Climate Change: Climate Risk Assessment, Adaptation and Resilience

Menu of Adaptation Options 2022

ICAO

ENVIRONMENT

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Menu of Adaptation Options

Introduction

This menu of adaptation options complements the Key Steps in Aviation Organisation Climate Change Risk Assessment and Adaptation Planning and Key Climate Change Vulnerabilities for Aviation Organisations documents. Once a State or organisation has determined where its civil aviation sector is vulnerable to climate change, it can use this menu to identify possible adaptation measures to build resilience against those vulnerabilities. In most cases, it is not practical for any State or organisation to protect against all vulnerabilities. For this reason, it is important to first prioritize objectives and identify barriers (including cost) to implementation (See the guidance on Key Steps in Adaptation Planning for further information). This menu is a starting point for identifying adaptation measures; every State and organisation is different so the measures listed here are not comprehensive of every option and should be adapted as appropriate to fit specific circumstances.

Additionally, every action taken has the potential for consequences – both positive and negative. For example, while certain nature-based solutions may offer cost-effective and environmentally friendly ways to address impacts from precipitation, sea level rise, storm surge, and erosion, some may also attract more frequent or different types of wildlife, which could have an impact on aviation operations and infrastructure. Similarly, some sea defences can affect wind profiles on runways. Additionally, moving departure times for heavier aircraft to cooler times of day to adapt to rising temperatures may change noise disturbance near an airport. As stakeholders consider each adaptation measure for possible implementation, they should consider it holistically, including any positive or negative consequences of the action.

States and organisations should also consider dependent relationships, and work in partnership with other stakeholders. This can include collaborating with other aviation and non-aviation stakeholders. Collaboration with aviation stakeholders may result in specific actions that enhance the resilience of the aviation community, for example operational improvements and changes that can support adaptation to changing climate conditions. Collaborating with non-aviation stakeholders ensures that adaptation measures are considered in the context of the broader community and environment, for example airports may prepare for future risks of weather events with local governments to integrate climate adaptation planning for an airport into community planning. Collaboration can also occur at the State level, for example multiple States collaborating to develop plans to assist each other with adaptation and building resilience.

Once adaptation plans are final, they should be executed on a specific timeline and revised as circumstances change. A key factor in developing resilience is the speed at which an organisation or State can resume operations after a disruptive event. Strong local plans

and adaptation measures that are fit for purpose, will enable an organisation to resume regular operations quickly. Contingency plans to address acute impacts during a storm or other weather event should be practiced so all stakeholders are prepared to implement them during an actual event.

Finally, although many organisations may have parallel but separate climate change mitigation and adaptation programmes, there may be potential synergies between the two. While this menu only focuses on climate change adaptation and resilience measures, some adaptation and resilience measures may also reduce greenhouse gas (GHG) emissions. For example, if adding more vegetation to a property or painting walls lighter colours to reflect more light reduces heat-island effects, less energy will be needed for cooling, which could lead to a reduction in GHG emissions.

States and organisations may identify important lessons learned or best practices as they consider and implement adaptation options to address vulnerabilities to civil aviation from climate change. There is value in sharing these lessons learned and best practices as they may help other States and organisations facing similar situations.

This menu is organized by organisation-type, to serve as a companion to the Key Climate Change Vulnerabilities in Adaptation section. Where possible, adaptation options are further organized by either “operational” or “infrastructure” adaptations. The menu ends with information from the Civil Air Navigation Services Organisation (CANSO) Air Traffic Flow Management (ATFM) Data Exchange Network for the Americas (CADENA), providing an example of international and cross-organisational collaboration to achieve greater resilience to extreme weather events and other disruptions.

Small Island Developing States

The vulnerabilities facing Small Island Developing States (SIDS) make adaptation measures particularly important. Unfortunately, some of the factors contributing to greater vulnerability of aviation to climate change for SIDS also make adaptation measures challenging. For example, SIDS often have constraints on personnel, funding, and limited land and water resources. For SIDS considering adaptation measures, creative solutions, like remote technologies that do not depend on the availability or accessibility of local infrastructure may be particularly helpful.

