urban trips that are much needed in dense metropolitan areas with acute congestion issues. Urban Air Mobility will be provided by electric Vertical Takeoff and Landing (eVTOL) vehicles of various sizes moving 2 to 6 passengers or light freight. Services will include air taxi by manned electric helicopters and parcel deliveries by small Unmanned Aerial Systems (sUAS).

High-speed rotorcraft as tiltrotor or helicopters equipped with propulsive engines are at the horizon as well and will complete the VTOL offer with higher flight performances. Although they might occupy a smaller portion of the civilian rotorcraft market and will have higher operating costs than eVTOL vehicles, they could be of interest for applications where speed is a key factor for the success of the mission such as medical air transportation, law enforcement, some air taxis, and offshore services. AgustaWestland has developed the first tiltrotor civilian vehicle. Airbus[56] and Sikorsky[57] have flown demonstrators of high-speed helicopters.

Electric aircraft is a broad category of aerial vehicles that include fixed-wing aircraft powered by electric engines. Several prototypes have been flying and the first commuter aircraft retrofitted with an electric engine flew in December 2019[58]. Electric aircraft have promising applications for general aviation, commuter services and regional aviation. It might become a commercial reality during the 2020 decade. The feasibility of powering larger commercial aircraft with electric engines is not yet clearly established. Instead, larger aircraft might have hybrid propulsion systems electrically assisted during the cruise for lowering the consumption.[p]

Older and smaller single-aisle aircraft are being replaced by jets of more advanced design such as the Airbus A220, Embraer E-Jet E2, and Mitsubishi SpaceJet. These single-aisle aircraft are now being used for international services and open new opportunities for small and medium hub airports. The A321LR and XLR will soon be flying long-haul routes formerly reserved to middle-of-the-market aircraft (Boeing 757 & 767). These trends mean that terminal facilities and aprons shall be more versatile than before and be compatible with a more diverse fleet.

The termination of the production of the A380-800 announced for 2021 is not the end of the Large Aircraft (LA). The Airbus A380 and Boeing 747-8 might still be operating commercial services at the 2040 horizon. The next generation of large and long aircraft is already here with the A350-1000 and 777-9. The growth of the worldwide population, the emergence of new megalopolis with a strong middle class, and the scarcity of airside/airspace capacity make the case for the "jumbo" aircraft.

Supersonic aircraft will likely be back in the air by 2040. Nearly 20 years after the last flight of Concorde, at least 3 projects driven by U.S. start-ups have clean-sheet concepts for small supersonic jets either for commercial service (Boom Overture) or business aviation (Aerion AS2 and Spike S-512). While an entry into service (EIS) before 2025 as announced by these firms seem ambitious, demonstrators from Boom (Baby Boom XB1) and NASA (Lockheed X-59 Quiet SuperSonic Technology) should be flying as early as 2021. New standards will be needed to regulate the emissions and noise of these aircraft.[59] The comeback of civilian supersonic flight should not hinder the effort made by the industry to reduce the environmental footprint of aviation.

[p] Airbus is developing the E-Fan X retrofitting a BAe 146 for demonstrating hybrid (electrically assisted) propulsion concepts.

A hypersonic civilian market could emerge at the 2070 horizon. The idea of using hypersonic aircraft, gliders, or rockets for providing very long-range mobility is not new and was first proposed at the end of World War II. The development of new technologies, materials and manufacturing processes could make them available to civil aviation for commercial services or corporate aviation. SpaceX has suggested that its reusable Starship under development could be used for flying intercontinental routes – such as New York City to Shanghai in less than 40 minutes.

Urban/Rural Air Mobility and the Future of Heliports

Urban Air Traffic Management (UATM)[60] and Unmanned Traffic Management (UTM)[61] concepts are being studied for allowing the safe operations of Unmanned Aerial Systems (UAS) – including beyond the visual line of sight (BVLOS) – and new VTOL aircraft. Allowing the operations of UAS beyond BVLOS will require these vehicles to broadcast their position in real-time to the remote pilot or station, operate within authorized airspaces, and ensure adequate separation with other users and obstacles. Part of the answer lies with remote identification – a key issue that the United States and the European Union try to address through rulemaking projects to expand the safe operations of UAS.[62,63] Specific provisions will be needed for enforcing geofencing at the proximity of airports[64], and the separation with manned aircraft within shared airspaces.[q] Options such as dedicated sUAS and air taxi corridors – similarly to existing helicopter routes in the denser urban areas or nearby aviation facilities – are under consideration as well. In a recent white paper, Embraer suggests that Urban Airspace Service Providers (UASP) should provide UATM in the lower airspace (below 1,000 ft. AGL) where appropriate.[65] The future of artificial intelligence for the control and command of these vehicles will require safe concepts of operations as well.[66]

Urban Air Mobility (UAM) is already a reality in some large metropolitan areas. Downtown São Paulo, Brazil, is home for over 200 helicopter facilities, and it accommodates over 400,000 helicopter operations per year with specific flight procedures ensuring remarkable safety records. However, the noise and safety concerns have limited or reduced their operations over several cities (e.g., Paris, France; New York City, USA). New eVTOL aircraft promise to significantly reduce noise, enhance safety, increase availability[r], and reduce the cost of operations. Legacy manufacturers (Airbus, Bell, EmbraerX, etc.) and startups (e.g., KittyHawk, Volocopter) have developed over 60 concepts and a dozen of flying prototypes. Along with potential operators (e.g., Blade, Uber Air), they have created a thriving community in research and development[67,68]. To become a reality, they now need to establish safe and efficient concepts of operations, work with the regulators to translate them into regulations[s], and then find a viable business model out of these constraints. eVTOL will be physically piloted at first but might ultimately be remotely or automatically piloted (2040+ horizon).

Vertiports, vertipads, and vertistops are very similar to current heliports, helipads and helistops. Heliport design standards may need very little changes to be compatible with the new eVTOL vehicles. Besides the need for battery charging stations, providing an effective Mobility-as-a-Service (MaaS) solution will call for fast access from the ground to the elevated heliport, strategically located facilities to offer a competitive transportation network, and connecting the offer (eVTOL) to the demand (client). A new ecosystem of stakeholders and business models slightly different than the legacy helicopter service providers will be needed. Few metropolitan areas have an adequate network of heliports. Their development in new cities will require consequent investments and time – including environmental studies. Procedures and perhaps navigational aids shall be provided for flying instrument procedures in order to operate below the strict visual conditions. These requirements raise the question of the ownership and funding of the facilities. Revenues could be generated from the services offered to eVTOL

[q] Small general aviation aircraft are less robust to collision with drones and might be more exposed to such accidents.

[r] Upon battery recharge cycles shorter or comparable to existing helicopter turnaround times.

[s] The EASA has ruled out that VTOL not fitting within existing aircraft and helicopter regulations should be certified under a Special Condition to these regulations.[s] The FAA has expressed a similar position without publishing specifics to date.

rotorcraft (e.g. facility charges, battery recharge) and their clients (e.g., amenities, lounges). It is also unclear if the vehicles will be owned and operated by the future aerial TNCs (e.g., Blade, Helifirst) or if they will connect the clients with certified operators (e.g., Helipass, Voom).

Airports already accommodate helicopter traffic and several of them even have heliport facilities. Helicopters typically account for a small percentage of the total operations, and with their unique flight performances their integration under these conditions is easily manageable even so VTOL are slow and generate significant wake turbulence compare to fixed-wing aircraft of similar weight[69]. If Urban Air Mobility blooms and is used to serve airports with a high frequency (several times per hour) at the peak hour, provisions shall be taken to preserve airside capacity for the existing users and accommodate this new VTOL traffic as well. A way to achieve this taking is to separate the latter from the general fixed-wing traffic with a heliport facility away from the runways. It should be equipped with adequate flight procedures not conflicting with those of the runways and helicopter routes channeling the VTOL traffic. Similar considerations should be given to small UAS operations from regional freight distribution centers based at airports with UAS corridors vertically and/or horizontally separated from the aircraft traffic.

Aircraft Configuration & Airport Compatibility

The latest generation of long-haul aircraft such as the Airbus A350-900/-1000 and the Boeing 777-8/-9 are more demanding than their predecessors on many aspects of airport compatibility, such as the length or pavement stress. The 777-9 is the longest commercial aircraft ever, and a longer version has even been considered (777-10X). There is an upward trend in the tire pressure of aircraft – meaning that the weight is getting concentrated on a smaller area. Large aircraft are also popular in the air cargo business as they can move extra-large payloads or support busy routes (777F, 747-8F, An 124). Domestic facilities also see similar trends with longer and heavier single-aisle aircraft for serving existing routes. Issues with aircraft compatibility are a reality for airports of all sizes, from large hub airports to smaller facilities serving remote communities. They can have an impact on air service development, certification, lifespan and maintenance cost of existing pavement, and capital expenditure for adapting the infrastructure and equipment or reconstructing for more demanding aircraft.

The emergence of the New Large and Long Aircraft (NLA) in the years 1990 and 2000 – the Airbus A340-600 and A380-800, and the Boeing 777-300/-300ER and 747-8 – compelled airports, airlines aircraft manufacturers, and regulators to work together for fitting these aircraft at existing airports. They conducted research in airport engineering and found consensus for safely accommodating them at aviation facilities that were not designed for them per the standard then in force. Specific industry documents have been issued for the Airbus A380-800[70], Boeing 747-8[71] and Boeing 777-8/-9[72]. Moreover, this approach led to the rise of the risk-based approach in airport design and operations, and to a remarkable work for preparing Amendments 13A and 14 to the Annex 14 of the Convention of Chicago that reviewed all airport design criteria, identified their safety objectives, associated levels of safety, and from there refined them based on rationales and statistical studies. Today, mature methodologies and models exist to support aeronautical studies requesting local modifications of standards on runway width[73,74], runway strip and runway end safety area[75], ILS protection areas[76], taxiways, etc. Airports have learned to develop their own technical policies as well[77] based on ICAO-approved approaches[78].

The traffic area is also concerned by airport/aircraft compatibility.[t] At the short- and medium-term horizons, airports will have to continue adapting their ramp infrastructure to fit new airframes of different shapes with potential issues in terms of aircraft stand depth, fuel pit location, and jetbridge compatibility. Electric aircraft or hybrid propulsion systems for larger aircraft might require airports to install powerful charging stations at the gate – similarly to the move to built-in 400Hz blocks in lieu of GPU. In the meantime, ground service equipment (GSE) are also turning electric. As of today, virtually all the

[t] On the non-movement area in the United States.

GSE vehicles have electric counterparts in the catalog of the main manufacturers – including tow-tractors. These vehicles need charging stations as well, increasing the power demand. Another change to come is the introduction of green taxiing technologies. Two technologies are in competition: built-in electric engines on or incorporated in the landing gear (e.g. Wheeltug, EGTS), and external equipment towing the aircraft from the gate to the threshold (e.g. TaxiBOT at FRA and DEL). The success of such equipment is for now driven by the price of the kerosene. However, the long-term increase in fuel price, the social pressure to get greener, and technical progress (e.g. reversible electric brakes) might make green taxiing more accessible in the near future. They need concept of operations and procedures that minimize their impact on airport operations and facilities.

A revolution in aircraft design configuration has yet to come. The general geometry of aircraft has not radically changed since the Boeing 707 and the Douglas DC8. New fuel-efficient, noise-friendly configurations have been explored by research centers and aircraft manufacturers – some of them under publicly funded initiative (e.g., EU Clean Sky[79], NASA Advanced Air Vehicles Program) to pave the way to the next generation of airliners that will replace the Airbus A320 and Boeing 737 families. These innovative features aim at reducing consumption and noise, but they can be challenging from an aircraft compatibility perspective. As the aviation community already explored these issues with the NLA, an aircraft program cannot be successful if it requires excessive adaptations of the existing airport infrastructure. The progress of structural design and manufacturing process enables the introduction of innovations that will facilitate their integration at existing airports, such as the Folding Wingtips (FWT) on the Boeing 777-8/-9. More generally, they shall be operations-friendly from the landside to the airspace as airport compatibility is not only about airfield engineering, but shall embrace and address airspace operations, airport terminal design, and operations, and noise and emissions aspects as well.

Becoming Gateways Toward the Sound Barrier and the Kármán Line

Future supersonic aircraft will have different approach speeds than conventional aircraft. The experience of Concorde and military-civilian joint-use facilities show that it is possible to have these aircraft coexisting together. However, it does have an impact on the capacity to have aircraft with different flight performance. Also, they will have longer runway length requirements compared to subsonic aircraft which might limit the options of supersonic business jets for operating from secondary airports. Supersonic aircraft are longer compared to subsonic aircraft of similar passenger capacity. Finally, the new generation of supersonic aircraft will have to minimize their noise and emission to at least not exceed those of existing subsonic airliners.[u]

Commercial aircraft already share the airspace with spacecraft worldwide. The diversion of commercial flights for avoiding large aviation hazard areas (AHA) of several hours posed by spacecraft launches and reentries causes significant delays occasionally. The growth of commercial space transportation with new spaceports and spacecraft operators will require to rethink this cohabitation that will even occur at airports. There are currently 11 licensed spaceports in the United States[80] that has a comprehensive regulatory framework for launch[81] and reentry[82] site operator licensing. Six of them are active general aviation airports. Some are in the immediate vicinity of hub airports such as the newest U.S. spaceport, Colorado Air and Space Port (CFO), is situated at less than 5 NM from Denver Intl. Airport (DEN). The U.S. FAA is developing new tools for a more dynamic allocation of airspaces such as the Space Data Integrator (SDI). ADS-B is being tested on rockets. The emerging Space Traffic Management (STM) will have to interface with Air Traffic Management (ATM). Looking toward 2040 and 2070, the frontier between aviation and space will become thinner. In the United States, it is the FAA that certifies spacecraft

[u] Ongoing U.S. projects typically target a ground noise lower than 75 EPN dB. They will most likely comply with ICAO Annex 16, Volume 1 Chapter 4 standards or U.S. 14 CFR Part 36 Stage 4 without achieving Chapter 5/Stage 5.

and spaceport operations. The next spaceport to open might be Spaceport Cornwall at Cornwall Airport Newquay (NQY) with Virgin Orbit operating a specially modified Boeing 747-400 as carrier vehicle.

Integrating New Energy Vectors at Airports

The main families of aviation fuel are currently the jet fuels (e.g. Jet A1) for turbo-engines, and the avgas (e.g., 100LL) for piston-engines. Sustainable Aviation Fuels (SAF) or “Alternative Fuels” are produced from sources such as biomass or waste and then mixed with fossil fuels under current standards. Aviation-certified SAF contains up to 50% of synthetic fuel. They are certified as Jet A1 and can fuel existing aircraft without technical modification. They can be delivered via existing hydrant systems or trucks. Commercial service airports delivering SAF at large-scale include Los Angeles (LAX), Oslo (OSL), Bergen (BGO), and Stockholm (ARN). The Port of Seattle has set a goal to power every flight refueled at SEA with at least a 10% SAF blend by 2028.

Electric aircraft are a more radical move away from fossil fuels. In addition to reducing emissions, this technology can dramatically reduce noise. At the 2040 horizon, we can expect most of the small aircraft (general aviation and commuters) and VTOL aircraft (UAM/RAM) to be electrical, and new larger aircraft to be powered by hybrid systems. Transitioning to electricity will require airports and their stakeholders to invest in charging stations and adapt their power supply – which could be a push for local production (e.g., solar farms) and microgrids. To keep e-aircraft competitive, battery charging should not adversely impact the turnaround time. Either the batteries should be able to stand a day of operation and be recharged overnight, or they should be replaced at the gate. Transitioning to electric aviation will also challenge the business model of the fixed-base operators (FBO) and aviation fueling service providers.

Liquid hydrogen (LH_2) has been tested on small aircraft prototypes and ground service equipment (GSE). However, powering large fleets of e-aircraft and eGSE on LH_2 would require new logistics and distribution infrastructures that do not exist today or are not yet adapted to such demand.

Emerging Stakeholders and Their Impact on Compatibility

The capacity of an airport to accommodate new types of aircraft in a safe and efficient way also lies in the level of cooperation between the stakeholders. While the civil aviation community has reached a certain maturity and experience in this domain, the emergence of new stakeholders at the visible horizon might require rethinking this order and plan proactively on integrating the new users and service providers within the greater airport family. The previous example on Urban Air Mobility listed several players that do not yet exist. The rise of electric aircraft will challenge the business model of the aircraft fueling service providers and many fixed-base operators.

What if airlines themselves break between flight operators providing ready aircraft and holding the air operator certificate, and mobility providers developing the commercial offer and selling tickets? These charters of a new genre could both help to leverage growth in booming regions where flight operators have yet to become safer and reintroduce more diversity on mature markets. These flight operators could actually be the aircraft manufacturer themselves – they already train pilots and lease aircraft. Agreements between the parties of these “compound airlines” that could easily be recomposed and adapt to the evolutions of the demand could be facilitated by a new generation of contracts and certificates powered by blockchain technologies.

Airport operators also evolve and adopt more complex profiles. We now find public operators, private operators, and more complex models where, for instance, the airport is publicly owned, but all the terminal facilities are operated by separate private entities competing for airlines (e.g., JFK).

Topic No. 7: Passenger Terminals and Customer Experience

From Facility Providers to Mobility Providers and Hosts

Airport operators used to be infrastructure managers providing aviation facilities as a public service. As their vision is now more passenger-centric, airport operators consider the passengers as their clients and might sometimes even compete with air carriers on providing specific services to them. The missions of airport operators are being transformed as they are transitioning from facility providers to mobility providers and hosts competing on the experience they offer.

They are mobility providers because they consider themselves as part of a broader door-to-door mobility-as-a-service (MaaS) continuum. Airports are just one step of the traveler journey. They shall work on a better integration and coordination with the non-airport steps of this journey with a "total customer experience" approach. This is about getting control of their overall competitiveness and attractiveness as passengers do consider ground accessibility when choosing their airport[83] or considering alternative modes of transportation[84]. It is also about the quality of service and the customer experience. Consequently, some airports are developing their own ground transportation offers, such as Groupe ADP partnering with Keolis on Le Bus Direct from Paris downtown to CDG and ORY. Groupe ADP is also part of a joint venture with the state-owned rail operator SNCF Réseau for commissioning by 2025 the light rail infrastructure for the CDG Express service[85]. Airports are also improving their curbside and ground transportation access. Airports such as Los Angeles Intl. Airport (LAX) with LAX-it and the Landside Access Modernization Program (LAMP)[86] are developing remote ground transportation centers (GTC) connected to the terminals with bus services or a people mover to ease congestion issues on a crowded landside.

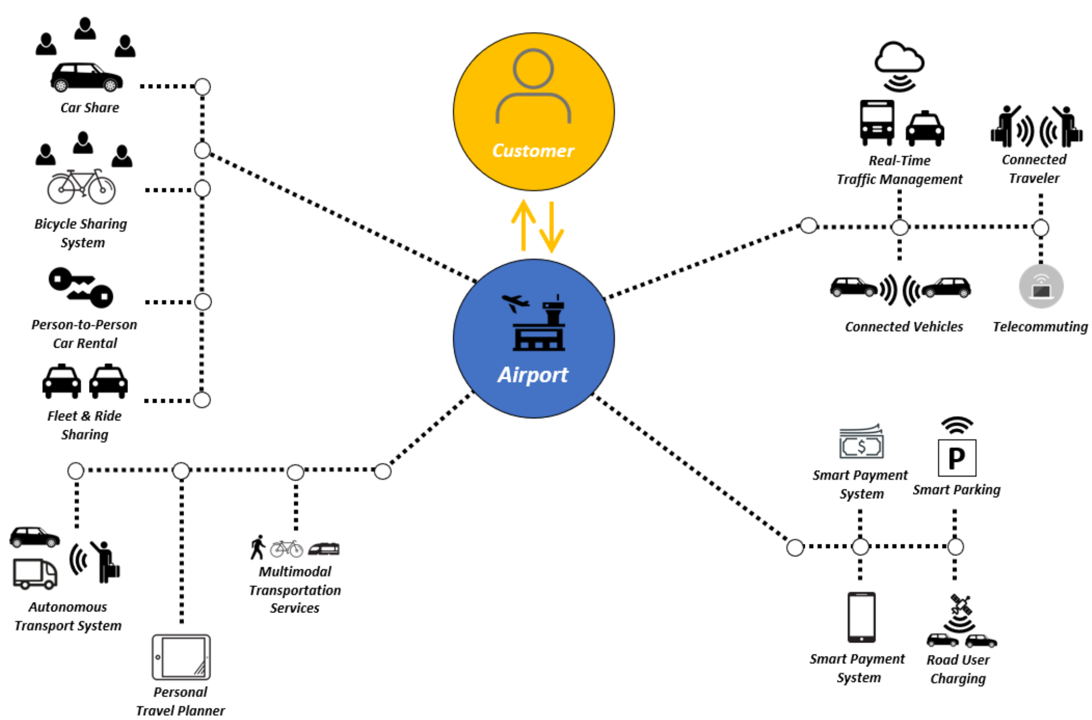

Figure 7-1 - Airport as a Door-to-Door Mobility-as-a-Service (MaaS)

They are hosts because they do not just provide a "shelter" where passengers transit through as at the dawn of commercial aviation. They serve a community, and the world is their guest. Airports are the first impression that visitors get of their destination. They shall be a gateway reflecting the region they serve. New York LaGuardia Airport (LGA) had been derided for decades with former U.S. Vice-President Joe Biden even declaring in 2014 that he "must be in some third-world country". Since then, the Port Authority of New York & New Jersey (PANYNJ) went under a Public-Private Partnership (PPP) for an ambitious redevelopment of the airport that will be experiencing a second life and become a top-notch facility once the program is complete.[87] Terminal 3 (TPS 3) at GRU Airport, SP, Brazil, significantly leveled up the customer experience to the best international standards on time for the 2014 FIFA World Cup. Signature atmospheres are developed to create a unique experience often in relation to cultural markers of their community. Munich International Airport (MUC) is well-known for its central Plaza featuring pubs and animations. Singapore Changi (SIN) opened in 2020 its 135,700 m^2 "Jewel" featuring over 300 retail and dining facilities on 10 floors arranged around a tropical forest with a 40-meter-tall indoor rainfall. Ted Stevens Anchorage International Airport (ANC), Paris-Charles de Gaulle (CDG), or Beijing Daxing (PKX) feature respectively Alaskan, Parisian and Chinese cultural elements all along the passenger journey. Smaller airports as well seek to provide a high-end experience such as Paine Field Passenger Terminal (PAE) in the Washington States, USA.

They develop services to passengers that may not all be commercially viable but have an overall positive impact on customer satisfaction. Innovative services include free lounge to connecting travelers, entertainment nearby the holdrooms, concerts and exhibitions, lactation rooms, water stations to replenish bottles, and even yoga rooms. Some of them, like the in-airport hotels, can be a competitive edge and a source of revenues as well like the iconic and retro TWA Flight Center Hotel at New York John F. Kennedy International Airport. Airport retail and concessions are another key to generate substantial ancillary revenues. These retail spaces are part of the experience itself (e.g., CDG, DBX, LHR). Airports have developed their own reward programs with perks and discounts (e.g., CDG, LHR, SAT) and personal shoppers (e.g., LHR). These services and experience should follow the evolution of passengers' expectations and values as well. Exclusivity is becoming outmoded as it is now accessible to many and does not have the same glamour as before at the era of social- and eco-consciousness. Passenger-centric and customized experience to everyone is the way of the future. It will be supported by information and intelligent systems. But bringing more IT in does not mean that airport helpers and other customer service employees shall go away. On the contrary, airports will need well-trained professionals as these services will need a continued and adequate staffing who can address complex requests, provide a warm and human interface, and ensure resilience if the systems go down.

Back to the Future: Designing Passenger-Centric Terminal Facilities

Passenger terminal facilities have tremendously evolved since the beginning of aviation. Simple block "shelters" after World War II, they quickly evolved into new concepts with the emergence of jet aircraft and supersonic flights at the horizon, and the introduction of the jetbridges and mobile lounges. The newest, largest facilities have a polyform and centralized layout that can accommodate several dozens of million annual passengers under one single roof. The gigantism should not hinder the customer experience, operational efficiency, and resilience. Future concepts shall also achieve simplicity and modularity – and this is not necessarily a question of shape or configuration of the building only.

Passenger facilities shall go beyond grand architectural designs and get back to the roots of terminal design: providing a straightforward, seamless, and pleasant access to the aircraft from the curbside. There is a race to the biggest "cathedral-terminal" building between mega-hub airports. But we shall not forget that many passengers just want to get from their car or mass transit system to the gate, or from the gate to the gate for short connections. Passengers expect not to have to face a complex itinerary through the airport, and spend time taking air trains and airport people movers (APM). Providing a unique experience and promoting retail, food and beverage are conciliable with this prospect. "Internal mobility" is a real issue at most of the large hub airports. This intraconnectivity shall transcend the terminal concepts and provide an interrupted journey, unlike most of the APM solutions that require a change of level and waiting time between trains. Bridges with mobile walkways (e.g., DEN, HKG, LGW, SEA) can provide an alternative. Cable cars also achieve the need for leveled, uninterrupted transportation. Mobile lounges are still intensively used at Washington Dulles International Airport (IAD) as they allow a flexible use of gates and terminal facilities.[v] Could personal rapid transit-like (PRT) systems address these challenges and create point-to-point and personalized connections?

Modularity should be another function achieved by future terminals. While air transportation has been experiencing strong long-term growth, air traffic is also highly sensitive to temporary economic turndowns that can lead to quick market transformations such as airline consolidations and strategic decisions with impactful decisions for airports, from a restructuration of the network to more dramatic reductions of the number of airline hubs. The past decade has seen emerged other novelties such as low-cost, long-range air carriers, single-aisle aircraft being used on long-haul routes that call for more agile passenger facilities that can handle fairly dynamically larger and smaller aircraft, and domestic and international passengers. Geopolitical changes (e.g., new countries, new custom unions, Brexit) and disruptive events changing standards and practices (e.g., 9/11, COVID-19) are other conundrums for airports. The information and intelligence technologies might ultimately influence how space and resources are used and change the main ratios and reference values used by the industry for planning and design. Self-service bag drops, biometric identity from the check-in to the gate, walk-trough security screening checkpoints, and similar emerging solutions will positively impact passenger flows. Airport planners and designers shall keep in mind that modularity and flexibility are keys to long-term success in a changing world that is constantly speeding up.

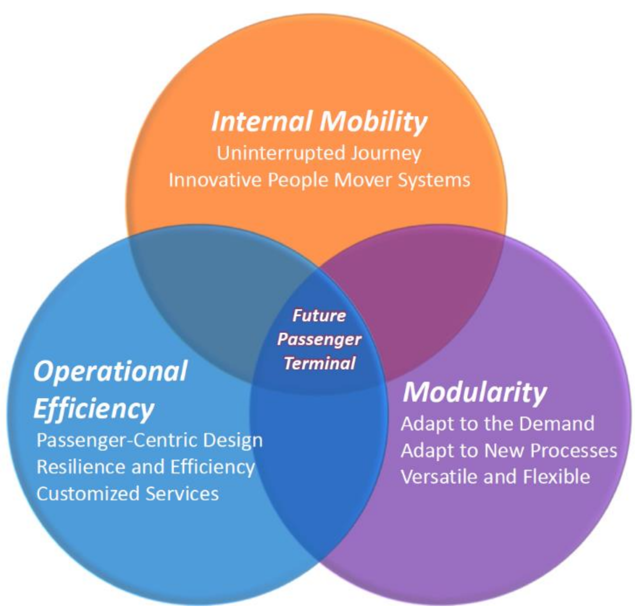

Figure 7-2 - Emerging Issues in Passenger Terminal Design

[v] The use of these vehicles was discontinued at other airports because of their operating costs. Some aviation facilities (ATL, YUL) has kept few mobile lounges as a contingency plan for supporting remote operations.

In the end, getting the basics right is as important as creating a “wow” effect. The top priority of a passenger is either locating the departure gate or recovering his bag and securing a ride to arrive on time to the final destination. Satisfying other needs usually occurs afterward to begin to fulfill discretionary needs.[88] Applications and services may alleviate this mental load, improve the experience, and perhaps increase ancillary revenues. But simplicity does not mean low-cost. No-frills terminals show their limits as they do not achieve passengers’ expectations. It might be a difficult paradigm to address for some airport operators that need funds to maintain or upgrade their facilities while facing a strong opposition of air carriers to collect adequate user fees to do so.[89,90,91]

The Coming Battle for Door-to-Door Services

The lack of regional integration and custom unions are an increasing concern for arriving passengers in some parts of the world. Travelers enjoy free movements without border control within the European Schengen Area. MERCOSUR citizens can travel within the block with their national ID cards only. Visa exemptions (e.g., CARIPASS, ESTA, ETA, ETIAS) and simplified electronic border controls (e.g., EGate, Global Entry, NEXUS, SENTRI, SmartGate, PARAFE) expedite border controls. However, most of Africa and the ASEAN region do not have some instruments yet and passport controls are mentioned as one of the first negative points of the journey by passengers.

Efficient and passenger-friendly terminals will be a key competitive advantage for air carriers. Individual carriers and wider alliances are spending a large amount of money modernizing terminal facilities and customizing them to offer a consistent high-end experience from airport to airport. For instance, Delta Air Lines is investing 12 billion USD over a five-year period in airport infrastructure with flagship projects at ATL, LAX, LGA, SEA, SLC and took ownership in 2016 of 5% of CLEAR – a private biometric screening process. Outside of the United States, airlines rarely own their passenger terminal facilities. Their brand is typically less visible, and they might share airport-owned infrastructure and equipment with other air carriers. In return, airports are competing to attract and retain these air carriers. This competitive edge of airlines at airports cannot be achieved without a close cooperation between airport or terminal operators and innovative partnerships with service providers.

The next competition will be on the first and last miles – from the door to the curbside. Airlines and airports might team or at least better coordinate with transportation network companies to simplify this part of the trip. It is already possible in some cities to check-in bags at hotels or the train station to the airport. Additional services will be proposed, such as the baggage pickup and delivery at home or the workplace. This is one of the multiple innovations that could help passengers “extracting” value out of their entire trip door-to-door. A real seamless journey shall allow clients to work, join a meeting, or be entertained during their trip including in the transit to the airport or final destination. Watching a movie on a smartphone with a bad connection or using a computer in precarious conditions is not what 21st century citizens deserve. As we now spend a significant part of our life in transportation, we need to unlock this lost time to make it available and effective. New technologies and behaviors might facilitate this move. Carry-on bags become lighter under the pressure of air carrier fees. Individual computers might become dematerialized and available everywhere through cloud-based solutions.

Topic No. 8: Operational Performance and Resilience

Airports and Aviation Systems are Increasingly Sensitive to Disruptions

Airports and aviation systems are complex ecosystems that support a global economy and provide for the safe and efficient movement of passengers and cargo. According to the Air Transport Action Group (ATAG), aviation supports 65.5 million jobs worldwide and enables 2.7 trillion USD[w] in global GDP.[92] In average, over 44,000 flights are controlled daily in the United States[93] and over 30,000 in Europe[x,94]. A significant disruption in the skies or at a single commercial service airport can rapidly cost millions USD to the society. A power outage at Hartsfield-Jackson Atlanta Intl. Airport (ATL) in December 2018 led to the cancellation of 1,400 flights and cost between 25 to 50 million USD to Delta Air Lines alone. Eurocontrol considers that the cost a flight cancellation ranges from 7,000 to 125,000 USD, including the passenger opportunity cost. The tactical (last-minute) delay to airlines can range from 40 to 200 USD per minute.[y,95]

While crises such as the Great Recession and the COVID-19 pandemic have short-term adverse effects, air traffic has a proven long-term resilience that leads forecasters to predict a world annual growth rate of at least 4.5% to the 2040 horizon.[z,96] Beyond 2040, the rise of Africa will continue to support this growth worldwide for several decades. Innovative air mobility will create a new demand as well. Enhancing the accommodation of this growing throughput with improving punctuality and resilience has been one of the main concerns of the air traffic management modernization effort that the world has undertaken under the umbrella of the International Civil Aviation Organisation's (ICAO) Global Air Navigation Plan (GANP). Leading local programs include NextGen in the United States and the Single European Sky (SES) in Europe. Other programs include Sirius in Brazil and CAAMS in the P.R. of China[97], and other countries are modernizing their ATM as well without a centralized management and branding.

Within an interconnected air traffic management process such as the U.S. National Airspace System (NAS) or the E.U. SES, issues faced by a single commercial airport and their impacts on the overall performance of the network have been highlighted. For instance, it was estimated in 2008 that 1 minute of original delay at a U.S. hub airport was resulting in 1.44 to 2.16 minutes of total delays considering the propagated arrival delay distributed across arrivals at one or more airports.[98] Airports are more interdependent and there is a need for an emerging concept of accountability for the delay one creates on the overall airport ecosystem. The Single European Sky (SES) approach includes a performance and charging scheme on air navigation services with an airport component.[99]

Collaboration Has Been a Game Changer

Collaboration between the stakeholders of real-time operations has been a game changer everywhere it has been implemented. The different organizations representing all the stakeholders of airport operations have called for the end of the "silo effect"[100] and have supported Airport Collaborative Decision-Making (A-CDM).[101,102] Airport CDM is now an international standard[103] and an objective of ICAO for advancing air navigation as part of the Global Air Navigation Plan (GANP).[104] The A-CDM concept that emerged in the years 1990 is about establishing a tighter relationship between the players of real-time airside operations and sharing information for the purpose of enhancing efficiency, reducing delays and improving resilience. The A-CDM "spirit" is based on trust and transparency to serve the common operational interest. One of the focus of A-CDM is to create a framework for the stakeholders to share operational data, have the same level of information, and decide collaboratively – not side-by-side only

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[w] 2005 USD. 1 trillion = 1,000,000,000,000.

[x] Flights controlled by European Civil Aviation Conference (ECAC) members.

[y] Rough orders of magnitude in EUR_{2020}. Original figures in EUR_{2018} adjusted to inflation. 1 $EUR_{2018} \approx 1.02$ EUR_{2020}. 1 $EUR_{2020} \approx 1.1$ USD_{2020}.

[z] Compound Annual Growth Rate (CAGR) of the Revenue Passenger Kilometers (RPK) over the 2012-2042 (ICAO, 2016).

anymore – on how to address operational issues in a timely manner. The extension of this approach to the rest of the airport, from the access road to the airfield, is called Total Airport Management (TAM). A practical application of TAM is the Airport Operations Center (APOC) that integrate the different functions of real-time airport operations into a "single" physical or virtual facility with, as far as possible, the participation of all the internal stakeholders of the airport authority and the external stakeholders as well.

Establishing collaboration and deciding together means that everyone speaks the same language and agrees on set objectives and consensual remedies to adverse conditions. Stakeholders at pre-A-CDM airports have notoriously different definitions for the same milestones of the flight turnaround process. "Capacity" itself is even sometimes a taboo so much it can be interpreted in different ways depending on the user and its purpose. Airport CDM brings a common framework with joint key performance indicators and definitions on airport performance[105] and capacity.[106] Freed from their cultural differences, the airport operations community can focus on monitoring these KPIs, detecting coming adverse conditions when possible, and proactively managing them together.

After establishing a list of flights and their reference times (milestones) updated by each stakeholder for real-time operations and short-term planning purpose, it is possible to expand this vision months before for long-term operations planning purposes taking into consideration the evolution of the demand and any foreseen change in capacity (e.g., due to construction projects). Most of the commercial service airports already have an operations planning process. But an A-CDM vision of operations planning as promoted by ICAO in the GANP under the name of Airport Operations Plan (AOP) is the ultimate step of A-CDM implementation for integrated planning and management of operations. In Europe, the AOP concept of EUROCONTROL looks 180 days ahead and inform a network-wide operations plan (NOP).[107]

The benefits of collaboration are tremendous. A 2016 assessment by EUROCONTROL shows that across 17 CDM airports in Europe, ATFM delay has been reduced by 10.3%, the average taxi-time by 7%, and the fuel consumption, CO_2 and SO_2 emissions by 7.7%.[108] Europe and the United States have pioneered Collaborative Decision-Making. In Europe, CDM started from airports, and this recipe has been applied all around the world. These local A-CDMs feed a network-wide CDM model. In the United States, CDM started from the FAA Air Traffic Control System Command Center (ATCSCC) and the air carriers under the FAA/Industry CDM Stakeholders Group (CSG). There is a network CDM, but not yet local airport focused CDM as it can be experienced elsewhere. Airports shall be included as well, and several initiatives aim at giving a push to this movement, especially on the collaborative management of adverse conditions.[109]

From Reactive to Predictive Management

The step forward will be predictive management. Advanced collaboration has made available a large quantity of flight operations data collected into Airport Operations Databases (AODB) and other repositories. Processing these data through intelligent systems and organizations to predict potential disruptions, triggering preventive actions before it happens, and eventually mitigating their effect is now becoming possible. Moreover, this predictive management approach might be the next step in the advancement of airport and air navigation management while major modernization programs such as SESAR and NextGen are coming to an end, and the ICAO GANP itself does not provide a framework for the period beyond 2030 yet.

Information systems are enabling the current modernization effort in the airport and air traffic management. Intelligence systems will power the continuation of this effort toward a more capacitive, integrated and resilient aviation system, from the landside to the airspace. In the air, air traffic control is at the threshold of more automation. Most of the achievable optimizations under current concepts of operations have been implemented. For instance, the Wake Turbulence Recategorization (RECAT) has introduced new categories of aircraft for safely decreasing wake turbulence separations between some pairs of aircraft categories. The next step could be to characterize further aircraft pairs, with more categories or even by aircraft types. Ultimately, these separation minima could take into consideration local parameters such as the wind, and flight information such as the weight of the aircraft. Such progress could increase capacity but is not achievable without a higher degree of automation in air traffic control, providing the controller with a visual aid on the minimum separation between a given pair of aircraft or the automation of this instruction. Similarly, building on the experience of the pre-departure sequencers (PDS) of the A-CDM solutions, based on up-to-date flight key schedules and infrastructure capacities, air traffic controllers managing ground movements at large airports could be supported by machine learning from the local specificities including the choices made by the controllers and artificial intelligence to optimize dynamically taxiing. Georeferenced mapping information for enhancing navigation on the ground could be transmitted by datalink to the cockpit as well. This information could consider all active ground movement restrictions – e.g., aircraft type limitations, work in progress, etc. – for improving safety, mitigating incidents, and taxi efficiency.

On the landside, intelligence systems can assist the operations community in optimizing resources and proactively identifying coming demand-capacity issues. Many airports are already equipped with sensors or systems for measuring passenger flows and queues. Simple algorithms can be used to deduct the resource needed to process this throughput. Machine learning could recognize patterns in these flows, understand how the resource dynamically responds, and provide advice and scenarios to operations manager on the best way to proceed. Augmented reality and other advanced interfaces will enhance the visualization of these scenarios and data to facilitate their understanding and utilization. With the implementation of self-service devices and automated control systems, part of this decision-making process on resource management might start being automated or semi-automated by 2040. Significant progress can be made outside of the terminal building as well. Ground resources are often congested or utilized in a suboptimal way. Various stakeholders are present on the landside with few or no coordination. A CDM-like coordination between airport operators, ground mobility providers, and transit agencies is emerging and will bring a tremendous improvement. Adding potential transfers or rebooking between the air and rail modes would be an innovation and was explored as part of the EU-funded research project META-CDM.[110] The introduction of automated and connected vehicles (AV/CV), as well as Urban Air Mobility (UAM) could open new horizons on the coordination of the ground transportation offer to fit the demand, increase predictability and reliability, and reduce congestion and waiting times.

Such systems will need adequate infrastructure to exchange data. The System Wide Information Management (SWIM) is a global air traffic management initiative that is offering a data-centric framework for sharing these data. SWIM is one of the ICAO GANP items to achieve the global interoperability of systems and data. While SWIM has been designed for minimizing the interfaces and standardizing data sharing between the stakeholders of air navigation and flight operations management, it is a very powerful system. It has the potential of bringing together more aviation stakeholders or at least inspire a broader pan-aviation framework that could exchange information with non-airside parties, interconnect non-ATFM systems, and even enable data exchange with passengers.

Digital twins is another airport application of big data and intelligence systems to foster efficiency and resilience. A digital twin of a system is a digital replica and a detailed model of physical assets and processes that can be used for predicting and anticipating future issues or simulate scenarios. Airport digital twins can help with planning maintenance actions for asset management and financial planning purpose. They can also be used for running detailed and realistic "what-if" scenarios of future operations and provide extensive help to stakeholders to plan for future activity, optimize resources, increase revenues from retail, or facilitate the commissioning of new facilities.

Performance & Resilience Will Still Depend on the Human in the Loop at the Era of Intelligence Systems

Resilience starts on the first day of operations of a new facility with the Operational Readiness and Airport Transfer (ORAT) process. The commissioning of a new facility can be challenging, especially when a massive capacity is being delivered at the same time such as the new Beijing Daxing International Airport (PKX) and Istanbul Airport (IST). Architects, designers, and engineers shall keep in mind that innovation shall ultimately serve the operations. The first intelligence systems in aviation are the aviation professionals. Airports shall be easy to maintain and operate. Too many architectural features master the art of making the task of the operating staff impossible. Changing a light fixture shall never require custom-made equipment. Mechanical, electrical, and plumbing (MEP) systems shall be accessible to maintenance teams. An airport is a masterpiece only if it looks beautiful and operates efficiently at the same time. Decision-makers shall maintain awareness that if cost-saving policies and operational requirements are not balanced, efficiency and resilience will be at risk. A well-planned preventive maintenance program saves money. Airport helpers in terminal facilities make the journey smoother and reduce the stress of passengers. Redundancies are never regretted the day they prevent the airport from shutting down.

While information and intelligence systems can enable more performance, efficiency, and resilience, we have to be careful that these information and intelligence systems expected to make us more resilient do not actually turn our airports weaker. Indeed, these systems themselves can fail. Beyond redundancies and failsafe designs, simple contingency plans can be prepared to maintain the activity based on less “techy” processes even if it means to operate in degraded mode. For instance, Geneva Airport (GVA) trains agents to process passenger boarding with paper documents to continue operating in case the computers or readers available at the gate are out of order. These “what-if” based training strategies can “save the day” and way more while we are becoming increasingly dependent on technologies and systems.

Enhancing the long-term resilience to sudden shocks of demand, such as the COVID-19 crisis, is possible. Such a strategy requires an interdisciplinary approach that goes beyond the means and powers of the aviation industry and should be led or coordinated by governments and international organizations. COVID-19 per se could not have been foreseen. But the emergence of a new pandemic of respiratory disease after SARS and MERS and its effects on our society and the economy were. Unfortunately, despite these warnings, our nations were poorly prepared when the SARS-nCOV-2 virus spread in mainland China and then to the rest of the world at the beginning of 2020. What is the “next COVID-19”? New influenza or coronavirus pandemics will happen, and we can hope that the lessons learned from the COVID-19 will be used for making our society more resilient. New terrorisms, the collapse of the IT infrastructure, collateral casualties of conventional wars, and the impact of extreme weather due to human-induced climate change are other threats to aviation. On all these threats, transparency, collaboration, and planning are keys to prevent adverse events and provide an adequate and timely response when required.

Climate Change Will Challenge Aviation System Resilience

Climate change raises specific threats to resilience. Its effects on our infrastructure systems are already visible in 2020. Significant climate anomalies with a direct impact on our lives have now been recorded for over two decades.[111,112] They range from frequent record high temperatures to violent winter storms, and they have direct consequences on the health and availability of airport assets and both the operating and capital expenditures. Some of these events have been creating new paradigms regionally. The winter season 2010/2011 in Europe led to significant investments in winter equipment and support facilities, an effort to make operations more resilient. Similarly, Kansai International Airport (KIX) decided to heighten seawalls and one its runway by 1 meter following the damages from typhoon Jebi in 2018.