SIDS are also uniquely dependent on aviation to transport people and exports, and import goods that are not available locally, including building materials, medical supplies and

food. Additionally, many SIDS economies depend on aviation to transport tourists. For this reason, it is especially critical for SIDS to prioritize adaptation measures and initiatives that ensure civil aviation can operate sustainably, even as the climate continues to change.

Another challenge facing SIDS is the issue of a total-country impact due to a severe weather event, which can affect recovery. While system redundancy (including high-capacity generators for essential systems), and more "weather-proof" communications systems (such as satellite phones) may be useful adaptation measures, if an entire island community is devastated by a storm, there may not be sufficient resources and infrastructure available locally to support recovery. For this reason, the aviation sector in SIDS must be prepared to be resilient independent of their local communities (e.g., have fuel for backup generators on site), while also building a strong network with neighbouring partners outside of their local communities who may be able to assist if they are impacted less severely.

While all of the options included in this menu may be relevant for SIDS, the ones that may be particularly critical are indicated with a "SIDS" marker. These options were selected because of their potential for relatively quick implementation at a low cost without expanding the footprint of existing property and infrastructure. Since SIDS are particularly vulnerable to increased intensity and frequency of storms and sea level rise, most of these measures are located in the Increased Intensity of Storms and Sea Level Rise sections of this menu.

SIDS Collaboration Example:
Sixteen of the thirty-eight Small Island Developing States are located in the Caribbean. Under the U.S.-Caribbean Resilience Partnership, the U.S. and Caribbean States have formed the Caribbean Aviation Resilience and Recovery Group (CARRG), seeking to strengthen coordination on aviation resilience and recovery from emergency events. One of the intentions of the CARRG is to ensure that if one State or island is impacted by a severe weather event, there is a plan to coordinate assistance to recover the aviation sector. CARGG works closely with the ICAO North American, Central American and Caribbean Regional Offices, and the Civil Air Navigation Services Organization (CANSO) ATFM Data Exchange Network for the Americas (CADENA), and Airports Council International Latin America and Caribbean regional office (ACI-LAC).

Adapting Airports

Higher Average and Extreme Temperatures

Operations

- ☐ Increase cooling capability in buildings
- ☐ Increase external air conditioning to match demand (e.g., air conditioning pumping cold air outdoors, or supply of pre-conditioned air to aircraft)
- ☐ Implement program to promote safety in the heat for ground staff – potentially extending to aircraft operator and ground handling staff
- ☐ Implement or update wildlife management plans to account for changes in wildlife impacts

Adelaide Airport in Australia is in a trial of irrigating the airport buffer, which may result in lowering airport surface temperatures and improving human thermal comfort.

Infrastructure

- ☐ Extend runway length
- ☐ Move obstacles at the end of the runway (to adjust for reduced take-off performance due to reduced thrust and lift)
- ☐ Cooling runways with recycled water
- ☐ White or pale external wall colour to reduce temperature (increase reflection of solar radiation)
- ☐ Pavement design for higher temperatures – design and re-design, maintenance as needed
- ☐ Use materials for runway design in the context of temperatures and resilience
- ☐ Minimize asphalt surface on the airside and increase nature based solutions **SIDS**
- ☐ More vegetation or irrigated green spaces **SIDS**
- ☐ Reinforcement of infrastructure and design modifications to runways, taxiways and aprons (e.g. surfacing materials, embankment materials and geometry , drainage design) to address or mitigate permafrost degradation (or thaw)

Changing Precipitation

Operations

- ☐ Operational measures to increase robustness and flexibility
- ☐ Operational decision making procedures such as Airport Collaborative Decision Making (A-CDM)
- ☐ Develop a snow and ice removal plan for airports
- ☐ Runway state message – for planning (take-off and landing) and for operations (timely status)