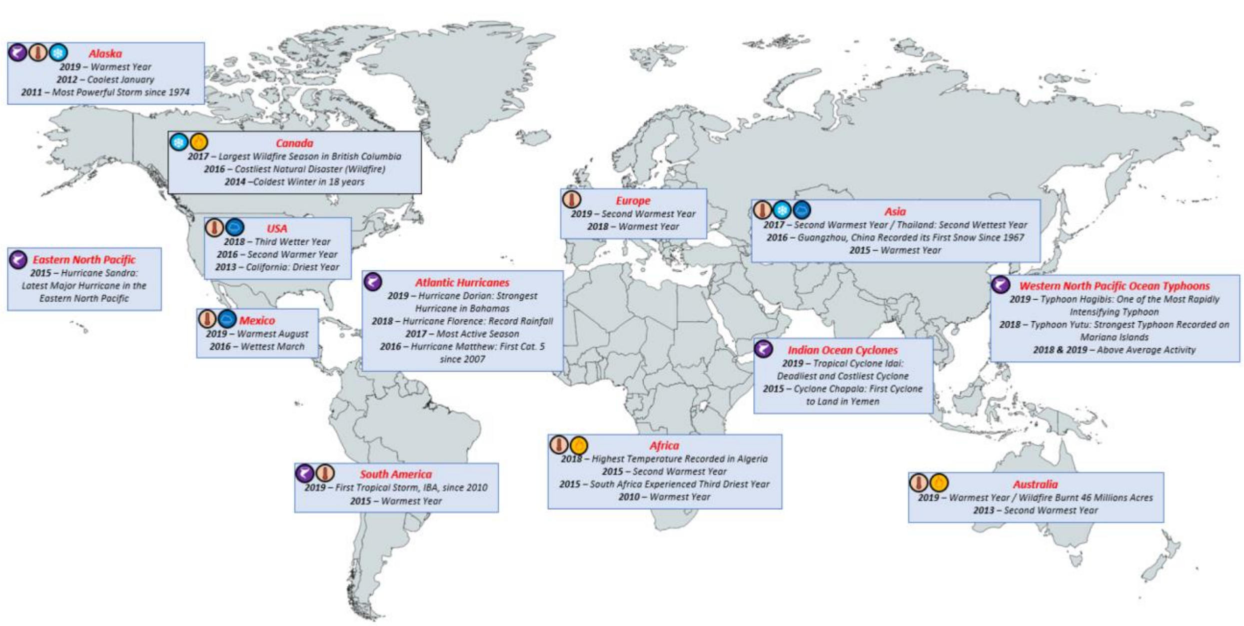

Figure 8-1 - Selected Climate Anomalies Between 2010 and 2013
Source: NOAA Annual Global Climate Report 2010-2019

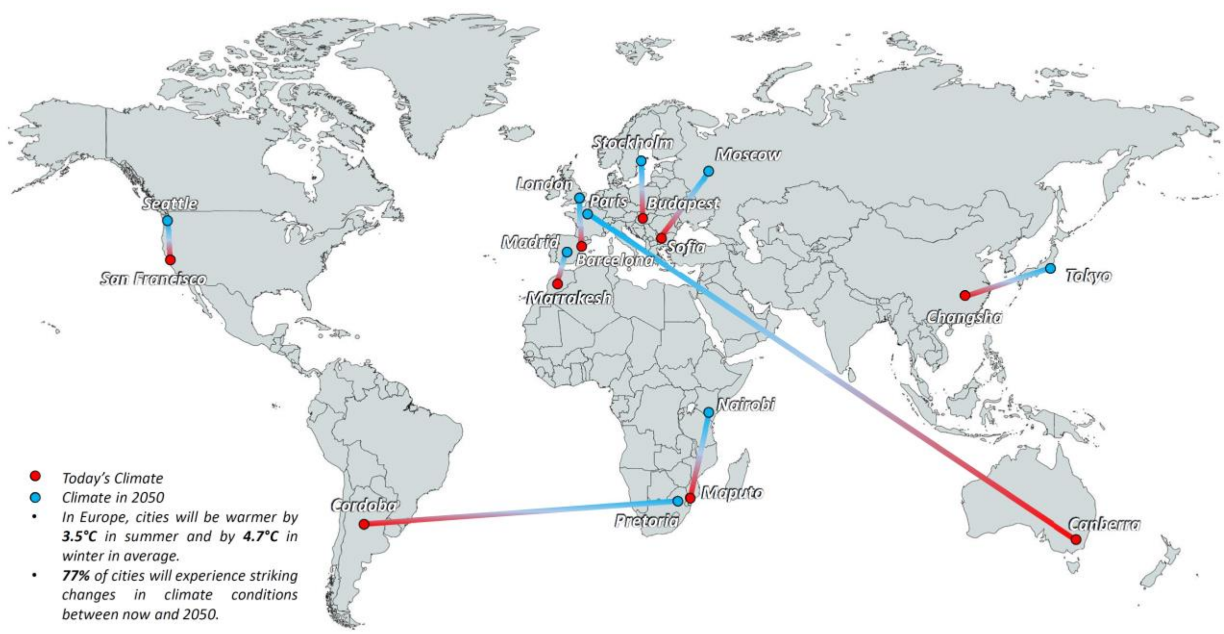

Figure 8-2 - Comparison Between City Analogues From a Climate Perspective
Source: Understanding climate change from a global analysis of city analogues, ETH Zurich, PLOS ONE, 2019

Beyond the extreme weather conditions, the overall climate is evolving. According to a study by a team of ETH Zürich researchers, the 2050 climate in London will be more similar to the current one in Barcelona. Seattle might experience conditions closer to today's San Francisco. Nairobi might feel like Maputo, and Tokyo like Changsha.[113] Such changes will redefine critical criteria for airport design and operations such as the 100-year floodplain, the average temperature, or the windrose. A significant change in climate might also have an impact on soils. The most expose airports to geotechnical changes are perhaps the facilities in the polar regions that lie on permafrost, a material whose specificities are changing under the warming of the local climate.[114]

The climate is warming globally, but it is also becoming more unstable, creating more anomalies that affect air traffic and damage infrastructure. For instance, NASA predicts an average of 2 to 3 days of additional days of thunderstorm conditions annually beyond the 2070 horizon compared to the second half of the 20th century.[115] Research works suggest that extreme El Niño–Southern Oscillation (ENSO) events could be more frequent.[116] ENSO is associated with wildfires in Australia and Southeast Asia (haze and low visibility) and heavy rains in Peru and Ecuador (flooding and erosion). In 2004, the southern States of Brazil experienced the landfall of Hurricane Catarina – a first by the weather records available.[117]

Global warming is not the end of aircraft de-icing activities – more the opposite as violent cold weather might happen even at locations that are usually spared by frost. While the frost-free season will be longer at several airports of the temperate zone[118], winter storms could be more frequent. In other words, to cover the same level of risk on operations as of today, airports and their stakeholders might have to conduct investments with lower benefit-cost ratios. Climate change will have a broader impact on operating costs. An increase in the number of hot days will trigger a higher utilization of air conditioning in the passenger terminal buildings – another case for more energy-efficient buildings – and can impact the commercial payload of some flights[aa]. They will require construction projects to consider higher contingencies for covering interruptions and delays due to adverse weather conditions, including heavy rain and heat waves.

One of the most impactful and dramatic effects of climate change is the rise in the average sea level. Coastal airports – and metropolitan areas – are directly threatened by the rise in the sea level. Models show that some metropolitan areas might be permanently underwater.[119,120] Most of the Asian delta areas are terribly exposed. By 2070, most of Bangkok, Ho Chi Minh City, Shanghai or Tianjin could be permanently flooded if massive adaptation plans are not undertaken. Annual and decennial flooding events would flood commercial airports such as GIG, JFK, LGA, PHL, SDU, SFO, VCE, AMS, LCY under the same assumption. Some inland facilities are not necessarily spared by the redefinition of extreme flooding scenarios due to more violent rainfall events.

The U.S. Transportation Research Board (TRB) identifies 5 key issues regarding climate change resilience of transportation infrastructure: how best to use climate information to improve risk-based decision-making; how to communicate adaptation successes from individual local governments; how to build flexibility and adaptability into policies, designs, and standards; how to make a business case for adaptation; and how to facilitate managed retreat and discourage risky investments.[121] Major civil engineering work might have to be conducted to increase the climate resiliency of several airports. Kansai International Airport is the perfect example of the symptoms and remedies that other airports might have to face. New facilities will have to be designed to sustain the conditions of the long-term future. Ultimately, retreating will be the most adequate scenario for some facilities that are excessively exposed to extreme weather events – e.g., aerodromes subject to permanent flooding due to the rise of the sea level if costly actions are not undertaken.

[aa] This statement applies to existing aircraft types only as new aircraft types have better takeoff performances.

Topic No. 9: Mobility and Communities

Airports are Part of their Community

Airports do not have "surrounding" or "neighboring" communities. They are part of and a member of these communities. Airport communities can take different forms and meaning even at a single airport, depending on the matter. For the purpose of this paper, the concepts of inner and outer communities are defined. Their exact extend and composition might vary from an airport to another.

The inner community, in the direct vicinity of the airport, is exposed to specific, direct economic benefits but also negative externalities (higher noise exposure). The inner community includes cities where the airport is sitting on, and adjacent ones turned toward the airport because they depend on it economically or are directly exposed to its externalities. A key attention from the airport should be seeking a peaceful and mutually beneficial coexistence with its "neighbors". This could be achieved by helping them insulate homes and workplaces against noise when relevant and developing an adequate land use plan for allowing a fair and balanced development.

The outer community is served by the airport and may encompass its primary catchment area to include the macro-region. The outer community encompasses a large diversity of parties benefiting from or concerned by the airport. This includes local passengers flying their community airport, business and economic development community looking for a dynamic airport supporting them with more direct flights, local governments, and various agencies involved with the wide range of airport-related challenges and opportunities, etc. Its footprint could include the metropolitan area and a broader region, depending on the aspects considered. Large hub airports are gateways for entire regions and countries. Airports in remote and scarcely populated areas enable opportunities for vast territories.

Inner Community: Mitigating Adverse Impacts and Making the Airport a Center for Opportunities

The inner community of the future should be connected to and supported by its airport. Adverse impacts and in particular noise must be better taken into considerations in countries where land-use policies and insulation programs are not yet in place or enforced. But community issues go beyond the noise and pollution aspects that are developed further in Topic No. 10. Accessibility around an airport can be paradoxically an issue when all ground transportation is directed toward the airport and designed for draining passengers to other centers of residence, consumption, and decision. Airports should be an opportunity to better connect territories and communities – not to divide or isolate them further. Mobility on and around airports should be improved, and it can be a testbed for sustainable solutions to prevent negative impacts on local air quality. Airports such as Amsterdam Airport Schiphol or Zurich International Airport are exemplary regarding local mobility with multiple modes serving the airports and extending to communities around – especially bike lanes and bus services. At the airport itself, multimodal hubs and other Ground Transportation Centers (GTC) facilitate the connection between the airport and the local public transportation.

Airports increasingly promote a recruitment in their inner communities for fostering the integration of their population, reducing unemployment and providing opportunities for social mobility, and growing an airport-centric community. In return, a dynamic inner community can develop a whole ecosystem of small businesses that can ultimately be connected to airport-based activities and an airport trade center that will be served by various local services. This is a positive "aerotropolis"-like dynamic that can be fostered by an adequate holistic vision of airport strategic planning. Airports and local governments should work closely to make coordinated plans to achieve these objectives. Similarly, the airport and local long-term visions and plans should align or at least be consistent. This requires a continued partnership for success between their governances and a crossed involvement in their respective planning initiatives.

Ideally, the nearest and most exposed land around the airport should be prioritized for industrial, commercial, and greenspace purposes.

However, several airports around the world have residential areas in their immediate vicinity. They are often inhabited by lower income households – and voiceless communities in some parts of the world. Sometimes, these communities relocate around airports pushed away from their original settlements because of uncontrolled gentrification without the social justice component. Climate gentrification is an emerging issue that might make this phenomenon more severe. At the same time, the same lands around airports might become the target of industrial or business real-estate developers. This calls for a special attention to social justice in planning and development. Comprehensive and inclusive public involvement and community outreach are vital for ensuring a fair and just representation of the local population – and compensation when insulation or relocation are warranted. Local governments and airports can also be innovative. For instance, participatory democracy has shown great achievements at non-airport locations in the improvement of the quality of life, the development and beautification of neighborhoods, and the enhancement of the local political system[122] with residents being in charge of part of the decision-making process regarding future orientations and budget allocation.

Figure 9-1 - Inner and Outer Airport Communities

Outer Community: Achieving a New Mobility on the Ground and in the Air

One of the main challenges of the 2040 and 2070 horizons for airports serving large outer communities will be mobility. Virtually all major metropolitan areas are facing some kind of acute congestion symptoms. Moscow, Istanbul, Bogota, Mexico City, Sao Paulo, London, Rio de Janeiro, Boston, Los Angeles, Roma are among the worst cities in the world for the average accrued number of hours spent sitting in traffic annually. Accessibility has a direct impact on the attractiveness of airports as both transportation mode and workplace.

We are at the edge of a revolution in urban mobility, and airports shall embrace it in order to increase their attractiveness and their connectivity to their communities. Mass transit is being implemented in new cities, including countries that have been historically reluctant to fund public transportation systems. Bus Rapid Transit (BRT)[123] that emerged in the 1970s in Brazil and Canada is sometimes seen as a less expensive and more flexible alternative to light rail as it can leave the dedicated BRT lanes to extend services on shared roads.[124] High-speed or express (higher-speed) rail corridors are conquering new territories – such as Central Florida[bb]. More direct trains are being built to connect airports to downtowns (e.g., Paris, São Paulo). Maybe closer to us than it might appear, automated and connected vehicles (AV/CV) will unlock new perspectives with widely available and accessible low-cost ridesharing that could even replace individual car ownership at some point. However, as AV/CV could optimize the utilization of roads through network coordination using artificial intelligence, they will not provide a relief to existing congestion as they share the ground-level resource available with existing modes and vehicles. AV/CV will replace or add vehicles to the existing traffic. If they are highly affordable, the AV/CV-based TNC offer might even seduce current users of mass transit, take revenues out of public transportation, and worsen congestion issues.

We have to rethink mobility and think out of the box to develop new capacities that are complementary to existing modes. In large cities that already have such systems but are still facing acute congestion issues, innovative modes are emerging. With the resource being scarce at ground level, they explore options underground and in the air. The City of Chicago has selected The Boring Company to implement a service of underground shuttles and individual car electric trailers based on its signature concept of Maglev-like electric skates[cc]. More traditional metro might benefit as well from lower boring costs thanks to the technologies and processes developed by The Boring Company. Start-up developing hyperloop systems have proposed lines including airport stations. Urban Air Mobility (UAM) is promising as well for providing point to point connections from the airport. In some cities, waterboats and ferries might revive or increase services to airports. Venice (VCE), Boston Logan (BOS), London City (LCY) have active docks nearby. In large metropolitan areas, the future is most likely a combination of these urban mobility solutions – like it is often already the case – to address the demand.

Ultimately, the evolution of ground airport access has an impact on airport planning and development. All these different users (passengers, aviation and airport professionals, local residents) and modes need to converge at some point, and this can be achieved through multimodal centers that increase interconnectivity, mutualize resources, and make a better utilization of space. This diversity of modes leads to a higher demand in space and infrastructure on the landside. At many historical airports, expanding or redeveloping the immediate curbside area might be excessively costly and impactful to ground accessibility. A solution can be to create a reasonably remote Ground Transportation Center (GTC) connected to the airport by a people mover.

[bb] Brightline/Virgin Trains USA plan to start express services to Orlando International Airport from South Florida via Cocoa starting in 2022.

[cc] This concept has recently evolved toward a car-centric tunnel system used by electric AV/CVs equipped with alignemnt wheels.

From an operations stand-point, these new modes will have an impact on revenues. The rise of AV/CV and Urban Air Mobility could deplete airport parking garages. Passengers might ride to the airport using automated ride share vehicles ordered from their smartphones. Personal vehicles themselves could be replaced by some kind of fractional ownership alternatives. Airports have to anticipate this change that might be more impactful and brutal than the development of Transportation Network Companies (TNCs). They could consider levying a user fee for future on-request AV/CV drop-off and pick-up. Existing parking garages could be turned into heliport/vertiport for Urban Air Mobility (UAM), office spaces, or hubs and maintenance centers for AV/CV fleets.

Another operations aspect of these new modes is their compatibility with the future remote service that will be offered to passengers. For instance, it is possible in many large cities to check-in bags at the train station in downtown (e.g., Hong Kong, Kuala Lumpur). The practicality of some of these services can be hampered by other aviation-specific needs. In particular, the value proposition of modal options should not adversely affect safety and security.[dd]

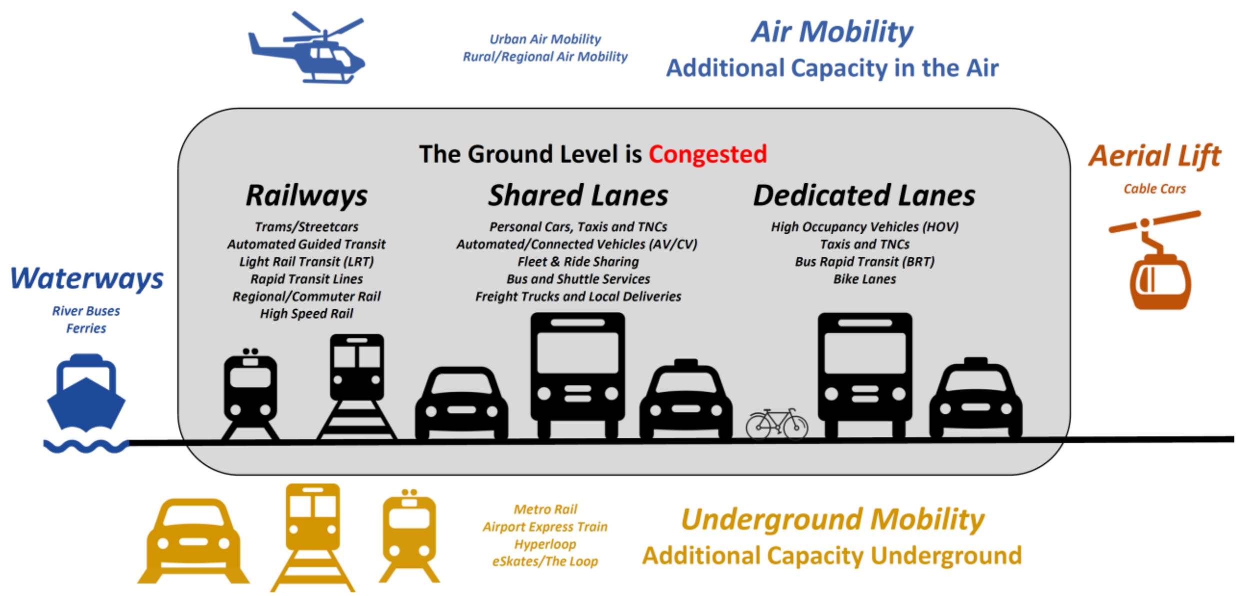

Figure 9-2 - Innovative Modes of Transportation Can Help Relieving Acute Urban Congestion

[dd] From 1956 to 1980, the Silver Arrow rail-air service proposed to passengers between Paris and London to ride by train from Paris to Le Touquet–Côte d'Opale Airport (LTQ) and take a plane from there to cross the Channel. From a period of time, the train was stopping on the apron and passengers could walk straight to their plane. Such seamlessness cannot be achieved today as it might require additional safety and security nets.

Topic No. 10: Sustainability and Airport-Citizens

The Negative Externalities of Aviation

Like any human activity, air transportation has negative externalities. Aircraft noise has been the first airport-related issue to be recognized as so. Programs and activities aiming at reducing the number of people affected by noise have had significant effects since the 1970s in several countries. However, according to ICAO, the footprint of the 55 dB DNL noise contour[ee] from 315 commercial service airports representing 80% of the global traffic could double if no progress is made on aircraft technology. The 2015 footprint represents 14,400 km^2 and 30 million people. Advanced but achievable technological improvement could stabilize this accrued noise exposure to its 2015 level and even reduce it. While the aircraft and engine design industries are working on such improvements, airports and governments also have a strong role to play for reducing this footprint, enhancing the insulation of the most exposed homes, and lowering the number of residents within this contour on the long-term. ICAO's standards and recommended practices (SARPs) on aircraft noise at airports include the framework for aircraft type noise certification expressed in the Assembly Resolution A39-1 of 2016[125]. It also includes the guidance developed through the “Balanced Approach to aircraft noise management” (Doc 9829) which is based on four main levers: Reduction at source, land use planning and management with policies and guidance provided in several documents[126,127,128], operational improvements such as noise abatement procedures[129,130] including the Noise Abatement Departure Procedures (NADP)[131] and the Continuous Descent and Climb Operations (CDO & CCO)[132,133], and operating restrictions including noise charges on the noisiest aircraft types[134,135]. This Balanced Approach analysis is specific to each airport geography, traffic, and conditions and a social and economic analysis must be undertaken for each measure envisaged.

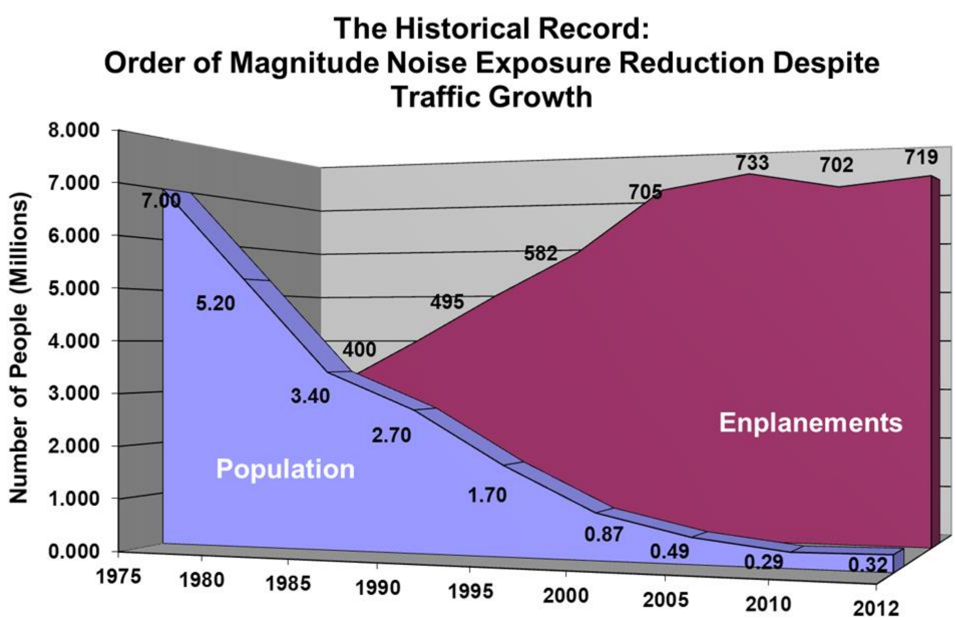

Figure 10-1 - Evolution of the Population Living Within 65 dB DNL Contours in the United States
Source: U.S. Federal Aviation Administration

[ee] The Day-Night average sound Level (Ldn or DNL) is the average noise level over a 24-hour period. The noise level measurements between the hours of 10PM and 7AM are increased by 10 dB before averaging. This noise is weighted to consider the decrease in community background noise of 10 dB during this period.

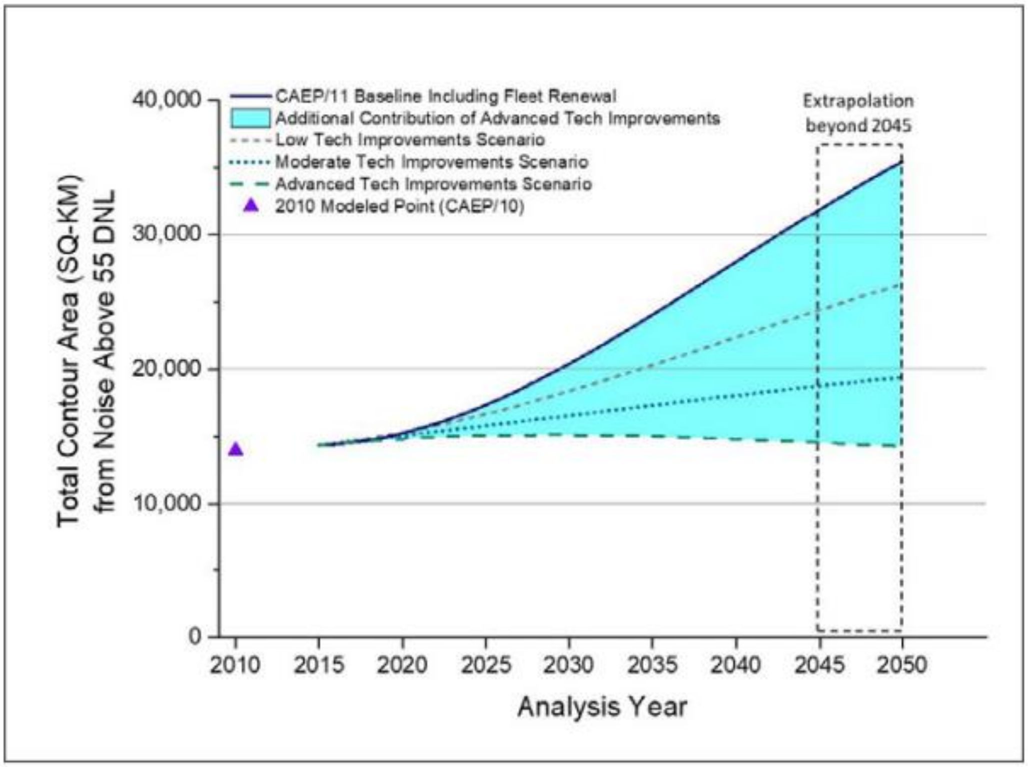

Figure 10-2 - Total Aircraft Noise Contour Area Above 55 dB DNL for 315 Airports (2010-2050)
Source: ICAO

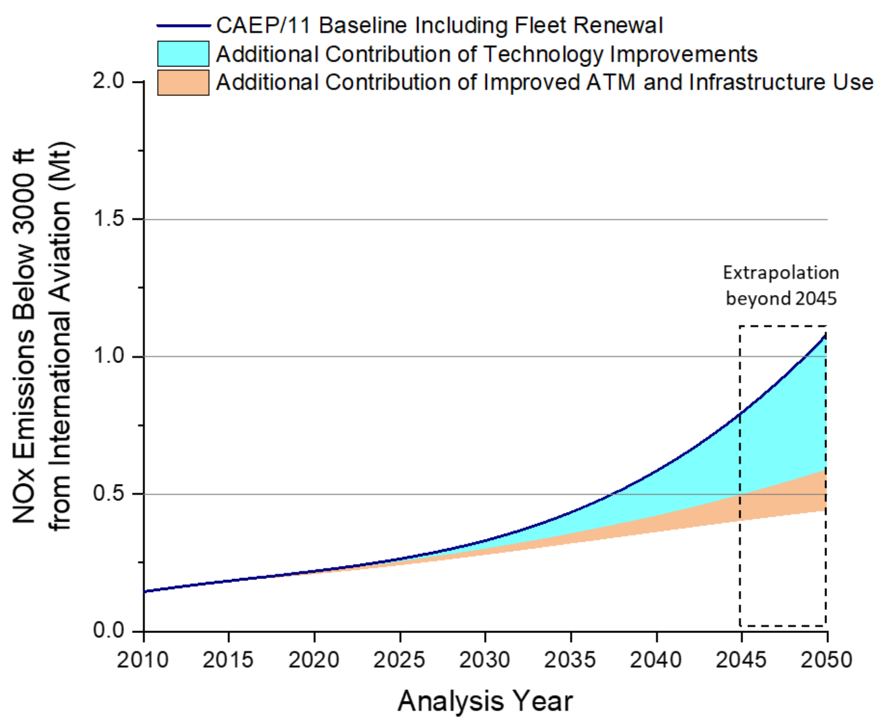

Figure 10-3 - Aircraft NOx Emissions Below 3,000 ft. from International Aviation (2010-2050)
Source: ICAO

Aerial pollution (e.g. NOx and particles) and greenhouse emissions (e.g., carbon dioxide) are the main types of gaseous externalities of an airport. Airports shall have a holistic vision of these emissions when preparing a sustainable plan. They should include the emissions of aircraft, ground handling services, passenger terminals and support facilities, landside facilities, but also ground transportation from and to the airport for passengers and airport workers, and emissions of their supply chain as well. On the airside, in addition to the tremendous improvements accumulated over the years by the introduction of new aircraft compliant with stringent certification requirements based on ICAO SARPs, the rapid dissemination of electric ground support equipment and the restriction of the use of APU have the potential to bring the direct emissions of the turnaround process at the gate down to zero. Lower-emission taxiing using tow-tractors (e.g., TaxiBOT) or built-in device (e.g., EGTS, Wheeltug) can reduce emissions from the gate to the runway threshold area. The attractiveness and commercial success of these technologies are highly dependent on the variation of fuel price and their compatibility with existing airport facilities. On the landside, providing and promoting mass transit and greener modes of transportation is an active part of a sustainable plan. Passenger terminal facilities are also major energy consumers and waste producers. Standards, building codes and certifications such as EDGE of the World Green Building Council (WGBC), Leadership in Energy and Environmental Design (LEED) in the United States, the Building Research Establishment Environmental Assessment Method (BREEAM) in the United Kingdom or the Green Building Index (GBI) in Malaysia lead the way toward greener buildings.

Impact on natural spaces – streams and biodiversity – have been recognized since the years 1970 with one of the first ever airport environmental studies carried out by the Everglades Jetport project in the United States. The study led to the cancellation of the project due to the significant impact it would have had on the Floridian Everglades. Since then, conducting environmental impact assessments has become progressively a standard in eco-responsible countries that have made them a requirement by law. Other externalities include water discharges that can be a specific concern during winter operations – salts from pavement de-icing and glycols from aircraft de-icing. More recently, the awareness of nocturnal artificial light as a public health issue has arisen. Its impact on wildlife has also been documented. Switzerland was one of the first countries to take measures to fight this pollution with recommendations made in 2005 by the Federal Office for Environment that was followed by local and then federal regulations. Other countries and local governments[ff] have followed with their own regulatory framework (Slovenia, 2010; France, 2018; Mexico, 2020).

The Value Added of Aviation to Society

Aviation is essential to our modern, globalized economy. Aviation supports most of the 17 Sustainable Development Goals (SDGs), developed by the United Nations in 2015. A comprehensive study was developed by the Air Transport Action Group (ATAG) in 2017.[136]

Airports make a massive contribution to the economic welfare of regions. They are centers of direct and indirect employment: personnel employed by airport operators directly and by other entities at the airport represent more than 6.1 million jobs globally. Airports trigger large investments for maintaining and developing their infrastructure that lead to further local jobs. The typical multiplier between direct (airport) and indirect (airport-induced) jobs at an airport is around 2. They require ground infrastructure that will benefit the outer community and the region, such as highways, trains, and utilities. They create revenues being taxed by governments, from additional income tax to VAT. Amsterdam Airport Schiphol accounts for about 3% of the Dutch GDP. The larger Schiphol Mainport region generates about 15% of the national GDP. High-quality air service increases the offer. It enables a broad range of opportunities and widens the horizon of possibilities, attracting businesses, residents and tourists.

[ff] While the U.S. does not have federal regulations on light pollution, nearly 20 of States and territories impose restrictions.

Airports create high speed mobility options between cities, regions, and countries offering direct connections to the world for manufacturers and investors. Some businesses require aviation to move their workforce (e.g., banking, insurance, consultancy, IT, etc.) and goods (e.g., pharmaceutical industry, IT, flowers). Aviation does not benefit to large corporations only. It creates new opportunities for small local producers. The Nuestra Huerta initiative of Mariscal Sucre International Airport in Quito, Ecuador, integrates small farmers to sell their product at the airport. Kenya's booming horticulture industry could not export their products to the world up to the worldwide market of Amsterdam without air freight.

Tourism has been a powerful economic contributor and development driver for many regions and countries all over the world such as the Greater Paris in France, the U.S. State of Florida, Brazilian's Nordeste, Morocco, Mauritius or Thailand. More than half of the international tourists travel by air[gg]. In 2001, 72% of tourists visiting Costa Rica arrived by plane. While the country has pledged to shutdown mineral extraction, stop deforestation, and focus on more sustainable resources such as responsible tourism, air transportation is a necessity to achieve these goals.

Airports provide mobility to remote or scarcely populated areas. Communities in the Great North, the Caribbean, and the Pacific Ocean or the Amazon forest are delivered with essential goods and services (freight and mail), have access to education and health services, and can move long-range by plane only. Juneau, the capital city of Alaska, is not served by any road. Traveling between major Andean cities can take days by roads that do not always meet the international practices on roadway safety. Aviation is vital to the Navajo Nation that operates its own system of airports for providing medevac and other services. Humanitarian aid and search and rescue missions need aviation facilities to support their operations as well. In remote areas and across vast territories, connectivity provided by air transport can be more sustainable than if ground infrastructure were built – assuming it is even realistically achievable and desirable. For many insular countries and overseas territories, air transportation is the only means to connect to the world and to move passengers and goods from island to island in a timely manner.

Aviation Has Worked for a Greener Future

The impact of airports – and aviation as a whole – on climate change have been taken into consideration for decades.[137] Aviation accounts for about 2% of the worldwide CO_2 emissions, a constant share since the early 1990s, even if the absolute emissions regularly increase due to the growing demand for air travel. Although CO_2 is the only greenhouse gas (GHG) significantly emitted by aviation, other pollutants (NOx, fine particulates, etc.) are also emitted. Part of these emissions occur at high altitudes, which might increase its net impact according to models. However, there is still an uncertainty on the exact direct contribution of aviation to climate change due to the complexity of its chemistry. For instance, aviation NOx contribute to ozone generation (increasing the greenhouse effect) under certain conditions, and to methane depletion at other altitudes (reducing this same effect). Also, the impact of contrails and their ability to generate cirrus clouds have to be taken into consideration.

This impact should be approached in a holistic way. For instance, comparisons between modes should take into consideration the carbon emitted by the construction and maintenance of the infrastructure, the production and procurement of the materials, and the real emissions of the trip itself – including emissions due to the electricity production for electric trains for instance. It should also include the other environmental impacts of the whole transportation system – e.g., modification of natural spaces and urban/rural discontinuity created by linear ground transportation systems. Modes should also be compared with what they provide. The value of time and the final mobility service should be considered.[hh]

[gg] 57% in 2017 according to the 2018 Aviation Benefits Beyond Borders of Air Transport Action Group (ATAG).

[hh] For instance, long-range, transoceanic flights cannot be compared to light rail.

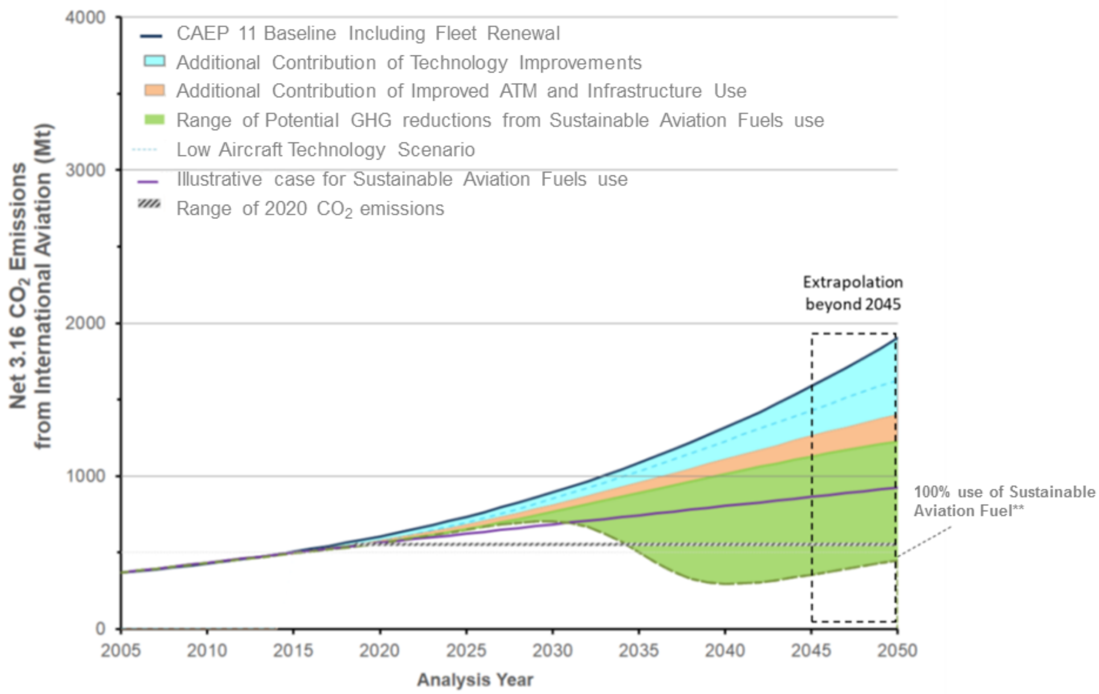

Figure 10-4 - Net CO2 Emissions from International Aviation Including Sustainable Aviation Fuels Life Cycle CO_2 Emissions (2005-2050)
Source: ICAO

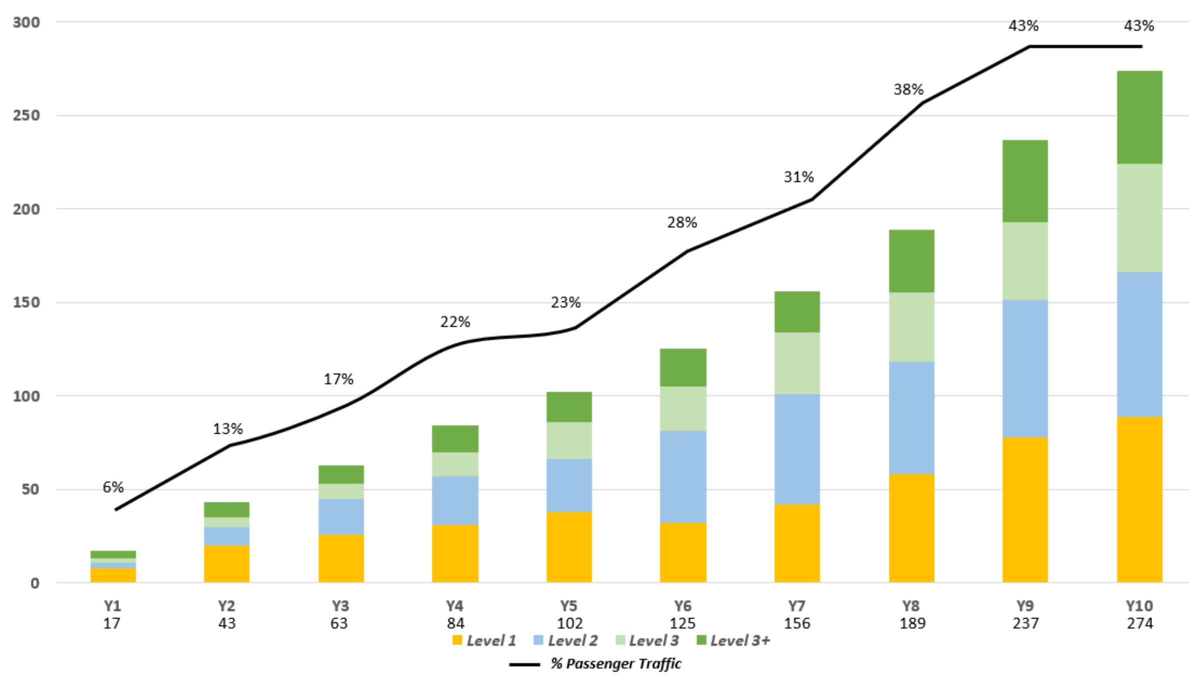

Figure 10-5 - Airports Certified Under ACI's Airport Carbon Accreditation Program (2009-2018)
Source: Airports Council International

The Airport Carbon Accreditation program of Airports Council International (ACI) is a global carbon management initiative that specifically targets airport emissions[ii]. The program has been endorsed by the ICAO since 2011. The initiative provides a framework for airports to reduce their carbon footprint through local green initiatives as well as carbon offsetting in an objective to carbon neutrality. Several airports have already achieved the highest certification Level 4 – which implies carbon neutrality. To apply for certification at one of the 4 levels of the program, airports must have their carbon footprints independently verified in accordance with ISO14064 (Greenhouse Gas Accounting). Evidence of this must be provided to the administrator together with all claims regarding carbon management processes, which must also be independently verified. The definitions of emissions footprints used by Airport Carbon Accreditation follow the principles of the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI) "Greenhouse Gas Protocol" Corporate Accounting and Reporting Standard, the reference in GHG accounting and reporting. When considering the emissions from aircraft within the airport perimeter and on final approach and initial departure, Airport Carbon Accreditation uses the International Civil Aviation Organisation's (ICAO) definition of the Landing-Take Off cycle and requires airports to comply with these definitions. As of 2020, 304 airports are accredited. They account for more than half of the global traffic. Among them, 62 airports around the world are certified Level 4 (5% of the global traffic). Moreover, ACI Europe members pledged in 2017 to become carbon neutral by 2030. Over 20 airport management companies have signed this commitment.

The Airport Carbon Accreditation and carbon offset as a way to reduce the footprint of individual airports should not be underestimated – as should not be ICAO's Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA)[138,139]. At the same time, it is just a first step toward greener airports. Comprehensive decarbonization of airports will require the reduction and, as far as practicable, the elimination of emissions at the source. This includes local ordinances banning excessively emitting solutions when lower-emission alternatives are available (such as the use of the APU at the gate when 400Hz blocks are provided) or incentives to encourage the transition to lower-emission technologies such as VALE in the United States. Avinor at OSL and Port of Seattle at SEA have contributed to the implementation of Sustainable Aviation Fuels (SAF). Per CORSIA, Sustainable Aviation Fuels (SAF) must be produced from sustainable biomass sources harvested from land whose uses changed after January 1, 2008. The first fuel standards were approved in 2009. SAF can be blended with fossil fuels and delivered via existing fueling systems. Electric aviation has a potential of further decarbonization, especially for the general aviation and for short-haul, commuter traffic starting over the coming decade. In Norway, Avinor is leading a national roadmap on the development of e-aviation. London Heathrow is committed to exempt e-aircraft from landing fees. A massive move to e-aviation should be part of a broader vision for a virtuous electric economy. The electricity used for charging aircraft batteries should be itself low-emission – including the supply chain – and the batteries should have a virtuous lifecycle – which might have yet to be developed.

Finally, airports are also stricken by the effects of climate change. The direct effects are specifically explored in Topic No. 8 on operational performance and resilience. In addition, it has several indirect effects in relation to sustainability and corporate responsibility. For instance, in some areas, climate gentrification where the move of higher-income households to areas protected from climate-related events drive a rapid increase of home values and rents might push lower-income households to consider airports' vicinity. Also, climate change will adversely impact the attractiveness of entire regions, and sometimes wipe out natural treasures and leisure activities inducing a loss of revenues – including for airports. It is in the interest of the airport industry to reduce its carbon footprint and work collaboratively with their communities on climate resilience. In 2009, the overall aviation industry (including

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[ii] Aircraft emissions are not included in the program.

manufacturers, airlines, airports and air navigation service providers) committed to reducing their impact on climate change through three main levers:

- Improve fleet fuel efficiency by 1.5% per annum between 2009 and 2020. It is noticeable that a drop of 2.1% per year was actually achieved over that period;
- Starting in 2020, net carbon emissions from international aviation will be capped through carbon-neutral growth. This will be achieved with the implementation of CORSIA, as part of the Basket of Measures defined by ICAO[140];
- By 2050, the net aviation carbon emissions will be half of what they were in 2005. The massive introduction of Sustainable Aviation Fuels (SAF) will highly contribute to this objective.

Aviation Shall Pay for Itself and its Future

In the recent years, several countries have passed or considered passing laws establishing green taxes also known as eco-taxes on aviation (France, Germany). Some have declared they will utilize the funds collected through these taxes to finance or subsidize non-aviation projects – which could include support to highway and railway projects. This would be a disturbing move diverting profits from a mode to give to another that is not necessarily greener, and would create competition distortion. It would raise further questions since rail and road transportation have been progressively privatized. Finally, this is sending a very negative message to aviation that should not been used as a band-aid to the general budget of governments. Furthermore, taxing airlines will reduce their financial ability to renew their fleet with more efficient and greener aircraft.

Such unilateral decisions miss the opportunity to make a bold political statement and create an impetus. Aviation eco-taxes should be used as incentives to aviation pursue further in that direction and reward the efforts made for a lower-emission aviation. In the United States, a popular expression is that “aviation shall pay for itself”. This has been the successful driver of the development of the U.S. aviation system since after World War II. This motto should be applied worldwide and to greener aviation as well.

Topic No. 11: Human Resources and Education

The World Changes and the Workplace as Well

Most of the job descriptions of 2040 and 2070 will include requirements and missions that do not exist today. 50 years or even 20 years ago, airports had no Community Manager or Safety Manager. They are now essential functions in modern airports. Technology is a big driver as well. For instance, Airport GIS created jobs and has proven itself to be an invaluable tool for others with applications from asset management to aeronautical information.[jj] Many vital jobs of the 2040 and 2070 horizons do not exist yet. Moreover, we might not even be able to imagine them.

The workplace itself is changing. Part of the jobs can now be performed from remote locations – including home – with the same or higher productivity. Virtual meeting rooms, document management, document sharing solutions, collaborative tools (e.g., BIM), and workflow management software are among the tools that can power partially remote organizations. These tools also allow employees to work on different projects and sites and have a better balance between their professional life and personal time without compromising work efficiency. This revolution will impact operational jobs as well. It already did it. For instance, ground handling operations are now supervised from hub control centers at several airports. Construction supervisors can be virtually present on a project site. Security perimeters can be inspected from a control center via automated vehicles and sensors. However, teams in the field will still be needed to resolve complex tasks where the machine is not proficient or expert enough, or where direct human interactions are required or preferred due to social choices and cultural acceptance. The most recent Airport Operations Centers (APOC) are good examples of this collaborative work between managers and coordinators at the APOC, systems, and sensors ensuring reporting, alert and assistance to decision-making, and teams in the field that are the arms of this organization and directly interact with the airport environment.

More generally, humans are social animals. They need to gather and share together. Well-being at work and a collaboration environment are keys to performance and efficiency. Being a “great place to work” is also important to attract and retain talents. Studies show that younger workers prefer having the option to work from home, but at the same time, they want a higher level of interaction with their coworkers and their management. The future cannot be about systems but about humans with more freedom and flexibility, interacting with each other and advancing at a faster pace thanks to the systems. Workers are increasingly giving importance to the values of their organization, the meaning of their work, the interaction with their management, the collaboration with their teammates and stakeholders, and the flexibility they can have in managing their daily routine.