Infrastructure

- ☐ Grooving of runways for increased braking action
- ☐ Acquire adequate snow and ice removal equipment.
- ☐ Ensure drainage networks are clear, functioning and with sufficient capacity for expected impacts **SIDS**
- ☐ Water to warm pavement during icing conditions
- ☐ Water management **SIDS**
  - ➢ Increasing vegetation (inducing biodiversity) – depending on the topography (trees), restoration of wetlands upstream of airports
  - ➢ Green roofs to minimize runoff, also reduces storage for water and demand for pumps
  - ➢ Replace concrete/asphalt with soil/vegetation to increase water storage
  - ➢ Improved or changed storm water management facilities to reduce flooding, minimize erosion, improve water quality
  - ➢ Grey infrastructure such as dykes
  - ➢ Planning for drought and water supply limitations
  - ➢ Consider water storage to counter water supply issues
  - ➢ Rainwater catchment systems to adapt to potential water scarcity

In 2019, Munich Airport Winter Services could clear a runway in 25 minutes using airblast sweepers and snow plows. Munich Airport Winter Services is staffed by 47 permanent employees, and nearly 500 farmers or truckers in the immediate vicinity of the airport who can be called upon as needed.

Increased Intensity of Storms

Operations

- ☐ Develop plan for storm events **SIDS**
  - ➢ Early warning systems and emergency management plan
  - ➢ Developing and engaging on existing network of support **SIDS**
- ☐ Improved weather data availability and quality for flight planning and during flight execution **SIDS**
  - ➢ Implementing or improving forecasting of weather events.
  - ➢ Research on seasonal forecasts
  - ➢ Improved real-time weather data availability for flight crew during flight execution

Before disruptive weather events occur, Hong Kong Airport coordinates with the Hong Kong Observatory and air traffic control (ATC). Based on weather data and advice from ATC on runway capacity the airport may trigger its Flight Rescheduling Control System. This handles airlines rescheduling requests and facilities a swifter return to regular operations.

Infrastructure

- ☐ Secure assets prior to storm events, by fastening, covering, or moving them indoors. **SIDS**
- ☐ Grey infrastructure based solutions (e.g., strengthening and reinforcement of infrastructure to make it more resilient)
- ☐ Ensure drainage networks are clear and functioning **SIDS**
- ☐ Deploy nature based solutions to help with wind reduction (e.g., wetlands, mangroves) **SIDS**
- ☐ Move IT, electricity, and other critical infrastructure (e.g. raise it up from ground level to a higher floor) **SIDS**
- ☐ Install backup generators/power **SIDS**
- ☐ Water storage (e.g., collect rainwater) to ensure resilience
- ☐ Design facilities for higher categories of hurricane, typhoon, and other extreme precipitation events. **SIDS**
- ☐ Evaluate wind impacts on all elevated structures and make recommendations for improvement **SIDS**
- ☐ Improve lightening detection systems around airports and lightening protection shelters on the air side
- ☐ Move infrastructure and assets out of the way of storm surge **SIDS**
- ☐ Protect electric wiring and connections to electric generators from flooding (e.g., relocate, elevate, bury) **SIDS**

- ☐ Partner with external stakeholders (e.g., local military or law enforcement) that may be able to provide backup satellite communications in case of loss of communication infrastructure at the airport **SIDS**

Sea Level Rise

Infrastructure

- ☐ Allow a safe degree of inundation **SIDS**
- ☐ Retain, restore, or introduce natural barriers **SIDS**
  - ➢ Mangroves and coastal vegetation (less sand, more trees)
  - ➢ Incorporation of more green areas, less concrete/asphalt
- ☐ Water management **SIDS**
  - ➢ Ensure pumps are current/adequate for the projected sea level rise and have been kept in good condition
  - ➢ Satellite information to better understand/plan for airport closures
  - ➢ Upgrade drainage capacity
- ☐ Raising infrastructure **SIDS**
  - ➢ Changing groundwater elevations can reduce storm water discharge rates - consider this in planning /design
  - ➢ Raise platform-level of buildings when redeveloping airport assets
- ☐ Install or reinforce sea defences **SIDS**
  - ➢ Levees
  - ➢ Raising level of perimeter and airport property roads
- ☐ Deploy tidal gates in airport drains to prevent seawater intrusion
- ☐ Relocation of airport