Change and Knowledge Management will be Part of Regular Operations

As new technologies are constantly appearing and the succession of innovational breakthroughs is accelerating, we will need a new approach for change and knowledge management. Technological shocks similar to the first IT revolution that required generations to learn and transition to computers and information systems not so long ago will be more frequent. Freshly graduated young professionals might already have to start learning new vital skills shortly after leaving school. Organizations might have to adapt as well. Change management will be part of regular operations. Successful airports will identify these emerging changes early, evaluate their effects on existing conditions, and adapt their organization and train their staff. It would not be surprising to have full-time change manager positions at many airport and stakeholder organizations.

[jj] GIS that was theorized in the late 1960s but its application to airports is mainly a thing of the 21th century.

The next big revolution might be another "IT" revolution with the emergence of intelligence technologies. We are at the threshold of the introduction of artificial intelligence and machine learning on a large scale. Thinking about this second IT revolution as a modification of the way we interact with existing electronic devices and systems is missing the point. This will open a broad field of completely new applications and systems that we can barely envision as of today. Some of them will assist human operators. Some others might even replace human decision-makers. It will create new needs for specialists able to develop and maintain these systems, make sure they interact adequately, and interpret their output – such as what-if scenarios – for final decision-making. This is going to deeply change our interactions with our world, including the way we move, communicate, enjoy, consume and work.

A New Gold Rush to Skilled Workers and Subject Matter Experts

As a consequence, there will be a growing need for continuing education to align skills to needs. As we see major firms creating e-learning hubs accessible to their employees from their computers, this mode of acquiring new skills might become increasingly widespread and organized. Airport training centers are emerging as well for fostering mutual learning across the internal and external stakeholders – such as the "University of Services" of Groupe ADP, the Dubai Airport Launchpad, or the Universidade Infraero. Some of these programs might be developed in partnership with legacy aviation universities to connect these new knowledges to the forefront of the research. Smaller airports will most likely outsource to specialized continuing education firms or utilize the resource of larger airports – raising the question of the financial burden of such a challenge. Mutualization and support from professional organizations are already proven to be a good way to address this, such as AAAE in the United States with training solutions, including the ACE programs[141] or the C2FPA in France that provide training programs and facilities for airport firefighters[kk].

Few universities in the world offer airport-specific programs to prepare the industry leaders of tomorrow. Remote learning and continuing education might fill part of the gap. However, some of the new skills that airports and their stakeholders will need at the 2040 and 2070 horizons might be so technically specific and out of their core business that outsourcing will be evident especially at smaller facilities. Most of the airport operators and aviation administrations will not be able to recruit and retain highly specialized experts able to master new critical tasks out of these core missions. Specialized firms and their subject matter experts will compete for providing the needed services. It is vital for the success of these collaborations that the specificities of airports are not missed by these experts. Aviation itself is an expertise, and moderators educated in aviation might be needed for helping future experts in these new technologies and processes to understand the needs of their aviation clients.

Let's close the gaps and get rid of biases once for all

Gender-based discrimination alone costs up to 12 trillion USD for the global economy – 16% of the global income. Women are historically underrepresented among the transportation workforce, and victim of biases during their career. Only 3% of the CEOs of the aviation industry are women, compared to 6.5% of all the Fortune 500 CEOs – which is still mind-blowing, considering that 49.6% of humans are females. However, pioneers have led the way for the next generations, and airport organizations are changing as well. Prominent female airport leaders among the top 10 busiest airports and major institutions include Angela Gittens, Director General of ACI World[ll] and former Director of ATL and MIA, Jamie Rhee, Commissioner of the Chicago Department of Aviation (CDA), Matrice Ellis-Kirk, Chair of the

[kk] C2FPA was founded in 2007 by a coalition of airport operators and The French-Speaking Airports (UAF&FA). Ownership was transferred to the private firm Groupe 3S.

[ll] Angela Gittens will step down from the leadership of ACI World in June 2020 after more than a decade serving this institution.

Board of Directors of DFW Airport, and Deborah Ale Flint, former CEO of Los Angeles World Airports recently appointed President and CEO of GTAA.

Because the world is our guest, we must reflect on the diversity of our clients and our communities to remain competitive and innovative. A diverse workforce and management are crucial for embracing and addressing the complexity of the challenges to come. Diversity is not limited to gender and ethnicity, but it includes and is not limited to age, sexual orientation, special needs, cultural background, socioeconomic status, and non-airport or aviation experience. Studies have shown the clear benefits of diversity in organizations. Organizations with a diverse workforce are significantly more likely to achieve above-average financial returns.[142] Firms with a diverse management team generate 19% more innovation revenue than those with average or lower levels of diversity.[143] Many leading airports now have a top executive manager in charge of diversity. They have also various initiatives for promoting diversity in their recruitment. However, they shall also ensure inclusion, with a diversity-friendly environment promoting fairness and mutual respect and assuring equal opportunities to everyone. Also, airports and their stakeholders should not be alone in this journey. They should ensure that their contractors and their supply chain embrace the same values and effectively implement diversity and inclusion programs.

While the 20th century fell short in delivering expectations of freedom, justice, and progress for all, we must not let this 21st century follow the same path. Our world cannot afford discriminations and biases. It is not only a question of fairness that should be enough to enact strong policies and effectively enforce them. It is also a matter of resilience of our societies while resources are becoming scarce, and our way of life is being challenged by threats that will strike blindly – even so, everyone is not necessarily equal facing them. Discriminations and biases do not only go against the very fundamental values of aviation that are expressed in the Convention of Chicago on Civil Aviation and are reflected in our diverse clients and workforces.[mm, 144] They prevent talents from emerging, innovations from blooming, and opportunities from coming true. To address the challenges of 2040 and 2070, let's close now these gaps and get rid of biases once for all.

[mm] The Preamble specifies that ""the future development of international civil aviation can greatly help to create and preserve friendship and understanding among the nations and peoples of the world".

Appendix 1-1 - Effects of the COVID-19 Crisis on the Aviation Industry

The COVID-19 pandemic led to a brutal and unprecedented decline in air traffic that has grounded a large part of the worldwide fleet of airliners. This crisis is challenging the aviation industry and its people. While many countries are considering or are implementing economic relief measures to help air carriers and airports, it is also important to remember that the broader aviation community – including ground handlers, fixed-base operators, etc. – is being deeply impacted and should benefit from this assistance as well. Some countries have considered supporting the aviation industry entirely. In the United States, for instance, the $2 trillion relief CARES Act[145] includes a $10 billion increase to the Airport Improvement Program (AIP) with $100 million specifically allocated to general aviation facilities. Provisions for tax relief are included for general aviation operators and direct loans and loan guarantees for repair stations.

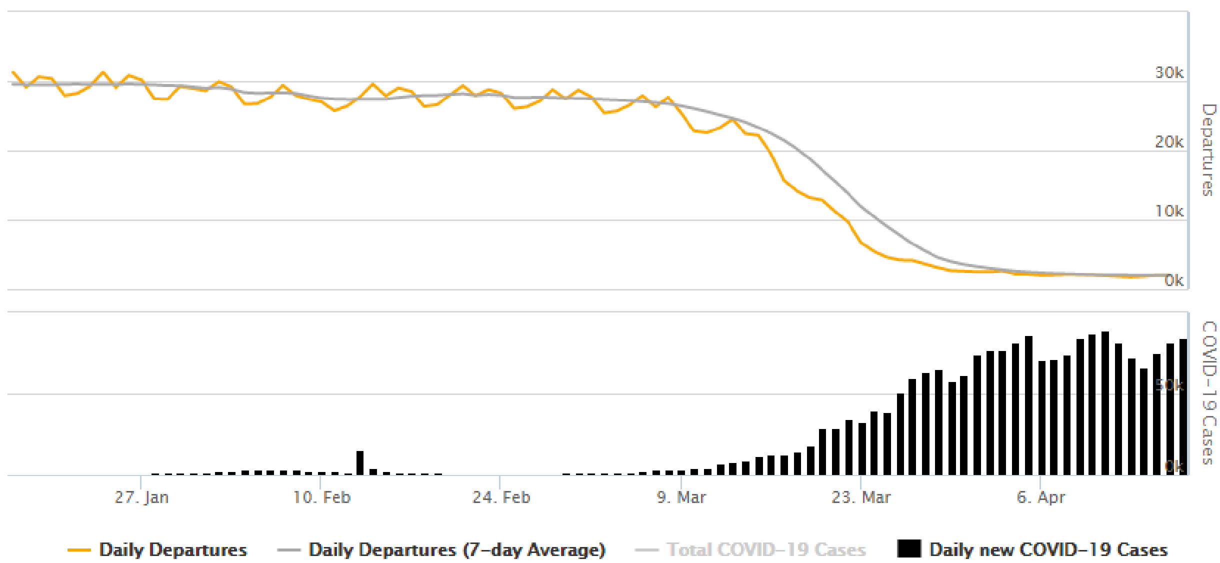


Figure A1-1 - Daily Number of Departures and COVID-19 Cases Worldwide from January to April 2020
Source: ICAO Global COVID-19 Airport Status on April 18, 2020

These bills and measures are critical to temporarily help the industry, but they will not completely offset the impact of the crisis. The effects of this pandemic on air transportation are still uncertain and they will depend on its duration, its severity, and the policies that will be undertaken locally and globally to support aviation and get back to regular operations. In addition, other factors might slow down the demand deep into 2021 and beyond. Without a vaccine, air travelers may reconsider some of their trips – especially the most fragile populations. Even with a vaccine or a cure, the prolongation of the current situation could drive longer-term changes in social behavior. For instance, remote work and web-meetings might further replace face-to-face interactions, decreasing the demand for business-related travels.

Just like 20 years ago after 9/11, we could see a restructuring of part of our industry. Airports should closely follow the choices being made by their air carriers and coordinate with them as far as practicable. Some airlines have already announced they will expedite evolutions of their fleet such as Lufthansa with the phase out of a significant part of their widebody aircraft. Air carriers will leave this crisis financially weakened. Some of them will get bankrupt (e.g., U.K. regional airline FlyBe). This will affect airports and their relationship with their airlines. Smaller airports might be the most impacted as air carriers will focus on the most profitable markets when resuming passenger operations.

We shall not forget that air transportation has already shown an exceptional long-term resilience to short-term shocks. Once the travel restrictions are lifted, air travel will gain momentum again. The path to recovery might be steep, but the road is straight. Its unique ability to move people and goods at high speed on long distances makes it vital for our societies and our economies. However, some conditions are required to facilitate the recovery. First, aviation must ensure passenger safety. Similar to after 9/11, new procedures might be warranted at airports to screen people and make sure they do not carry the virus. COVID-19 shows that monitoring the temperature is not enough as this procedure does not detect asymptomatic carriers. New tests might be able to provide results within 15 minutes which could make them good candidates to integrate the passenger journey at the airport – at least for international flights. Even after a vaccine is found, protocols for checking passengers' health might be warranted to learn from this crisis and limit future outbreaks.

The second condition is that airports might need financial assistance in order to maintain their infrastructure and conduct the necessary development projects to meet the future demand. While the traffic decrease might be temporary, the impact of COVID-19 on airports' cash availability could last longer. The need for investment in capacity and level of service that were identified before the COVID-19 will still be here once the traffic recovers. Also, a slowdown in capital improvement programs will impact contractors and the broader ecosystem of airport construction projects. The United States has already dramatically increased its Airport Improvement Program (AIP) and lifted the need for airport operators to provide part of the funding. Brazil and Canada are waving rents and other concession fees due to the federal government. Other mechanisms such as government loans could be needed to temporarily support the modernization and development of airport facilities.

In the meantime, many aviation facilities are partially closing or seeing a significant drop in their activity – including general aviation airports. This will be momentary. To make the best of a bad situation, this is an opportunity to perform maintenance and construction activities that would be impacting the traffic otherwise, as long as these operations can be funded and are compatible with the local orders and movement restrictions, national recommendations, and industry practices[146,147]. While most of the commercial service airports around the world now have some arrangements for the temporary parking of overflow aircraft, this storage shall be organized to preserve airfield assets.[148] Finally, this forced slowdown can be utilized for reflecting on current and longer-term policies – including sustainable airport initiatives and innovation roadmaps.

Through these difficult times, it is important that all the stakeholders work together and help each other. This is not the first time that aviation has gone through strong turbulences. With our exceptional resilience, if we stay united, and if we learn from this crisis to mitigate the impact of future pandemics, we will prevail, adapt, and leave this crisis stronger and more resilient than ever.

Appendix 2-1 - Current Examples and Trends on Airport Business Models

	Status	Examples	Trends
Private Companies	Majority Private Shareholding Corporations	ACSA, ADR, Aeropuertos Argentina 2000, Aéroports de la Côte d'Azur, Aéroports de Lyon, Aéroport Toulouse-Blagnac, ASUR, Auckland International Airport Limited, Australia Pacific Airports Corporation, AvPorts, Edeis, Ferrovial, GMR, Grupo Aeroportuario del Pacífico, GRU Airport, SOCICAM Aeroportos, Sydney Airport Holdings, Vinci Airports, Voa São Paulo	This model has been growing since the years 1980. Private airport management groups include firms founded by investors, and former public operators sold by their governments to private interests. Both seek concessions of airports, or joint-venture (PPP) with local governments.
Toward Corporatization	State-Owned Companies	ADAC, AENA Aeropuertos, Airports of Thailand, Airports Corporation of Vietnam, Avinor, Bahrain Airport Company, Capital Airport Holding, Changi Airport Group, Dubai Airports Company, Finavia, Groupe ADP, Isavia, Malaysia Airports, Schiphol Group, Swedavia	Many former governmental agencies or companies became autonomous state-owned companies in the years 1980 to 2010. Most of the time, central governments still own a majority shareholding. The question of maintaining ownership is raised in some of these countries with governments reconsidering their role. Their degree of autonomy authorizes them to pursue concessions outside of their historical airports and export their know-how.
	Local government-Owned Companies	Flughafen München, Flughafen Zürich AG, Fraport, Manchester Airport Holdings	In Germany and Switzerland, the federal system promoted a development of airports by the local governments. Later, operators followed a similar process than central government-operated airports and became incorporated with a majority shareholding from local authorities. Their degree of autonomy authorizes them to chase concessions outside of their historical airports and export their know-how.
	Non-For-Profit	ADM, GTAA, YQB	This status is particularly popular in Canada as an alternative to Airport Authorities.
Public Entities	Public Companies	ACITA (State of Coahuila), Aeropuertos y Servicios Auxiliares, EGSA/Alger, EGSA/Oran, EGSA/Constantine, EHCAAN, Infraero, ENANA-EP, ONDA, Régie des voies aériennes	This model, that was common in Europe in the years 1950 to 1980, is now limited to few operators in the world (mostly in Africa, Central Asia, Middle East, Latin America). Public companies are chartered by governments or parliaments. They are not incorporated. Management typically answers to the Department of Transportation. Employees are public workers or similar status.
	Port Authorities	AAI, AAJ, Kenya Airports Authority, MWAA, PANYNJ	This model is popular in the United States to move airport management toward more independence from the political agendas of local governments.
	Governmental Aviation Departments	Alaska DOT, Civil Aviation Authority of Mongolia, DAESP, DEN Airport, GACA, LAWA, MDAD, SAAS	We observe a transition of the business models of Aviation Departments toward concessions and other PPP for the larger airports. Smaller, community-service airfields are still operated by local governments.

Appendix 4-1 - Selection of Physical Attacks Against Airports

Year	Airport	Description	Pattern
1975	SGN	MANPADs hit a Douglas C-54D-5-DC in Vietnam flying from Vientiane to Saigon. Six crew members and 20 passengers were killed in the crash	MANPAD
1978	*Enroute* VFA - SBY	MANPADs hit an Air Rhodesia Vickers 782D Viscount passenger airline by the Zimbabwe Peoples Revolution Army. Four crew members and 34 of the 56 passengers were killed in the crash.	MANPAD
1979	IAD	Bomb planted by Unabomber in the cargo hold of Boeing 727, operated by American Airlines, exploded forcing an emergency landing. 12 passengers were injured.	Bombing
1982	ESB	Bombing and shooting in the middle of a check-in area at Ankara Esenboğa Airport. The attack killed 9 people and injured 72 others.	Firearm attack in terminal
1983	ORY	Bombing of Turkish Airlines Check-in counters at Orly Airport by Armenian militants. The explosion killed 8 people and injured 55.	Terminal bombing
1984	LHR	Bombing at baggage claim of Terminal 2. 22 out of the 60 people present were injured.	Terminal bombing
1985	FRA	Bombing at the international departure lounge in Frankfurt Airport by Palestinian group with Libya complicit. The attack killed 3 people and wounded 74 other others.	Terminal bombing
1985	NRT	Bomb planted by Sikh separatists intended for Air India Flight 301 exploded during baggage handling ops. 2 baggage handlers were killed, and four of them were injured.	Terminal bombing
1985	FCO	Detonated hand grenades and opened fire at people queuing in front of the check-in of El-Al airlines (Palestinian-nationalists). 16 people were killed and 99 wounded.	Firearm attack in terminal
1985	VIE	Detonated hand grenades and opened fire at people queuing in front of the check-in of El-Al airlines. (Palestinian-nationalists) 2 people were killed and 39 wounded.	Firearm attack in terminal
1986	GMP	Bomb explosion outside a terminal building at Kimpo International Airport by North Korea. Five people were killed and 36, injured.	Terminal bombing
1988	AGA	MANPADS hit two Douglas DC-7 from Senegal to Morocco by POLISARIO militants in the Western Sahara on approach to Morocco. One DC-7 crashed killing all 5 crew members. The other DC-7 landed safely in Morocco.	MANPAD
1993	SUI	MANPADs hit a Tupolev 154B operated by Transair Georgia by Abkhazian separatist forces as it was approaching Sukhumi-Babusheri Airport. It crashed onto the runway and caught fire, killing 108.	MANPAD
1994	ALG-MRS	Air France Flight 8969 was hijacked by Armed Islamic Group of Algeria (GIA). Three passengers were murdered.	Hijacking airliner
1994	KGL	MANPADs hit a Dassault Mystère-Falcon 50 executive jet on final approach to Kigali. Aboard the jet were the Presidents of Rwanda and Burundi and its French flight crew. The attack killed all aboard and sparked massive ethnic violence and regional conflict.	MANPAD
1996	REU	Euskadi Ta Askatasuna planted two bombs in a rubbish bin that detonated in the passenger terminals. 35 people were injured.	Terminal bombing
1998	KND	MANPADs hit a Boeing 727-30 Lignes Aeriennes Congolaises airliner just after take-off from Kindu Airport by Tutsi militia. The attack killed all 3 crew members and 38 passengers.	MANPAD

1998	JAF	MANPADs shot by Liberation Tigers of Tamil Eelam terrorists hit an Antonov An-24RV, operated by Lionair, off the coast of Sri Lanka after take-off from Jaffna-Palaly Air Base. The attack killed all 7 crew members and 48 passengers.	MANPAD
1998	NOV	MANPADs hit a United Nations-chartered Lockheed C-130 Hercules transport over Angola flying from Huambo to Saurimo by UNITA forces, killing 14.	MANPAD
1999	NOV	MANPADs shot by UNITA forces hit a United Nations-chartered Lockheed C-130 Hercules transport a few minutes after take-off from Huambo. All 4 crew members and 5 passengers were killed.	MANPAD
2001	USA	A series of four coordinated terrorist attacks by Al-Qaeda. Four passenger planes were hijacked. Two of the planes crashed into the World Trade Center complex, the third crashed into the Pentagon and the last crashed into a field in Stony Creek Township. 2,996 people were killed and over 6,000 were injured.	Hijacking airliner
2001	*Enroute* CDG-MIA	A failed bomb attempt (AQ) to detonate explosives hidden in his sneakers on American Airline Flight 63. Passengers thwarted his plan, and the plane landed safely in Boston. No casualties.	Plane bombing
2001	CMB	Tamil Tigers attacked air force planes. All 14 attackers were killed, along with six Sri Lankan air force personnel and one. Twelve soldiers were injured, along with three Sri Lankan civilians and a Russian engineer. No tourists were harmed during the attack. Five SriLankan Airlines aircraft were destroyed.	Firearm attack
2002	MBA	MANPADs hit an Arkia Airlines Boeing 757-3E7 with 271 passengers and crew as it took off from Mombasa, Kenya by terrorists. Both missiles missed.	MANPAD
2002	LAX	Radicalized individual (Palestinian-nationalists) active shooter opens fire at the EI Al ticket counters. Two people were killed and four others were injured.	Active shooter
2003	BGW	MANPAD hit a DHL Airbus A300B4 cargo jet transporting mail shortly after take-off from Baghdad International airport. Though hit in the left fuel tank, the plane was able to return to Baghdad airport and land safely.	MANPAD
2006	MAD	Van bomb explosion in Terminal 4 parking area (ETA). The attack damaged the airport terminal and destroyed the entire parking structure and killed two people and injured 52 others.	Parking bombing
2007	MGQ	MANPADs hit an Ilyushin 76TD cargo plane shortly after take-off from Mogadishu International. The attack killed the crew of 11.	MANPAD
2007	GLA	Car loaded with propane canisters was driven at the glass doors of the Glasgow Airport terminal and set ablaze. It rammed into passengers. Five people were injured and 1 of the perpetrators died.	Vehicles ramming
2007	JFK	Aborted Islamic Terrorist plot for bombing a system of jet fuel supply tanks and pipelines that feed fuel to JFK. No casualties.	Airport bombing
2009	*Non-Airport*	Body Cavity Bomb (BCB) attack against bin Nayef (SIIED), who was injured.	Active shooter
2009	CMB	Air attack with GA aircraft used as flying bombs by Tamil Tigers targeting military facilities in and around Colombo, Sri Lanka. Two people died and over 50 were injured.	Aerial attack with GA
2011	FRA	Active shooter opened fire at USAF bus parked outside a terminal building. Radicalized individual (AQ). Two people were killed and two other injured.	Active shooter
2011	DME	Suicide bombing by North Caucasus groups in the international arrival hall of Moscow's Domodedovo International Airport. 37 people were killed and 173 injured.	Terminal bombing

2012	PEW	At least five rockets were fired towards the airport by Taliban extremists. Three of those landed within the facility and two hit nearby residential areas. Militants then rammed a car bomb into the perimeter wall, sparking a firefight with troops posted nearby. Nine people were killed.	Firearm attacks
2013	PEK	Individual tries to kill himself with explosives. The explosion only injured the bomber.	Terrorism
2013	ICT	Failed bombing attack by radicalized individual (AQ) with the intention of detonating a car bomb. No causalities.	Terminal bombing
2014	KHI	Ten Taliban extremists attacked the cargo terminal of the Jinnah International Airport with automatic weapons, hand grenades, rocket-propelled grenades, and other explosives. 36 people were killed and 18 injured.	Firearm attack
2014	DOK	Destruction by civil war. Pro-Russian separatist insurgents captured the terminal building of Donetsk International Airport. Paratroopers launched an assault on the airport, accompanied by airstrikes against insurgent positions	Act of War
2015	SAW	Bombing by Kurdish nationalists in the apron area of Sabiha Gökçen International Airport. One person was killed, and one was injured.	Terminal bombing
2015	KDH	Attack and bombing by Taliban extremists at Kandahar Airfield (joint-use airport). 61 people (11 attackers) died and at least 35 wounded.	Firearm attack and bombing
2016	BRU	Two suicide bombers (ISIS) attacked a departure hall at Brussels Airport. The attack killed 32 civilians and three terrorists, and more than 300 people were injured.	Terminal bombing
2016	ISL	Two assailants (ISIS) approached a security checkpoint and opened fire before detonating the bombs they were carrying. 3 attackers and 45 people were killed. More than 230 people were injured.	Firearm attack and bombing
2017	FNT	Radicalized individual (AQ) stabbed a police agent in the neck at Bishop International Airport. Police agent survived the attack.	Terrorist attack
2017	FLL	Active shooter opened fire near the baggage claim in Terminal 2. Five people were killed while six others were injured.	Active shooter
2017	ORY	Radicalized individual fails seizing weapon from a soldier of the Sentinelle operations. The individual was killed.	Firearm attack
2017	KUL	Kim Jong-Nam (brother of Korean dictator Kim Jong-Un) was attacked by two women with VX nerve agent near an airport self-check-in kiosk. Assassination was said to be ordered by the DPRK regime.	Chemical weapon
2019	AHB	Houthi rebels launched drone and missile attacks on a touristic Saudi civilian airport. One person was killed and several others were wounded.	Act of War

Appendix 4-2 - Selection of Cyberattacks Against Airports

Year	Airport	Description	Target(s)
2013	ISL	Access to the passport control system used at the international departure checkpoint was blocked by an alleged cyber-attack on July 26. Passengers stood in lines for hours and plane departures were delayed.	Passport Control System
2015	WAW	Around 1,400 passengers of the Polish airline LOT were grounded at Warsaw's Chopin airport on Sunday after hackers attacked the airline ground computer systems used to issue flight plans	Airline System
2016	BKP	Malware used to attack 3 Ukrainian energy providers was detected in a computer of the IT network of Kyiv's main airport (Boryspil). This network connects to air traffic control systems as well.	Energy Management
2016	HAN/SGN	Hackers successfully pulled-off cyberattacks against Vietnam's two largest airports and Vietnam Airlines. The attacks were attributed to a Chinese hacking group known as 1937CN. The govt. reported that hackers failed to cause any significant security issues or air traffic control problems.	Flight information Screens
2018	ATL	Hartsfield-Jackson Atlanta International Airport shut off its internal Wi-Fi network as a security measure as the City of Atlanta's network underwent a ransomware attack. ATL switched off the Wi-Fi service to avoid any malicious ransomware spreading to airport authority computers, airline computers, and possibly customers' computers.	IT systems Airport Wi-Fi
2018	BRS	A cyberattack caused flight information screens to fail for two days. A spokesman said the displays were ultimately taken offline as a precautionary measure to contain the attack, which has been described as similar to a ransomware. The airport temporarily displayed departure times to passengers off whiteboards.	Flight Information System
2018	MHD	Monitors at an airport in Iran were reportedly hacked in protest of the Iranian government. The messages on the screens at Mashhad's airport denounced Iranian casualties in regional conflicts.	Flight Information System

Appendix 5-1 - Enhancing Aviation Safety During Airport Construction

This case study provides an example of how stakeholders can tackle together significant operational safety challenges in a reduced timeframe and cost-efficiently with a risk-based approach.

Prior to the mid-2010s, standards and practices in operational safety during airfield construction were deficient. The ICAO Standards and Recommended Practices (SARPs) still feature very few provisions on this matter.[149] One of them (Pattern A for displaced threshold) can actually be confusing. Few countries (Australia, United States) have local standards. Some of them are still a potential source of accidents.[150,151]

In 2009, Chicago O'Hare Intl. Airport (ORD) and John F. Kennedy Intl. Airport (JFK) prepared for runway construction projects involving a temporarily shortened runway with a displaced threshold. Despite a long preparation with the stakeholders and a detailed safety risk assessment with a mitigation plan going beyond the standards, serious incidents happened.[152] In 2011, Paris-Charles de Gaulle (CDG) performed a comprehensive safety risk assessment for a similar configuration to be implemented the next year. The initial search for previous incidents revealed a tremendous number of precursors all around the world and highlighted the lack of a standardized approach for mitigating the related risks.[153]

Research efforts were quickly initiated to correct these deficiencies. The two groups met in Paris in 2011. They shared their views and mutually benefited from their lessons learned. They have maintained contact since then. In the United States, the FAA developed an orange construction signage[154] and new standard layouts for markings that are now featured in AC 150/5370-2G. In Europe, Paris-CDG evaluated different messages for these signs[155], and developed various safety devices within the Infrastructure WG of The French-Speaking Airports (UAF&FA). Both sides worked on enhanced phraseology and dissemination of the aeronautical information to the cockpit.

In September 2016, the Infrastructure Workgroup of The French-Speaking Airports released the initial version of its guidebook on Markings and Signage During Airfield Construction[156]. This publication provides comprehensive guidance on markings and signage, lessons learned on the information of the airfield users, and best practices in safety risk management and stakeholder involvement. Plates propose comprehensive safety mitigation systems combining obliteration of existing items non-applicable during construction and the creation of temporary visual aids. They cover 20 situations including runway, taxiway, helipad, and service roads. They most importantly propose a mature configuration for temporarily shortened runways and runway closures. They introduce innovations such as color runway closure markers, mobile runway closure markers, and the orange construction sign.

In 2017, the European Action Plan for the Prevention of Runway Incursions (EAPPRI) V3.0 featured a new Appendix L on Maintenance, Inspections, Works in progress and Temporary Modifications of the Aerodrome that referenced the guide of The French-Speaking Airports and presented some of its signature mitigation – including the orange construction sign.[157] The same year, the French CAA (DGAC) discussed it during the National Symposium on Runway Construction Safety.[158] In 2018, Airports Council International (ACI) published the most important items of the guide in its guidebook on Managing Operations During Construction[159]. Most of the safety items were adopted by ANAC (Brazil) in its new Manual of Maintenance and Airfield Construction.[160]

In 2020, the Infrastructure Workgroup of The French-Speaking Airports will revise the guidebook to take into consideration the Amendment 14 to the Annex 14 and subsequent update of national and regional standards (e.g. CS-ADR-DSN Issue 4 or the coming FAA Draft AC 150/5300-13B). They will also introduce novelties such as the built-in lighted "X" runway closure lighting system. It will also prepare an action plan to disseminate best practices in the less developed regions of the world.

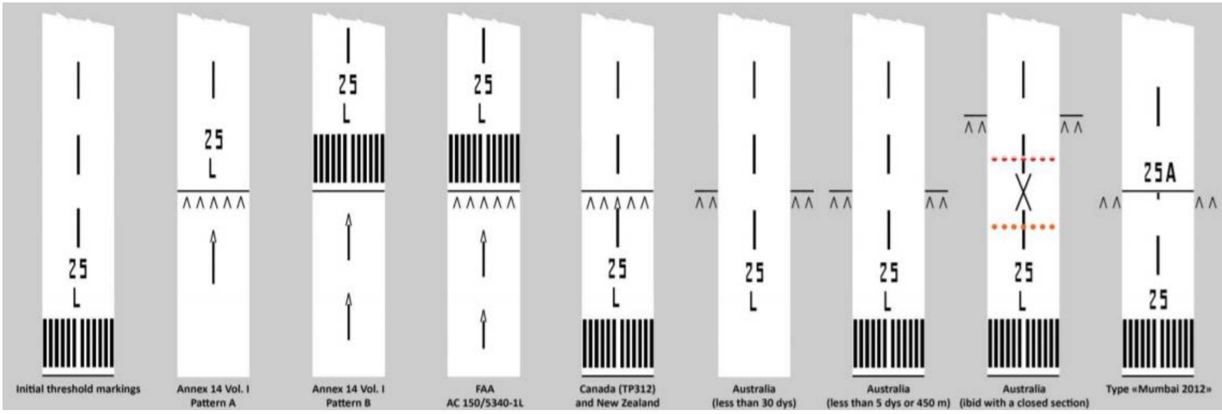


Figure A5-1 - Standards and Practices on Temporarily Displaced Threshold Markings

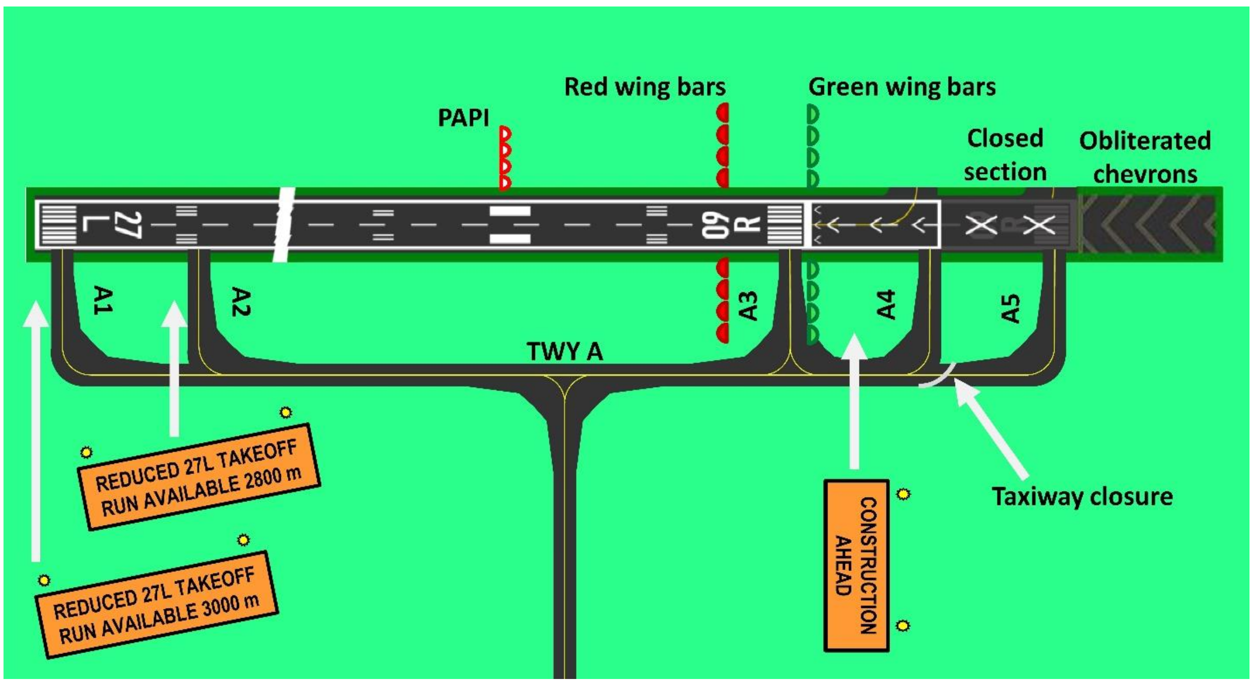


Figure A5-2 - Safety Devices Recommended for Temporarily Displaced Thresholds, Infrastructure WG of The French-Speaking Airports (UAF&FA)

Prior 2010
Standards and practices are not efficient. Accidents are regularly nearly avoided. Safety Risk Assessments are not systematic.

2010-2015
Individual airports become aware of these weaknesses through SMS and team together to create new practices.

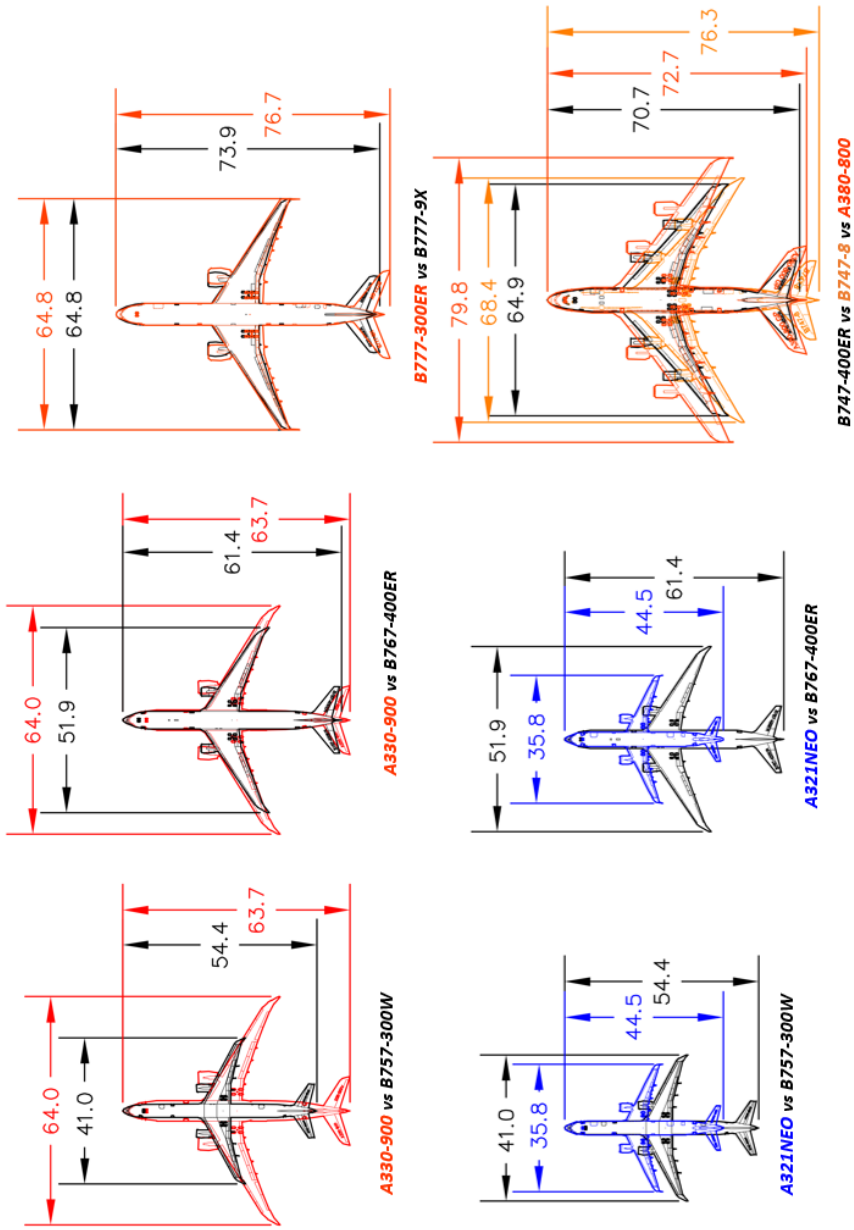
2015-2020
These new practices are codified and adopted worldwide. They are being implemented at a growing number of airports.

2020-2025
Dissemination in the less developed countries. Lessons learned and experience sharing become widespread worldwide.

Toward 2040+
Airports providing real-time information to aircraft and automation increase awareness.

Figure A5-3 - Improving Operational Safety During Airfield Construction

Appendix 6-1 - Comparisons Between Legacy Airliners and Their Successors



Appendix 6-2 - Aircraft Characteristics for Airport Planning

Table A6-1 - Characteristics of a Selection of Airliners at the 2025 Horizon

Manufacturer	Airbus	Airbus	Boeing	Embraer	Mitsubishi
Type	A220-300	A321XLR[2]	777-9[3]	E195-E2	M100
Expected EIS	2020	2023	2021-2022	2019	2023
Wingspan x Length	35.1 m x 38.7 m (115 ft. x 126 ft.)	35.8 m x 44.5 m (117 ft. x 146 ft.)	64.8 m x 76.7 m[2,3] (213 ft. x 252 ft.)	35.1 m x 41.5 m (115 ft. x 136 ft.)	27.8 m x 34.5 m (91.3 ft. x 113 ft.)
Engines	2	2	2	2	2
Seats	120-150	200-244	349-426	120-146	76-84
Max. Range	3,350 NM 6,200 km	4,700 NM 8,700 km	7,300 NM 13,500 km	2,600 NM 4,800 km	1,900 NM 3,550 km
Runway Length Requirement[1]	2,743 m (9,000 ft.)	2,811 m (9,222 ft.)	3,048 m (10,000 ft.)	1,750 m (5,141 ft.)	1,760 m (5,770 ft.)

1 – Takeoff requirement assuming MTOW, ISA, Sea Level, Dry Runway.
2 – The runway length requirement was computed based on the data released for the A321neo.
3 – The runway length requirement was computed based on the data released for the 777-300ER based on Boeing's recommendations.
3 – The 777-8 and -9 will have folding wingtips (FWT). When the FWT are unfolded (takeoff & landing), the wingspan will be 71.8 m (235 ft.).
4 – A proposed lengthened version (777-10X) had a length of 80 m (263 ft.).

Table A6-2 - Comparison Between Concorde and Proposed Future Supersonic Aircraft

Manufacturer	Aérospatiale/BAC	Aerion	Spike	Boom Technology
Type	Concorde	AS2	S-512	Overture
Market Segment	Commercial Service	Business Aviation	Business Aviation	Commercial Service
Expected EIS	1976	2025	2023	2025-2027
Wingspan x Length	25.6 m x 61.7 m	23 m x 52 m	17.7 m x 37 m	18 m x 52 m
Cruise Speed	2.04	1.4	1.6	2.2
Engines	4	3	2	3
Passengers	92-128	8-11	18	45-55
Max. Range w/ Supersonic Cruise	3,900 NM 7,223 km	4,200 NM 7,780 km	6,200 NM 11,482 km	4,500 NM 8,300 km
Runway Length Requirement*	3,600 m (11,800 ft.)	2,286 m (7,500 ft.)	1,828 m (6,000 ft.)	3,048 m (10,000 ft.)
Low-Boom Technology	No	Yes	Yes	No
Airport Compatibility Features	None	Non-afterburning engines	"Boomless" technology	Non-afterburning engines
Unit Cost	160 MUSD	120 MUSD	60-100 MUSD	200 MUSD
Clients	Air France British Airways	Flexjet	–	Virgin Group Japan Airlines

**** Takeoff requirement assuming MTOW, ISA, Sea Level.***

Table A6-3 - Concepts of Hypersonic Aircraft

Manufacturer/R&D	Aérospatiale	Boeing	Reaction Engines	SpaceX
Type	Avion à Grande Vitesse	*Currently Unnamed*	Skylon	Starship
Status	Late 1980s Concept	2020 Concept	In Development	In Development
Type of Flight	Atmospheric	Atmospheric	Suborbital	Suborbital
Wingspan x Length	–	"Smaller than a 737"	26.8 m x 83.1 m (88.0 ft. x 273 ft.)	9 m x 118 m* (30 ft. x 387 ft.)
Cruise Speed	Mach 5	Mach 5	Mach 5.5	Mach 20
Engines	4 ramjets	–	2 ramjets	37+6 rocket engines*
Passengers	150	<100?	30	>100
Max. Range	13,900 km	–	–	–

**** Diameter x height with booster. This is a Two-Stage-To-Orbit, vertical launch/vertical landing rocket. Lower stage has 36 Raptor rocket engines. Starship is equipped with 6 Raptor rocket engines.***

Table A6-4 - Selection of Existing and Proposed Rotorcraft

Manufacturer	AgustaWestland	Bell	Volocopter	Boeing/AFS	Airbus
Type	AW609	Nexus	2X	PAV	CityAirbus
Configuration	Tiltrotor	Tiltrotor	18-Axis/-Rotor	Compound	4-Axis / 8-Rotor
Missions	Multirole	UAM/RAM	UAM/RAM	General Aviation	UAM/RAM
First Flight	2003	<2025?	2013	2019	2019
Overall Length	13.4 m (44.0 ft.)	12 m (40 ft.)	9.15 m (30.0 ft.)	–	–
Rotor Diameter or Overall Width	17.9 m (58.7 ft.)	12 m (40 ft.)	9.15 m (30.0 ft.)	–	–
Engines	2 turboshafts	6 hybrid engines	18 electric engines	1 + 8 electric	8 electric engines
Passengers	6-9	5	1	2-4	4
Max. Range	750 NM	130 NM	17 NM	47 NM	50+ NM

Table A6-5 - Innovative Aircraft Features and Their Impact on Airport Compatibility

Design Feature	**Comments on Airfield Compatibility**	**Example(s)**
Propfan (Open Rotor)	- Less emissions but noisier than comparable turbojets.	Antonov An-70 Boeing 7J7
Tail-Mounted Engines	- Less noise to the ground when airborne than comparable turbojets. - Lower hazards for ground handling. Low risk of FOD ingestion. - Jet blast hazard at higher height.	Airbus A30X CleanSky HSBJ
High-Aspect Ratio Wings	- Wider wingspan might warrant folding wingtip technologies for airport compatibility purpose.	Hurel-Dubois Nasa TTBW
Blended Wing	- Aircraft evacuation concepts to be developed. Existing bridge compatibility? - Doors are farther from lead-in line (jetbridge compatibility). - Larger wheel span for ensuring lateral stability (taxiway compatibility). - Larger high-capacity flying wings (if any) will challenge airport compatibility.	Airbus Maveric Boeing BWB
Boxed-Wing	- Smaller wingspan than comparable turbojets. - Opportunity for engines mounted on upper wing.	NASA/Lockheed
Folding Wingtips	- Significantly increase compatibility with existing airport infrastructure. - Requires airport-friendly CONOPS (see BACG2).	Boeing 777-8/-9

Table A6-7 - Selected Spacecraft Characteristics

Spacecraft Manufacturer	Northrop Grumman IS	The Spaceship Company	SNC Space Systems	Blue Origin	SpaceX
Spacecraft Model	L-1011 Stargazer/ Pegasus XL	WhiteKnight/ Spaceship Two	Dream Chaser	New Shephard	Spaceship
Spacecraft Operator	Northrop Grumman IS	Virgin Galactic	NASA	Blue Origin	SpaceX
Status	In service	Flight tests	In development	In service*	In development
Mission	Small satellites	Suborbital flights	ISS resupply (manned or cargo)	Suborbital flights	Heavy orbital multi-missions
Dimensions	See L-1011	43 m x 24 m (141 ft. x 79 ft.)	(23 ft. x 30 ft.)	7 m x 18 m (23 ft. x 56 ft.)	9 m x 118 m (30 ft. x 387 ft.)
Launch	Under L-1011	Under WK2	ULA Vulcan	Vertical	TSTO
Reentry	N/A	Glided Reentry	Glided Reentry	Vertical	

**** Scientific and commercial payloads only. Will ultimately provide manned flights.***

Appendix 8-1 - Long-Term Threats to Airport Resilience

Threat	Recent Examples	Typical Effects on Airports	Global Mitigation	Airport-Specific Actions
Pandemics and epidemics	Ebola, SARS, MERS, COVID-19, Zika	Short-term & brutal drop in air traffic and revenues, workforce on sick leave, overflow aircraft to store on airfield, etc.	International coordination, trans-national transparent collaboration, national readiness, enhanced hygiene, disease-specific actions (e.g. mosquito control, stay-at-home, etc.), change in social behaviors, economic relief plans, etc.	Airport response plan, prevention plan, designs preventing airborne spread, regular cleaning of parts touched by passengers and workers, soap and hand sanitizer available, prevention voice messages in terminal buildings, specific measure toward arriving passengers, etc.
Climate change-induced extreme weather	Hurricane Barry, Hurricane Catarina, Typhoon Jebi	Interruption of air traffic, destruction of facilities, higher operating costs and capital expenditures, etc. *Note: climate change might create favorable conditions for a wider spread of mosquito-borne diseases.*	Climate resilience, strong reduction of overall carbon emissions and “negative emissions”, etc.	Airport climate resilience plan, incorporation of future climate in planning & design, financial resilience to more regular extreme weather conditions, etc.
Terrorism	Salafi jihadism, white supremacism, radical anarchism, murder-suicide patterns	Medium-term drop in air traffic and revenues, etc.	Global War on Terrorism, intelligence and police efforts, state security strategies, mitigating the roots of terrorism, etc.	ICAO GASeP, local implementation of state security plan, secure-by-design facilities, airport community awareness programs, etc.
Cyberwarfare	State-sponsored cyberattacks	Power outages, systems are out of service, malicious diversion of systems, etc.	National cyber-counter terrorism, cooperation between intelligence community and industry, etc.	IT system hardening, redundancies, operational resilience with low-tech contingency plans, etc.
Conventional warfare	Libyan Civil War, War in Donbass	Drop in air traffic, destruction of facilities	Prevention of conflicts and promotion of enduring peace	Airport-to-airport mutual assistance, evacuation of civilian aircraft toward safe aviation facilities, etc.