Adapting ANSPs

Higher Average and Extreme Temperatures

Infrastructure

- ☐ Reinforce infrastructure and equipment in remote and exposed locations (may be particularly critical in areas experiencing permafrost thaw)
- ☐ Adjust performance-based navigation (PBN) approach glide path for temperature difference compared to International Standard Atmosphere (ISA)

Changing Precipitation

Operations

- ☐ Operational measures to increase robustness and flexibility
- ☐ Augmented low visibility procedures (e.g., ground based augmentation system (GBAS))
- ☐ Improved use of weather data : **SIDS**
  - ➢ Increased access to satellite data
  - ➢ Broad dissemination of consistent, standards-based weather data, products, and imagery to aviation stakeholders
  - ➢ Integrate Meteorological experts into Operations team to supply data and advice to mitigate operational impacts

At National Air Traffic Services (NATS), the UK's air navigation service provider, Meteorological experts are integrated into the operations team to provide real-time data and advice to facilitate operational decision-making in disruptive weather situations.

Increased Intensity of Storms

Operations

- ☐ Develop plan for storm events **SIDS**
- ☐ Early warning systems and emergency management plan **SIDS**
- ☐ Developing and engaging on existing network of support **SIDS**
- ☐ Air Traffic Management (ATM) improvements for precision approaches **SIDS**
- ☐ Improved strategic traffic flow management systems to adjust capacity and demand imbalances for planning **SIDS**
- ☐ ATM flexibility need for approach and departure areas
- ☐ Improved use of weather data **SIDS**
  - ➢ Implementing or improving forecasting of weather events.
  - ➢ Research on seasonal forecasts
  - ➢ Broad dissemination of consistent, standards-based weather data, products, and imagery to aviation stakeholders

- ☐ Back-up / redundancies such as remote tower facility **SIDS**
- ☐ Agree on contingency measures with adjacent, or nearby ANSPs in case of loss of Air Traffic Control (ATC) facility, especially in locations that are prone to natural disasters

Infrastructure

- ☐ Secure assets prior to storm events **SIDS**
- ☐ Grey infrastructure based solutions (e.g., strengthening and reinforcement of infrastructure to make it more resilient)
- ☐ Deploy nature based solutions to help with wind reduction (e.g., wetlands, mangroves) **SIDS**
- ☐ Move IT and electricity or other critical infrastructure (e.g., raise it up from ground level, or bury wiring and electrical cables underground) **SIDS**
- ☐ Backup generators/power **SIDS**
- ☐ Water storage (e.g., collect rainwater) to ensure resilience
- ☐ Design facilities for higher categories of hurricane or typhoon **SIDS**
- ☐ Evaluate wind impacts on all elevated structures and make recommendations for improvement **SIDS**
- ☐ Move infrastructure and assets out of the way of storm surge **SIDS**

Sea Level Rise

Infrastructure

- ☐ Retain or introduce natural barriers **SIDS**
  - ➢ Mangroves and coastal vegetation (less sand, more trees)
  - ➢ Incorporation of more green areas, less concrete/asphalt
- ☐ Water management **SIDS**
  - ➢ Ensure pumps are current/adequate for the projected sea level rise and have been kept in good condition
  - ➢ Satellite information to better understand/plan for airport closures
- ☐ Raising infrastructure **SIDS**
  - ➢ Changing groundwater elevations can reduce storm water discharge rates - consider this in planning /design