Appendix 9-1 - Existing and Emerging Modes of Transportation to Airports

Mode of Transportation	Examples	EIS	Description and Opportunity for Airports
Direct Express Train	AirTrain-JFK Express (JFK), CDG Express (CDG), Heathrow Express (LHR), Gatwick Express (LGW), Flytoget (OSL), KLIA Ekspres (KUL), Skytrain (CGK)	1970s	Direct Express trains usually make a small number of stops, usually major destinations, allowing faster service than local trains that stop at most or all of the stations along their route. Airports utilize this mode of transportation for faster commutes for passengers, unlike the normal trains.
Metro Rail, Light Rail and Regional Train	Berlin U-Bahn (BER), Blue Line (ORD), RER B (CDG), CPMT Line 13 (GRU), OrlyVAL-RER B (ORY), TER (MRS), VLT Carioca Linhas 1 e 3 (SDU), SRT Dark Red Line (BKK)	1972	Light Rail is a form of passenger urban rail transit characterized by a combination of tram and metro feature. Utilization of light rail at airports will aid in the reduction of traffic congestion at the curbside of the airport and also reduce carbon emissions.
Bus Rapid Transit (BRT)	Linha 208 (CWB), Luton Busway (LTN), MICiTi (CPT), Transcarioca (GIG), Viva(Canada non-airport),	1973	BRT is a bus-based public transport system designed to improve capacity and reliability relative to a conventional bus system. BRTs are not new, but some regions of the world are not yet widespread to connect airport. Utilizing BRTs at airports would cut down the travel times for passengers to reach their destinations or get to the airports since they have dedicated bus lanes, and also will help in the reduction of carbon emissions.
Personal Rapid Transit (PRT)	T5-Parking (LHR), Morgantown PRT (non-airport)	1975	The PRT is a public transport mode featuring small automated vehicles operating on a network of specially built guideways. The PRT system in Heathrow will replace shuttle buses. This compared to the Airport Automated People Movers (AAPM) would result in short wait and trip times combined with seated travel to provide an exceptionally high level of service
High Speed Train (HST)	Brightline (Florida), ICE (Germany), TGV (France), InterCity 125 (Britain), Fuxing Hao Dolphin Blue (China), Haramain Western Railway(Saudi Arabia)	1964 (Shinkansen) 1994 (TGV at CDG)	High-speed Train (HST) is a type of rail transport that runs significantly faster than traditional rail traffic, using an integrated system of specialized rolling stock and dedicated tracks. This system can connect customers from one point to another as fast as air travel.
Maglev	Shanghai Maglev Train (SMT)	2002	Maglev is a system of train transportation that uses two sets of magnets, one set to repel and push the train up off the track, and another set to move the elevated train ahead, taking advantage of the lack of friction. With the use of Maglev in airports, it can connect passengers to their final destinations quicker and more efficiently compared to other modes of transportation.
Transportation Network Companies	Lyft, Ola Cabs, Snapp, Uber, Cabify (Spain), Taxify/BOlt (Estonia), Grab (Singapore), Gett (Israel), Ola (India), DIDI (China), Shebah (Australia), TappCar (Canada), Enshika (Ghana)	2017 (Uber)	They offer door-to-door, nonstop transportation at the request of customers via smartphone applications, or apps, that the companies offer and operate. They have increased the transportation options available to airport customers by expanding the menu of available ground transportation services and, offering a service that customers consider to be reliable, convenient, and comfortable
Autonomous Personal Vehicles	None	2025?	AVs are vehicles where some aspects of a safety-critical control function such as steering, throttle control or braking occurs without direct driver input. This will reduce traffic congestions and aid in climate control by reducing CO2 emissions

Mode of Transportation	Examples	Entry into Service	Description and Opportunity for Airports
Electric Skates and High-Speed Tunnels	The Boring Company "Loop" a.k.a. The Elevator (prototype)	2025?	A concept of vehicles transported through tunnels on autonomous electric skates capable of carrying cars and people at speeds of up to 125-150 mph. The most recent evolution of The Loop concept of The Boring Company does not feature electric skates anymore.
Urban Air Mobility	Blade, UberElevate	2025?	It is an on-demand and automated passenger and cargo air transportation services, typically without a pilot, also known as 'flying taxis'. This mode of transportation will add to the industry's stakeholder revenue, and also create more airport transportation jobs.
Vactrain/Hyperloop	Chicago Downtown-ORD (Project)	2025?	Vactrain/Hyperloop is a sealed tube or system of tubes through which a pod may travel free of air resistance or friction conveying people or objects at high speed while being very efficient, thereby drastically reducing travel times over medium-range distances. This may be an alternate option to air transport since it might be as fast or faster than flying.

Appendix 11-1 - Emerging and Potential Airport Jobs at the 2040 and 2070 Horizons

Job Title	Horizon of Emergence	Main Airport Stakeholder(s)	Potential Mutualization	Potential Outsourcing	Description
Database Specialist	2000	Airport Operator	Low	Medium	Database specialists support operations by organizing large amounts of data. They are responsible for making sure data is stored properly and backed up, while using necessary security measures so that the data remains protected.
Safety Manager	2004	All Stakeholders	Low	Low	The safety manager is responsible for providing guidance and direction for the planning, implementation and operation of the airport's Safety Management System (SMS).
CDM Manager (Airside)	2010	AO/ATCT	High	Low	The CDM Manager is the project/program manager of the A-CDM initiative appointed by the Steering Group. He is responsible for the implementation of A-CDM at the airport.
A-CDM Project Manager	2010	AO/ATCT	High	Medium	The A-CDM Project Manager is responsible for the management of the day to day airport project coordination between stakeholders.
Community Manager	2010	All Stakeholders	Low	Low	Community Managers serve as a public virutal face of the airport. They are generally responsible for managing and handling communications in both directions. Community Managers are involved in various activities such as communications, PR, social media, events, and content creation.
Climate Resilience Specialist	2015	Airport Operator	Medium	High	Climate Resilience Specialist is responsible for establishing a framework to design, operate and maintain facilities and systems to decrease their vulnerability to impact of climate change.
Big Data Specialist	2025	Airport Operator	Low	High	Big data Specialists are responsible for utilizing data analytics to evaluate an organization's or system's technical performance and providing recommendations on enhancements.
UAM Coordinator	2025	AO/ATCT	Medium	Low	UAM Coordinator coordinates with the stakeholders to establish a safe operational environment for the UAM traffic.
Airport Operations Planner	2030	Airport Operator	High	Low	Airport Operations Planner will be responsible for the establishment and continued updating of the Airport Operations Plan (AOP).
Personal Hosting Manager	2030	Airport Operator	Low	Low	Personal Hosting Managers at airports will be responsible for managing the airport hosting programs and their customized services to passengers – e.g., personal shoppers, customized offers, etc.

Job Title	Horizon of Emergence	Main Airport Stakeholder(s)	Potential Mutualization	Potential Outsourcing	Description
CDM Manager (TAM)	2030	Airport Operator	High	Low	The CDM Manager is the project/program manager of the A-CDM initiative appointed by the Steering Group. He is responsible for the implementation of a broader Total Airport Management at the airport.
Proactive Cyberdefence Mgr.	2030	All Stakeholders	Medium	Medium	Proactive Cyberdefence Managers will develop security systems, analyze current systems for vulnerabilities, identify potential threats, prepare for future attacks and reconfigure the IT infrastructure in conseaience, and handle any and all cyberattacks at the airport in an efficient and effective manner.
Blockchain Specialist	2030	Airport Operator	Low	High	Blockchain Specialist will develop blockchain based solutions for airport business and management purposes.
AI & Machine Learning Specialist	2035	AO/ATCT	Low	High	IT professional specialized in developing Machine learning, a branch of computer science that focuses on developing algorithms which can “learn” from or adapt to the data and make predictions.
Knowledge Manager	2040	AO/ATCT	Low	High	HR professional specialized in handling knolwedge management programs including the identification of present and future organizations’ needs, analyzing gap with current individual knowledges and skills, and the definition and management of training programs for addressing these gaps.
Meta-CDM Job-Related	2040	AO/Airlines/GND	High	Medium	All jobs related to the Collaborative Decision Making of multimodal and efficient transportation from, to, and at the airport.
Spacecraft Operations Manager	2040	AO/ATCT	Medium	Medium	Spacecraft Operations Manager will be responsible for the management of scheduling and logistics of passenger and freight spacecraft operations.
Biowarfare Expert	2070	Airport Operator	Medium	High	Biowarfare Experts are responsible for the protection from the threat of biological weapons of mass destruction.
Complex Fleet Mix Expert	2070	ATCT	Medium	High	Complex Fleet Mix Experts will be responsible for analyzing and addressing the impact of new additional fleet mixes at the airport on all the aspects of airport operations.

Appendix 11-2 - Selected Higher Education Programs in Airport

University	Campus, Country	Program	Level
Purdue University	West Lafayette, Indiana, USA	Airport Management and Operations	Bachelor's Degree
Florida Tech	Melbourne, Florida, USA	Airport Development and Management	Master's Degree
Ecole Nationale de l'Aviation Civile (ENAC)	Toulouse, France	Aviation Engineering, Advanced Masters in Airport Management, ATM and ANS	Master's Degrees
Instituto Tecnológico de Aeronáutica (ITA)	São José dos Campos, SP, Brazil	Engenharia de Infraestrutura Aeronáutica	Master's Degree / Ph.D.
Cranfield University	Cranfield, England	Airport Planning and Management	Master's Degree
University of West London	West London, UK	Airline and Airport Management	Bachelor's Degree
City University of London	Northampton Square, UK	Airport Management	Master's Degree
University College of Birmingham	Birmingham, UK	Aviation and Airport Management	Bachelor's Degree
Vaughn College	Queens, New York, USA	Airport Management	Bachelor's Degree
Everglades University	Boca Raton, Florida, USA	Aviation / Aerospace Concentration in Airport Operations Management	Bachelor's Degree
University of North Dakota	Grand Forks, North Dakota, USA	Airport Management	Bachelor's Degree
Modern College of Business and Science	Oman	Airport Management	Bachelor's Degree
Civil Aviation University of China	Tianjin, P. R. of China	Aviation Engineering, Air Traffic Management, Air Navigation	Master's Degree / Advanced Masters
Southern New Hampshire University	Manchester, New Hampshire, USA	Aviation Management (BS) Concentration in Airport Mgmt.	Bachelor's Degree

Important: This table is not an exhaustive inventory of airport-related academic programs. It provides a short-selection of higher education programs with a major or concentration in airports for illustrative purpose.

Abbreviations

AAI	Airports Authority of India
AAJ	Airport Authority of Jamaica
ACAC	Airport Construction Advisory Council
A-CDM	Airport Collaborative Decision Making
ACRP	Airport Cooperative Research Program
ACSA	Airports Company South Africa
ADAC	Abu Dhabi Airport Company
ADM	Aéroports de Montréal
ADR	Aeroporti di Roma
AENA	Aeropuertos Españoles y Navegación Aérea
AFIS	Aerodrome Flight Information Service
AHA	Aviation Hazard Areas
AI	Artificial Intelligence
AMS	Amsterdam Airport Schiphol
ANAC	Agência Nacional de Aviação Civil (Brazil)
ANN	Artificial Neural Network
AOP	Airport Operations Plan
APOC	Airport Operations Center
APM	Airport People Mover
ARIWS	Autonomous Runway Incursion Warning System
ASEAN-SAM	ASEAN Single Aviation Market
ASUR	Grupo Aeroportuario del Sureste, S.A.B. de C.V.
ATAG	Air Transport Action Group
ATC	Air Traffic Control
ATCT	Air Traffic Control Tower
ATCo	Air Traffic Controller
ATFM	Air Traffic Flow Management
ATL	Hartsfield-Jackson Atlanta International Airport
ATM	Air Traffic Management
AV/CV	Automated Vehicles/Connected Vehicles
BCB	Body Cavity Bomb
BKG	Branson Airport
BNDES	Banco Nacional de Desenvolvimento Econômico e Social
BVLOS	Beyond the Visual Line of Sight
CAAC	Civil Aviation Administration of China
CAAMS	China’s Strategy for Modernizing Air Traffic Management
CAG	Changi Airport Group
CAGR	Compound Annual Growth Rate
CAH	Capital Airport Holding
CDG	Paris-Charles de Gaulle Airport
CDM	Collaborative Decision Making
CNS	Communication, Navigation and Surveillance
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
DAC	Dubai Airports Company
DAESP	Departamento Aeroviário do Estado de São Paulo
DECEA	Departamento de Controle do Espaço Aéreo (FAB)

DFW	Dallas-Fort Worth International Airport
DGAC	Direction générale de l'aviation civile (France)
DOK	Donetsk Airport
EASA	European Aviation Safety Agency
ECAA	European Common Aviation Area
EGSA	Etablissement de Gestion de Services Aéroportuaires
EHCAAN	Egyptian Holding Company for Airports and Air Navigation
EMI	Electromagnetic Impulse
ENAC	Ecole Nationale de l'Aviation Civile
ENANA-EP	Empresa Nacional de Exploração de Aeroportos e Navegação Aérea E.P.
ENSO	El Niño–Southern Oscillation
ERAU	Embry-Riddle Aeronautical University
FAA	U.S. Federal Aviation Administration
FAB	Força Aérea Brasileira
FAB	Functional Airspace Block
FIT	Florida Institute of Technology
GACA	General Authority of Civil Aviation
GANP	Global Air Navigation Plan
GASeP	Global Aviation Security Plan
GASP	Global Aviation Safety Plan
GIG	RIOgaleão - Tom Jobim International Airport
GMF	Global Market Forecast
GMR Group	Grandhi Mallikarjuna Rao Group
GRU	GRU Airport / São Paulo/Guarulhos–Gov. André Franco Montoro Intl. Airport
GTAA	Greater Toronto Airport Authority
GTC	Ground Transportation Center
HCC	Hub Control Center
HKG	Hong Kong International Airport
IAD	Washington Dulles International Airport
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
Infraero	Empresa Brasileira de Infraestrutura Aeroportuária
IoT	Internet of Things
IPCC	Intergovernmental Panel on Climate Change
IST	Istanbul Airport
JFK	John F. Kennedy International Airport
KIX	Kansai International Airport
KUL	Kuala Lumpur International Airport
LAC	Latin American and Caribbean
LAMP	Landside Access Modernization Program
LAWA	Los Angeles Airport World
LAX	Los Angeles International Airport
LCY	London City Airport
LGA	New York LaGuardia Airport
LGP	LaGuardia Gateway Partners
LGW	London Gatwick Airport
LHR	London-Heathrow
MaaS	Mobility as a Service

MANPAD	Man-Portable Air-Defense System
MDAD	Miami-Dade Aviation Department
META-CDM	Multimodal, Efficient Transportation in Airports and CDM
MIA	Miami International Airport
ML	Machine Learning
MRS	Marseille-Provence International Airport
MUC	Munich International Airport
MWAA	Metropolitan Washington Airports Authority
NEXTT	New Experience Travel Technologies
NFC	Near-Field Communication
NM	Network Manager
NOAA	U.S. National Oceanic and Atmospheric Administration
NOP	Network Operations Plan
O&C	Ownership & Control
OCC	Operations Control Center
OER	Örnsköldsvik Airport
ONDA	Office National Des Aéroports
ORD	Chicago-O'Hare International Airport
ORY	Paris-Orly International Airport
PHL	Philadelphia International Airport
PPP	Public-Private Partnership
PPP	Purchasing Power Parity
PKX	Beijing Daxing International Airport
PRT	Personal Rapid Transit
RAM	Rural (or Regional) Air Mobility
RESA	Runway End Safety Area
RIPS	Runway Incursion Prevention System
RIPSA	Runway Incursion Prevention through Situational Awareness
RIRP	Runway Incursion Reduction Program
ROAAS	Runway Overrun Awareness and Alerting System
ROPS	Runway Overrun Prevention System
RPA	Regional Plan Association
RPK	Revenue Passenger Kilometer
RPZ	Runway Protection Zone
RTC	Remote Tower Center
rTWR	Remote Tower
RVA	Régie des Voies Aériennes de la République Démocratique du Congo
SAAS	San Antonio Airport System
SAATM	Single African Air Transport Market
SAC	Secretaria de Aviação Civil (Brazil)
SAF	Sustainable Aviation Fuels
SAT	San Antonio International Airport
SARP	Standards and Recommended Practices
SDI	Space Data Integrator
SDL	Sundsvall–Timrå Airport
SDU	Rio de Janeiro-Santos Dumont Airport
SES	Single European Sky
SFB	Orlando Sanford International Airport

SFO	San Francisco International Airport
SIIED	Surgically Implanted Improvised Explosive Device
SIN	Singapore-Changi International Airport
SJU	San Juan Luis Muñoz Marín International Airport
SMS	Safety Management System
SWIM	System Wide Information Management
TAM	Total Airport Management
TIP	Tripoli International Airport
TNC	Transportation Network Companies
TOSC	Technical, Operations & Safety Committee
TRB	Transportation Research Board
TRT	Turnaround Time
UAM	Urban Air Mobility
UATM	Urban Air Traffic Management
USOAP	Universal Safety Oversight Audit Programme
UTM	Unmanned Traffic Management
VCE	Venice Marco Polo Airport

References

[1] *World Population Prospects: The 2019 Revision*. Department of Economic and Social Affairs, Population Division, United Nations, 2019

[2] Kharas, H. and Hamel, K. A global tipping point: Half of the world is now middle class or wealthier. The Brookings Institution, September 27, 2018

[3] Demand for Air Travel. In *Global Market Forecast: Cities, Airports & Aircraft 2019-2038*, Airbus, 2019, pp. 12-23.

[4] Commercial Aviation Market Dynamics. In *Commercial Market Outlook 2019-2038*, Boeing, 2019, pp. 4-6.

[5] World – Total passenger traffic: history and forecasts. In *ICAO Long-Term Traffic Forecasts, Passenger and Cargo*, ICAO, April 2018, p. 3.

[6] Yi, Y. China needs 216 new airports by 2035: report. Xinhua, December 11, 2018. http://www.xinhuanet.com/english/2018-12/11/c_137665637.htm. Accessed December 15, 2019.

[7] von Einsiedel, S. et al. Civil War Trends and the Changing Nature of Armed Conflict. United Nations University Centre for Policy Research, Occasional Paper 10, New York, 2017

[8] Dupuy, K. et al. Trends in Armed Conflict, 1946-2016, Center for Security Studies, ETH Zurich, Switzerland, 2017

[9] Ngumba, A. and Karita, M. Single African Air Transport Market – Is Africa ready?, Deloitte, 2018

[10] Law Nº 13.842 of June 17, 2019 modifying Law nº 7.565 of December 19, 1986 (Código Brasileiro de Aeronáutica), Pub. in the DOU of June 17, 2019, Extra Edition, Section 1, Brasília - DF, 2019.

[11] ANAC aprova concessão da Globalia Linhas Aéreas. Agência Nacional de Aviação Civil. https://www.anac.gov.br/noticias/2019/anac-aprova-concessao-da-empresa-air-europa-no-brasil. Accessed April 18, 2020.

[12] Megaregions. In *America 2050*, Regional Plan Association. http://www.america2050.org/content/megaregions.html. Accessed December 15, 2019.

[13] Hoornweg, D. & Pope, K. Socioeconomic Pathways and Regional - Distribution of the World's 101 Largest Cities. Working Paper No. 04, Global Cities Institute, Toronto, ON, Canada, January 2014

[14] Yves, M. Recyclers Cringe as Southeast Asia Says It's Sick of the West's Trash. In *The New York Times* of June 17, 2019, Section B, Page 2 as 'Plastic Backlash In Southeast Asia'. New York, June 7, 2019. https://www.nytimes.com/2019/06/07/world/asia/asia-trash.html. Accessed April 18, 2020.

[15] Summary for Policymakers of IPCC Special Report on Global Warming of 1.5°C approved by governments. IPCC, United Nations, Geneva, Switzerland, 2018

[16] Emissions Gap Report 2018. United Nations Environment Programme, Nairobi, Kenya, November 2018

[17] Report of the Conference of the Parties on its twenty-first session, held in Paris from 30 November to 13 December 2015, Addendum, Part two: Action taken by the Conference of the Parties at its twenty-first session, FCCC/CP/2015/10/Add.1, United Nations, January 29, 2016

[18] Anticipating Surprises. In *Abrupt Impacts of Climate Change*, National Academies, Washington, D.C., USA, 2013

[19] Masson-Delmotte, V. et al. Summary for Policymakers, *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*, IPCC, United Nations, Geneva, Switzerland, 2018

[20] Our Changing Climate. *National Climate Assessment*, U.S. Global Change Research Program (USGCRP), Washington, D.C., 2014

[21] The Impact of Climate Change on Aviation. Presented at the Safety and Flight Ops Conference, IATA, San Francisco, CA, April 2019

[22] Airport Carbon Accreditation, ACI Europe. https://www.airportcarbonaccreditation.org/. Accessed Dec. 15, 2019.

[23] 2018 Highlights. *IATA Global Passenger Survey*, IATA, Montreal, Canada, 2018

[24] Latinobarómetro: Informe 2018. Latinobarómetro Corp., Providencia, Chile, 2018

[25] *Alaska Airports and Aviation – 2018 Annual Report*. Alaska Department of Transportation & Public Facilities, Division of Statewide Aviation, Anchorage, AK, USA, 2018

[26] Tang R. Y. Airport Privatization: Issues and Options for Congress. Congressional Research Service, August 2017

[27] Loi du n° 2005-357 du 20 avril 2005 relative aux aéroports. NOR: EQUX0400177L. Version consolidée au 20 décembre 2019. https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000000786314. Accessed December 15, 2019.
[28] *The continuing development of airport competition in Europe*. Oxera for ACI Europe, September 2017
[29] Airport infrastructure auctions. BNDES, Rio de Janeiro – RJ, Brazil, 2016. https://www.bndes.gov.br/SiteBNDES/bndes/bndes_en/Institucional/Press/Noticias/2016/airport_infrastructure_auctions.html. Accessed December 15, 2019.
[30] EIB financing of airport projects. EIB, Kirchberg, Luxembourg, 2008. https://www.eib.org/en/press/news/eib-financing-of-airport-projects.htm. Accessed December 15, 2019.
[31] San Diego International Airport Innovation Lab. San Diego International Airport/Detecon Innovation Institute, San Diego, CA, USA, July 30, 2018
[32] ASTM F2656 / F2656M-18a. *Standard Test Method for Crash Testing of Vehicle Security Barriers.* ASTM International, West Conshohocken, PA, 2018
[33] *Global Aviation Security Plan*. Doc 10118, 1st edition, ICAO, Montreal, QC, Canada, 2017
[34] Trafficking in Persons Report. U.S. Department of State, Washington, D.C., USA, June 2019
[35] Statistical Summary of Commercial jet Airplane Accidents, Worldwide Operations | 1959-2016, Boeing, 2017
[36] Craig, P. A. The Killing Zone – How and Why Pilots Die, 2nd Edition, McGraw-Hill, 2013, pp. 1-16.
[37] Annex 14 to the Convention on International Civil Aviation, Volume I – Aerodrome Design and Operations, 8th Edition, ICAO, July 2018, Montréal, Canada
[38] Engineered Materials Arresting Systems (EMAS) for Aircraft Overruns, Advisory Circular 150/5220-22B, FAA/AAS-100, September 2012, Washington, D.C.
[39] The Airport and its Neighbors, The Reprt of the Preisdent's Airport Commission, Washington, D.C., May 16, 1952
[40] Section 310 – Runway Protection Zones, "Airport Design", Advisory Circular 150/5300-13A Chg. 1, FAA, February 2012, Washington, D.C.
[41] Interim Guidance on Land Uses Within a Runway Protection Zone, Memorandum, FAA, September 2012, Washington, D.C.
[42] Safety Management Manual (SMM), Doc 9859, 2nd Edition, ICAO, 2009
[43] Airport Cooperative Research Program, Transportation Research Board. http://www.trb.org/ACRP/ACRP.aspx. Accessed January 25, 2020.
[44] Autonomous runway incursion warning system, "Annex 14 to the Convention on International Civil Aviation", Volume I – Aerodrome Design and Operations, 8th Edition, ICAO, July 2018, Montréal, Canada, pp. 9-16 to 9-17 & ATT A-31 to A-33.
[45] Runway Status Light (RWSL), FAA. https://www.faa.gov/air_traffic/technology/rwsl/. Accessed January 25, 2020.
[46] Runway friction characteristics measurement and aircraft braking (RuFAB), EASA.2008/4, March 2010. https://www.easa.europa.eu/document-library/research-reports/easa20084. Accessed January 25, 2020.
[47] Jacob A. et. al. The Runway Overrun Prevention System, Safety First #08, Airbus, July 2009
[48] Jenkins, M. & Aaron R. F. Jr. Reducing Runway Landing Overruns, Aero QTR 03.12, Boeing, 2012
[49] The New Global Reporting Format for Runway Surface Conditions, ICAO. https://www.icao.int/safety/Pages/GRF.aspx. Accessed January 25, 2020.
[50] Chapter 4. Coefficient of Friction and Friction Measuring Devices, "Industry best Practices Manual for Timely and Accurate Reporting of Runway Surface Conditions by ATS/AIS to Flight Crew, Draft Version 4.0, ICAO/RASG/APRAST, June 2013
[51] IATA Forecast Predicts 8.2 billion Air Travelers in 2037, October 2018. https://www.iata.org/pressroom/pr/Pages/2018-10-24-02.aspx. Accessed April 19, 2020.
[52] 2017-2019 Global Aviation Safety Plan, Doc 10004, Second Edition, ICAO, 2016
[53] Safety Report, 2018 Edition, ICAO, 2018
[54] State safety programme (SSP), Chapter 6. ICAO Safety Management SARPs, Safety Management Manual (SMM), Doc 9859, 2nd Edition, ICAO, 2009, Montréal, QC, Canada, p 6-2.
[55] Nzuzi, A. A Balanced Approach to Safety Oversight and Management in States with a Low Level of Compliance to ICAO SARPs, ENAC Alumni Magazine No. 20, September 2017, pp. 44-46.
[56] "Eurocopter's X3 hybrid helicopter makes aviation history in achieving a speed milestone of 255 knots during level flight", Airbus Helicopters. https://www.airbushelicopters.com/website/en/press/Eurocopter%27s-X3-hybrid-

helicopter-makes-aviation-history-in-achieving-a-speed-milestone-of-255-knots-during-level-flight_1159.html. Accessed April 19, 2020.

[57] "Expanding the Envelope for Future Vertical Lift", Lockheed Martin. https://www.lockheedmartin.com/en-us/products/s-97-raider-helicopter.html. Accessed April 19, 2020.

[58] "Harbour Air and magniX Announce Successful Flight of World's First Commercial Electric Airplane", December 10, 2019. https://www.harbourair.com/harbour-air-and-magnix-announce-successful-flight-of-worlds-first-commercial-electric-airplane/. Accessed March 9, 2020.

[59] ACI's Views on the Reintroduction of Supersonic Aircraft and the Development of Appropriate SARPs, Working Paper A40-WP/225 EX/85, ICAO's Assembly – 40th session, Executive Committee, August 02, 2019

[60] Thipphavong, D. et al., "Urban Air Mobility Airspace Integration Concepts and Considerations", AIAA Aviation Forum (Aviation 2018), June 2018

[61] Unmanned Aircraft System (UAS) Traffic Management (UTM), NASA. https://utm.arc.nasa.gov/index.shtml. Accessed March 9, 2020.

[62] Remote Identification of Unmanned Aircraft Systems, FAA Docket No. FAA-2019-1100 Notice No. 20-01, December 31, 2019

[63] "EASA publishes Opinion "Standard scenarios for UAS operations in the 'specific' category". https://www.easa.europa.eu/newsroom-and-events/news/easa-publishes-opinion-%E2%80%9Cstandard-scenarios-uas-operations-%E2%80%98specific%E2%80%99. Accessed April 19, 2020.

[64] Drones in the Airport Environment: Concept of Operations & Industry Guidance, ACI Europe, April 2020

[65] Flight Plan 2030 – an Air Traffic Management Concept for Urban Air Mobility, EmbraerX/Atech

[66] Cluzeau J. M. et al. Concepts of Design Assurance for Neural Networks (CoDANN), Public Report Extract, Version 1.0, EASA AI Task Force, March 2020

[67] Fast-Forwarding to a Future of On-Demand Urban Air Transportation, Uber Elevate, October 27, 2016

[68] UberAir Vehicle Requirements and Mission, Uber, 2020

[69] Wang, Y. et al., Helicopter Wake Turbulence Encounter Study, Version 1.0, University of Liverpool, March 2015

[70] ACI World, Common Agreement Document – Airbus A380 Airport Compatibility Group (AACG), 2002

[71] ACI World, Common Agreement Document – Boeing 747-8 Airport Compatibility Group (BACG), 2008

[72] ACI World, Common Agreement Document – Boeing 777-8/-9 Airport Compatibility Group (BACG2), May 2018

[73] Minimum Runway Width – for aeroplanes engaged in RPT and Charter operations with a maximum take-off weight greater than 5700 kg, Draft CAAP 235A-1(0), CASA, May 2013

[74] Root, R., Narrow Runway Operations Guidelines for Narrow Runway Operations, Boeing

[75] Improved Models for Risk Assessment of Runway Safety Areas, ACRP Report 50, TRB, 2011

[76] DFS et al., Assessment of ILS protection areas impact on large aircraft operations, 2006

[77] Le Bris, G., Accommodating the next generation of airliners, International Airport Review, February 2014

[78] International Civil Aviation Organization, Operation of New Larger Aeroplanes at Existing Aerodromes, Circular 305 AN/177, 2004

[79] An overview of all our work in innovative technologies, Clean Sky. https://www.cleansky.eu/an-overview-of-all-our-work-in-innovative-technologies. Accessed March 9, 2020.

[80] U.S. Federal Aviation Administration, Active Spaceport Operator Licenses, Commercial Space Data. https://www.faa.gov/data_research/commercial_space_data/licenses/. Accessed April 19, 2020.

[81] U.S. 14 CFR Part 420 – License to Operate a Launch Site. Electronic CFR. Accessed April 19, 2020.

[82] U.S. 14 CFR Part 499 – License to Operate a Reentry Site. Electronic CFR. Accessed April 19, 2020.

[83] Welch, T. F., Mishra, S., & Wang, F. (2015). Interrelationship between Airport Enplanements and Accessibility: Case of Three Airports in Metropolitan Washington, D.C., Region. Transportation Research Record, 2501(1), 46–55. https://doi.org/10.3141/2501-07

[84] Clever, R., & Hansen, M. M. (2008). Interaction of Air and High-Speed Rail in Japan. Transportation Research Record, 2043(1), 1–12. https://doi.org/10.3141/2043-01

[85] CDG Express. Accessed on March 22, 2020. https://cdgexpress.groupeadp.fr/

[86] Landside Access Modernization Program (LAMP), Connecting LAX, Los Angeles World Airports. Accessed March 22, 2020. https://www.lawa.org/en/connectinglax

[87] A Whole New LaGuardia, PANYNJ. Accessed March 22, 2020. https://www.anewlga.com/about-the-project/

[88] Boudreau, B. J. et al., Improving the Airport Customer Experience, ACRP Report 157, TRB, Washington, D.C., USA, pp. 14-16
[89] Members of Congress Announce Framework for Infrastructure Bill That Includes a PFC Increase, ACI-NA, Feb. 3, 2020. Accessed on March 22, 2020. https://airportscouncil.org/2020/02/03/members-of-congress-announce-framework-for-infrastructure-bill-that-includes-a-pfc-increase/
[90] Five More Reasons to Oppose an Increase to the Passenger Facility Charge, Airlines for America. Accessed on March 22, 2020. https://www.airlines.org/news/five-more-reasons-to-oppose-an-increase-to-the-passenger-facility-charge/
[91] How Airport Tax Increases Might Affect You, Air Asia. Accessed on March 22, 2020. https://newsroom.airasia.com/how-airport-tax-increases-might-affect-you
[92] The economic & social benefits of air transport, Air Transport Action Group (ATAG), Geneva, 2005
[93] Air Traffic by the Numbers, U.S. Federal Aviation Administration, June 2019
[94] Industry Monitor, Issue No.205, Network Manager nominated by the European Commission, EUROCONTROL, February 28, 2019
[95] Standard Inputs for EUROCONTROL Cost-Benefit Analyses, Edition 8.0, EUROCONTROL, Brussels, January 2018
[96] ICAO Long-Term Traffic Forecasts, Passenger and Cargo, ICAO, July 2016
[97] China's Strategy for Modernizing Air Traffic Management, presented by the People's Republic of China, Working Paper, 39th Assembly – Technical Commission, ICAO, August 2016
[98] Welman, S., et al., Calculating Delay Propagation Multipliers for Cost-Benefit Analysis, MITRE Product MP1000039, CAASD, The MITRE corporation, February 2010
[99] Commission Implementing Regulation (EU) 2019/317 of 11 February 2019 laying down a performance and charging scheme in the single European sky and repealing Implementing Regulations (EU) No 390/2013 and (EU) No 391/2013, Official Journal of the European Union, February 25, 2019
[100] Airport Collaborative Decision-Making: Optimisation through Collaboration, An Introductory Guide for Air Navigation Service Providers, Civil Air Navigation Services Organization (CANSO), 2016
[101] CANSO and ACI Partner on Promoting A-CDM Implementation, ACI World, June 14, 2012. https://aci.aero/news/2012/06/14/canso-and-aci-partner-on-promoting-a-cdm-implementation/. Accessed March 29, 2020.
[102] Airline Airport Collaborative Decision Making Group (AACG) A-CDM Coordination, IATA, 2018
[103] Manual on Collaborative Air Traffic Flow Management (ATFM), Doc 9971, 3rd Edition, ICAO, 2018
[104] 2016-2030 Global Air Navigation Plan, 6th Edition, Doc 9750, ICAO, 2019. https://www4.icao.int/ganpportal/. Accessed March 29, 2020.
[105] Guidelines on Airport-Collaborative Decision Making (A-CDM) Key Performance Indicators, Civil Air Navigation Services Organization (CANSO)
[106] Airport Capacity Assessment Methodology/ACAM Manual, Edition 1.1, Network Manager nominated by the European Commission, EUROCONTROL, November 2016
[107] Airport Network Integration – Concept for Establishment of an Airport Operations Plan (AOP), Netowkr Manager nominated by the European Commission, Edition 1.1, EUROCONTROL, November 7, 2018
[108] A-CDM Impact Assessment, Final Report, EUROCONTROL, Brussels, 2016
[109] Using Collaborative Decision Making to Enhance the Management of Adverse Conditions, ACRP 10-27, Transportation Research Board. https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4633. Accessed March 29, 2020.
[110] Multimodal, Efficient Transportation in Airports and Collaborative Decision Making, Project Final Report, Grant Agreement 314453, Barco-Orthogon, Cambridge University and ENAC, June 2014
[111] Folland, C.K., Karl, T.R. et al., Observed Climate Variability and Change, in Climate Change 2001: The Scientific Basis, Contribution of Working Group I to the Third Assessment Report of the IPCC, 2001
[112] NOAA National Centers for Environmental Information, State of the Climate: Global Climate Report for February 2020, published online March 2020. https://www.ncdc.noaa.gov/sotc/global/202002. Accessed April 11, 2020.
[113] Bastin JF, Clark E, Elliott T, Hart S, van den Hoogen J, et al., Understanding climate change from a global analysis of city analogues, Published in Plos One, July 10, 2019. https://doi.org/10.1371/journal.pone.0217592.
[114] Peter J. Williams, M. Wallis, P. Wadhams, J. A. Dowdeswell and Andrew Noel Schofield, Permafrost and climate change: geotechnical implications. Philosophical Transactions of the Royal Society of London. Series A: Physical and Engineering Sciences 352: 347–358. August 15, 1995. http://doi.org/10.1098/rsta.1995.0075.

[115] Severe thunderstorms and climate change, NASA, April 7, 2013. https://climate.nasa.gov/news/897/severe-thunderstorms-and-climate-change/. Accessed April 12, 2020.
[116] Cai, W., Borlace, S., Lengaigne, M. et al. Increasing frequency of extreme El Niño events due to greenhouse warming. Nature Clim Change 4, 111–116, 2014. https://doi.org/10.1038/nclimate2100.
[117] Silva Dias, Pedro & Gan, Manoel & Beven, J & Pezza, A & Holland, G & F, A & McTaggart-Cowan, F & Diniz, A & Seluchi, Marcelo & Brag, H. The Catarina Phenomenon. 2006.
[118] Zhong S, Yu L, Winkler JA, Tang Y, Heilman WE, Bian X. The impact of climate change on the characteristics of the frost-free season over the contiguous USA as projected by the NARCCAP model ensembles. Clim Res 72:53-72, 2017. https://doi.org/10.3354/cr01450.
[119] Climate Central, Coastal Risk Screening Tool, Land projected to be below tideline, annual flood level, and 10-year flood level in 2070. Assuming moderate cuts in pollution, mid-range result from sea-level projection range (50th percentile) and the mid-range sea-level-projection per Kopp et al., 2014. Exclude currently protected areas per physical features. https://coastal.climatecentral.org/map/. Accessed April 12, 2020.
[120] Sea Level Rise Viewer, U.S. NOAA. Accessed April 12, 2020. https://coast.noaa.gov/slr.
[121] National Academies of Sciences, Engineering, and Medicine. Critical Issues in Transportation 2019. The National Academies Press, Washington, D.C., 2018. https://doi.org/10.17226/25314.
[122] Wampler, Brian. "When Does Participatory Democracy Deepen the Quality of Democracy? Lessons from Brazil." Comparative Politics, vol. 41, no. 1, 2008, pp. 61–81. JSTOR, www.jstor.org/stable/20434105. Accessed April 20, 2020.
[123] Institute for Transportation & Development Policy, "What is BRT?". https://www.itdp.org/library/standards-and-guides/the-bus-rapid-transit-standard/what-is-brt/. Accessed April 20, 2020.
[124] Lindau, L. A., et al. "Curitiba, the Cradle of Bus Rapid Transit." Built Environment (1978), vol. 36, no. 3, 2010, pp. 274–282. JSTOR, www.jstor.org/stable/23289717. Accessed April 20, 2020.
[125] Resolution A39-1: Consolidated statement of continuing ICAO policies and practices related to environmental protection – General provisions, noise and local air quality, Appendix F, 39th Triennial Assembly, ICAO, 2016
[126] Annex 16 to the Convention on International Civil Aviation, Environmental Protection, Volume IV — Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), 1st Edition, ICAO, October 2018
[127] Airport Planning Manual, Part 2 — Land Use and Environmental Control, Doc 9184, 4th Edition, ICAO, 2018
[128] Recommended Method for Computing Noise Contours around Airports, Doc 9911, 2nd Edition, ICAO, 2018
[129] Review of noise abatement research & development and implementation projects, Doc 9888, 1st Edition, ICAO, 2010
[130] Guidance on Environmental Assessment of Proposed Air Traffic Management Operational Changes, Doc 10031, 1st Edition, ICAO, 2014
[131] Procedures for Air Navigation Services — Aircraft Operations (PANS-OPS), Part I & II, Doc 8168, 6th Editions, ICAO
[132] Continuous Descent Operations (CDO) Manual, Doc 9931, 1st Edition, ICAO, 2010
[133] Continuous Climb Operations (CCO) Manual, Doc 9993, 1st Edition, ICAO, 2013
[134] ICAO's Policies on Charges for Airports and Air Navigation Services, Doc 9082, 9th Edition, ICAO, 2012
[135] Airport Economics Manual, Doc 9562, 3rd Edition, ICAO, 2013
[136] Flying in Formation: Air Transport and the Susstainable Development Goals, 1st Edition, ATAG, October 2017
[137] J.E.Penner, D.H.Lister, D.J.Griggs, D.J.Dokken, M.McFarland (Eds.). Aviation and the Global Atmosphere. Prepared in collaboration with the Scientific Assessment Panel to the Montreal Protocol on Substances that Deplete the Ozone Layer Cambridge University Press, UK, 1999. pp 373
[138] Resolution A40-19: Consolidated statement of continuing ICAO policies and practices related to environmental protection - Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA), Assembly – 40th Session, ICAO, 2019
[139] 2019 ICAO CORSIA Regional Workshops, Presentation Materials, ICAO, March-April 2019. https://www.icao.int/Meetings/RS2019/Pages/Presentations.aspx. Accessed April 20, 2020.
[140] Introduction to the ICAO Basket of Measures, ICAO Environmental Report, 2016. https://www.icao.int/environmental-protection/Documents/EnvironmentalReports/2016/ENVReport2016_pg97-98.pdf. Accessed April 20, 2020.

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[141] Airport Certified Employee (ACE), American Association of Airport Executives (AAAE). https://www.aaae.org/aaae/AAAEMBR/AAAEMemberResponsive/PD/Training/Onsite_Training/ACE_PROGRAMS.aspx. Accessed April 15, 2020.
[142] McMahon, A. Does Workplace Diversity Matter? A survey of Empirical Studies on Diversity and Firm Performance, Sept. 2000. Journal of Diversity Management, Vol. 5, No. 2, 2010, pp. 37-48.
[143] Lorenzo, R. et al., The Mix That Matters Innovation Through Diversity, The Boston Consulting Group, April 2017. https://www.bcg.com/publications/2017/people-organization-leadership-talent-innovation-through-diversity-mix-that-matters.aspx. Accessed April 10, 2020.
[144] Preamble, Convention on International Civil Aviation, Doc 7300/9, 9th Edition, ICAO, 2006
[145] Coronavirus Aid, Relief, and Economic Security Act (CARES) Act of 2020, Pub. L. 116–136 amending the U.S. Internal Revenue Code of 1986
[146] COVID-19 standardized protocols, Version 4, Canadian Construction Association, April 16, 2020
[147] Recommendations: COVID-19 Exposure Prevention, Preparedness, and Response Plan for Construction, Construction Industry Safety Coalition, 2020
[148] Le Bris, G. Best Practices on Temporary Parking of Overflow Aircraft. WSP, April 2020. https://www.wsp.com/en-US/insights/2020-temporary-parking-of-overflow-aircraft. Accessed April 19, 2020.
[149] Displaced thresholds (5.2) and Runway closure markers (7.1). In *Annex 14 to the Convention on International Civil Aviation*, Volume I – Aerodrome Design and Operations, 8th Edition, ICAO, July 2018, Montréal, Canada
[150] Aviation safety investigations & reports Airbus A340 ZS-SLA. Investigation No 200501819, ATSB
[151] Operational non-compliance at Perth Airport, WA on 9 May 2008. Transport Safety Report (Final), AO-2008-033, ATSB, June 2009
[152] Rosenkrans, W. What's on Your Runway? Lessons Learned During RWY28 Threshold Relocation at ORD, AeroSafety World, Flight Safety Foundation, 2009
[153] Le Bris, G. Working Safely on an Operative Runway, AeroSafety World, Flight Safety Foundation, 2013
[154] Bassey, R. Development and Evaluation of Safety Orange Airport Construction Signage, FAA, 2015
[155] Berlucchi, R., Le Bris, G. and Siewert, D. Enhanced airfield signage to improve situational awareness in the vicinity of construction works, HindSight no 23, Eurocontrol, Brussels, 2016
[156] Markings and Signage during Airfield Construction [Marquages et signalization temporaires (chantier)], Infrastructure WG of The French-Speaking Airports (UAF&FA), November 2017
[157] Eurocontrol et al., European Action Plan for the Prevention of Runway Incursion, Brussels, 2017
[158] Travaux sur Pistes – Construire Ensemble la Sécurité, DGAC/DSAC, 2017
[159] Airports Council International, Managing Operations during Construction Handbook, 2018, http://www.aci.aero/Publications/Safety-Security-Operations/Managing-Operations-During-Construction-Handbook
[160] Manual de Obras e Serviços de Manutenção, ANAC, 2018.