Adapting Operators

Higher Average and Extreme Temperatures

Operations

- ☐ Move departure times for heavier aircraft cooler times of day
- ☐ Adjust regular flight schedules to account for hotter temperatures (e.g., heavier departures at cooler times of day)
- ☐ Reduce payload of aircraft
- ☐ Increase turnaround times to account for sufficient brake cooling when there are higher ambient temperatures
- ☐ Take measures to mitigate high temperatures inside aircraft, such as closing window shades during longer turn-arounds.
- ☐ Implement or expand occupational safety and health programs to account for changing weather conditions and its potential impacts on the workforce

Pilot's Note: When conducting a PBN approach with a certain glidepath, the actual glidepath flown is dependent on temperature as the PBN glidepath is calculated from barometric values which depend on temperature. A higher temperature of 10 degrees versus ISA gives 0.3 degrees extra glidepath angle. Glidepath angles are restricted in certification and actual glidepath angles may influence path stability.

Infrastructure

- ☐ Increase provision of aircraft cooling capabilities such as Preconditioned Air (PCA).

Changing Precipitation

Operations

- ☐ Operational measures to increase robustness and flexibility
- ☐ Adapt to different types of precipitation – for example new procedures for de-icing or operating procedures for heavy precipitation or freezing rain
- ☐ Improved use of weather data for forecasting: **SIDS**
  - ➢ Implementing or improving forecasting of weather events.
  - ➢ Research on seasonal forecasts
  - ➢ Increased access to satellite data, and using the data to make informed decisions.

Increased Intensity of Storms

Operations

- ☐ Develop plan for storm events **SIDS**
- ☐ Early warning systems and emergency management plan **SIDS**
- ☐ Pre-emptive cancellation or diversion of flights **SIDS**

- ☐ Relocate or expand operations at locations that are at lower risk of adverse effects from climate change
- ☐ Improved use of weather data SIDS
  - ➢ Implementing or improving forecasting of weather events.
  - ➢ Research on seasonal forecasts

Infrastructure

- ☐ Secure assets prior to storm events SIDS
- ☐ Backup generators/power SIDS
- ☐ Design facilities for higher categories of hurricane or typhoon SIDS
- ☐ Move infrastructure and assets out of the way of potential storm surge SIDS

Strengthening Climate Change Resilience: CADENA Example

As explained in the introduction to this section and throughout this document, climate change will affect civil aviation across all organisations and states. It is therefore critically important for states and organisations to collaborate in resilience and adaptation efforts. The CANSO ATFM Data Exchange Network for the Americas (CADENA) is an example of this international and cross-organisational collaboration. CADENA coordinates across states and organisations and provides real-world benefits for adapting collaboratively to disruptions that have impacts across multiple ANSPs affecting many civil aviation operators in the region (e.g., impacts from extreme weather and other disasters). Through its coordination, CADENA by improving operational efficiencies, has also mitigated some aviation greenhouse gas emissions by reducing fuel burn.

CADENA was established in 2016 to support the implementation of air traffic flow management (ATFM) based on collaborative decision making (CDM) principles. One of the many benefits CADENA offers is coordinating and exchanging information during contingency events, especially during the hurricane season. In collaboration with participating ANSPs and airlines, CADENA has developed Planned Airway System Alternatives (PASA) contingency routes and the ANSP Contingency Forms. The PASA contingency routes help to improve predictability, mitigate delays, and enhance safety during these rare events. The PASA route database is reviewed and updated quarterly so that users can take advantage of these routes to avoid the impacted airspace when necessary.

Since its establishment, CADENA has facilitated 16 ad-hoc hurricane and tropical storm web conferences attended by ANSPs, airlines and stakeholders. One of CADENA's achievements in dealing with hurricanes can be seen in Hurricane Delta that impacted the region in October 2020. The airlines requested the hurricane avoiding route (Figure 1) via the

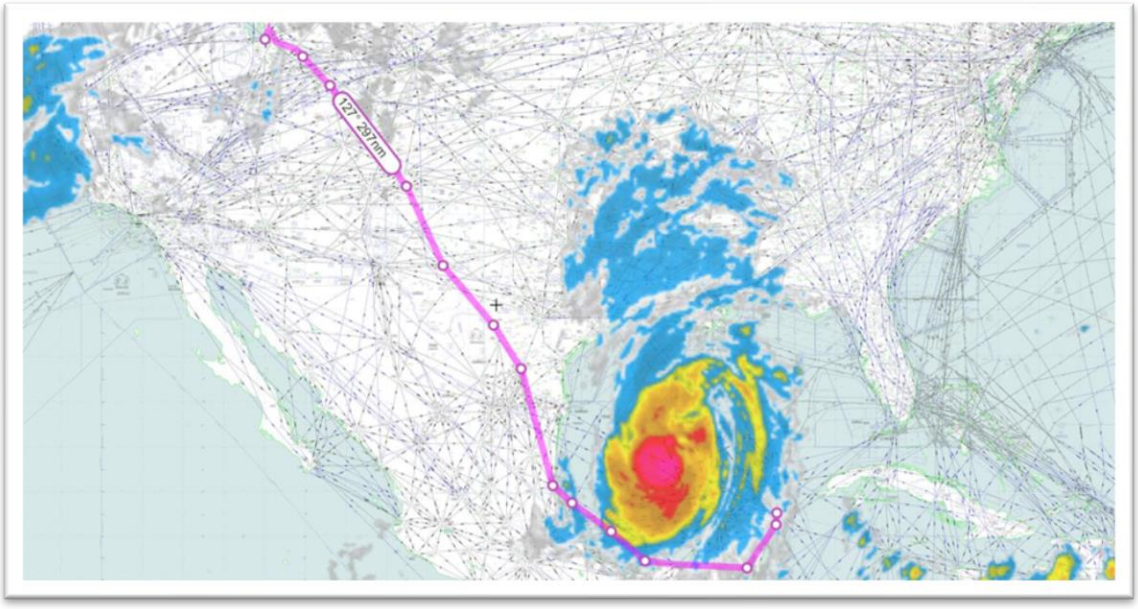

Figure 1 - PASA route requested October 7, 2020 (North America)

PASA request function of CADENA Operational Information System (OIS) and within 30 minutes, the impacted ANSP had approved the airline's route requests. The affected airline was issued a contingency route like the one illustrated below, allowing the flight to bypass the hurricane with a safe and viable choice to destination, saving both time and money, while the ANSPs obtained advanced notifications of the change in their overflight demand.

CADENA organises quarterly contingency training exercises. The contingency exercise goal is always to "train as we respond" and simulate how critical it is to ensure good communication and teamwork. Below are examples from CADNEA of savings to the airlines during severe weather events, other emergencies, and in trials of the PASA route optimization.

Airline	**Event**	**Savings (USD)**	**Savings (minutes)**	**Fuel Savings**	**CO_2 Reduction**
Airline 1	2017 Hurricane Maria Recovery Operation	$1-5.4M	NA	NA	NA
Airline 2	2017 Return Home from Hurricane Maria	$182,000	NA	NA	NA
Airline 3	2017 Loss of Radar Surveillance	$225,000	NA	NA	NA
Airline 4	2017 Loss of Radar Surveillance	$175,500	NA	NA	NA
Airline 5	2017 Loss of Satellite Communication	$192,000	NA	NA	NA
Airline 6	2021 PASA Optimization Pilot Test	$77,756	414 minutes	122,403 lbs.	175,403 kg
Airline 7	2021 PASA Optimization Pilot Test	$35,053	194 minutes	52,702 lbs.	75,541 kg
Airline 8	2021 PASA Optimization Pilot Test	$16,189	114 minutes	16,125 lbs.	23,113 kg
Airline 9	2021 PASA Optimization Pilot Test	$16,772	129 minutes	11,900 lbs.	17,057 kg
Airline 10	2021 Filed Flight Plans via CADENA OIS during a regional Aeronautical Fixed Telecommunications Network (ATFM) outage	$1.3M	NA	NA	NA