

The background of the entire page is a photograph of two commercial airplanes in flight against a dramatic sunset sky. The sky is filled with warm, orange and yellow clouds. The airplane on the left is in the foreground, flying towards the viewer. The airplane on the right is further away, flying away from the viewer. A large, white, curved line arches across the upper portion of the image, framing the title.

# AIR TRAFFIC FLOW MANAGEMENT (ATFM) TOOLKIT

A reference for Air Navigation Service  
Providers

**SHAPING  
OUR  
FUTURE  
SKIES**

# Acknowledgements

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# Executive Summary

Air Traffic Flow Management (ATFM) is a service designed to ensure the safe, orderly, and efficient flow of air traffic by optimising Air Traffic Control (ATC) capacity utilisation and aligning air traffic demand with available resources. ATFM plays a critical role in maintaining safety within Air Traffic Management (ATM) operations, particularly during periods of high traffic volume or when capacity disruptions occur.

To balance air traffic demand and ATC capacity across the ATM network, ATFM Managers have a range of solutions available to them. Broadly speaking, effective ATFM Managers prioritise solutions that increase or optimise the use of available capacity wherever possible, thereby minimising delays for airspace users and preventing disruption to aerodrome and network operations. These solutions are known as *Capacity Optimisation Activities*.

When capacity optimisation alone does not suffice and capacity enhancement is not readily feasible, ATFM Managers may apply *ATFM Measures* to achieve demand–capacity balance. These ATFM Measures are tools to manage the flow of air traffic into constrained or congested ATM resources such that the level of traffic demand is kept at the level appropriate to the available ATC capacity.

Selecting and implementing the most appropriate ATFM solution, whether in the Capacity Optimisation Activities or ATFM Measures category, is essential to maintaining operational efficiency and network stability. CANSO has recognised the need for greater clarity and consistency in this area, underscoring the importance of clear guidance for the ATFM community.

This document therefore provides ATFM Managers with an inventory of potential ATFM solutions available for use, along with detailed descriptions, application criteria, and guidance for implementing them under varying operational conditions.

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# 1. Introduction

This chapter provides an overview of ATFM and how it is currently implemented around the world. Understanding the basics of ATFM can help readers better understand the need to consider a variety of solutions for implementing ATFM strategies, procedures, and technologies.

## 1.1 Overview of ATFM

ATM is defined as the dynamic, integrated management of air traffic and airspace, and comprises air traffic services (ATS), airspace management (ASM), and ATFM. This comprehensive concept, having evolved in response to increasing traffic demand and rising complexity in airspace usage, enhances the conventional ATS processes with improved planning through ASM and ATFM. This comprehensive concept allows for more well-planned management of complex networks of aerodrome and airspace resources to facilitate air traffic safely and efficiently.

Given that ATFM is an important element of an ATM system, *Annex 11 to the Convention on International Civil Aviation* (15<sup>th</sup> Ed., Amdt. 53 – Nov 2024) specifies in Section 3.7.5 that,

***“Air traffic flow management (ATFM) shall be implemented for airspace where air traffic demand at times exceeds, or is expected to exceed, the declared capacity of the air traffic control services concerned.”***

The requirements for ATFM as outlined in Annex 11 are supported by *International Civil Aviation Organisation (ICAO) Procedures for Air Navigation Services - Air Traffic Management* (Doc 4444 – PANS-ATM, 16<sup>th</sup> Ed., Amdt. 12 – Nov 2024) and ICAO Manual on Collaborative Air Traffic Flow Management (Doc 9971, 13<sup>th</sup> Ed., 2018), which defines ATFM as:

***“A service established with the objective of contributing to a safe, orderly and expeditious flow of air traffic by ensuring that ATC capacity is utilised to the maximum extent possible, and that the traffic volume is compatible with the capacities declared by the appropriate ATS authority.”***

In principle, ATFM is an overarching concept that reflects the solutions to balance the traffic demand on the ATM resources with the available capacity to accommodate that demand.

It is important to note that ATFM does not generate delays but rather aims to manage delays inherent in demand-capacity imbalance situations, and to enhance stakeholders' predictability. Delays are not necessarily minimised without a concerted capacity enhancement effort.

ATFM is implemented at differing levels of complexity globally. Some implementations are at the local level, covering primarily flights within the air navigation service provider (ANSP)'s area of responsibility such as in a Flight Information Region (FIR). Examples of these “domestic” implementations are in the United States, Japan, and Australia; each with customised automated demand-capacity balancing systems to suit their needs. Other implementations are at the regional level with a single regional ATFM center providing the service for the region. This is the case in Europe, with EUROCONTROL Network Manager providing the ATFM service for the European airspace network. In the past decade, a concept of a regional *distributed* cross-border ATFM network has also been explored and implemented, in which the ANSPs in the region are each responsible for demand-capacity balancing within their areas of responsibilities but are connected with each other on a network of efficient ATFM information exchange. This interconnectedness, coupled with common ATFM operating principles adhered to by the network members, allows for cross-border ATFM operations affecting transboundary flights without the need for a single regional ATFM center. This concept has been implemented in Asia-Pacific under the APAC Cross-Border Multi-Nodal ATFM Collaboration (AMNAC) It has also been accepted in the Middle East and may eventually become the concept that enables a globally interconnected ATFM network. Another regional initiative has been implemented in Latin America and the Caribbean under the Civil Air Navigation Services Organisation (CANSO) ATFM Data Exchange Network for the Americas under the CANSO Operational Messaging Platform for Air Traffic Flow Management (ATFM) Sharing and Synchronisation (COMPASS) platform. Additional details of each ATFM implementation concept are described in Appendix A of this document.

# 1. Introduction

## 1.2 ATFM Phases

The *ICAO Manual on Collaborative ATFM (Doc 9971)* identifies that ATFM activities should be carried out in three ATFM execution phases - Strategic ATFM, Pre-Tactical ATFM, and Tactical ATFM. The ATFM solutions that fit into these phases can differ between regions/States/ANSPs depending on their operational environments. The focus of the operations in these phases is in balancing traffic demand with the available capacity of an ATM resource, which is a function of airspace/aerodrome design and complexity, technical infrastructures such as communications, navigation, and surveillance systems, ATC staffing defined by workload, training, and capability, and meteorological conditions among other factors.

**Strategic ATFM** is defined as actions carried out more than one week prior to the day of operations and includes activities such as airline scheduling, aerodrome slot coordination, performance prediction, capacity analysis, large-scale event planning (e.g. sport, military exercises, air shows etc.), and planning for seasonal weather activities (e.g. hurricane/typhoon season).

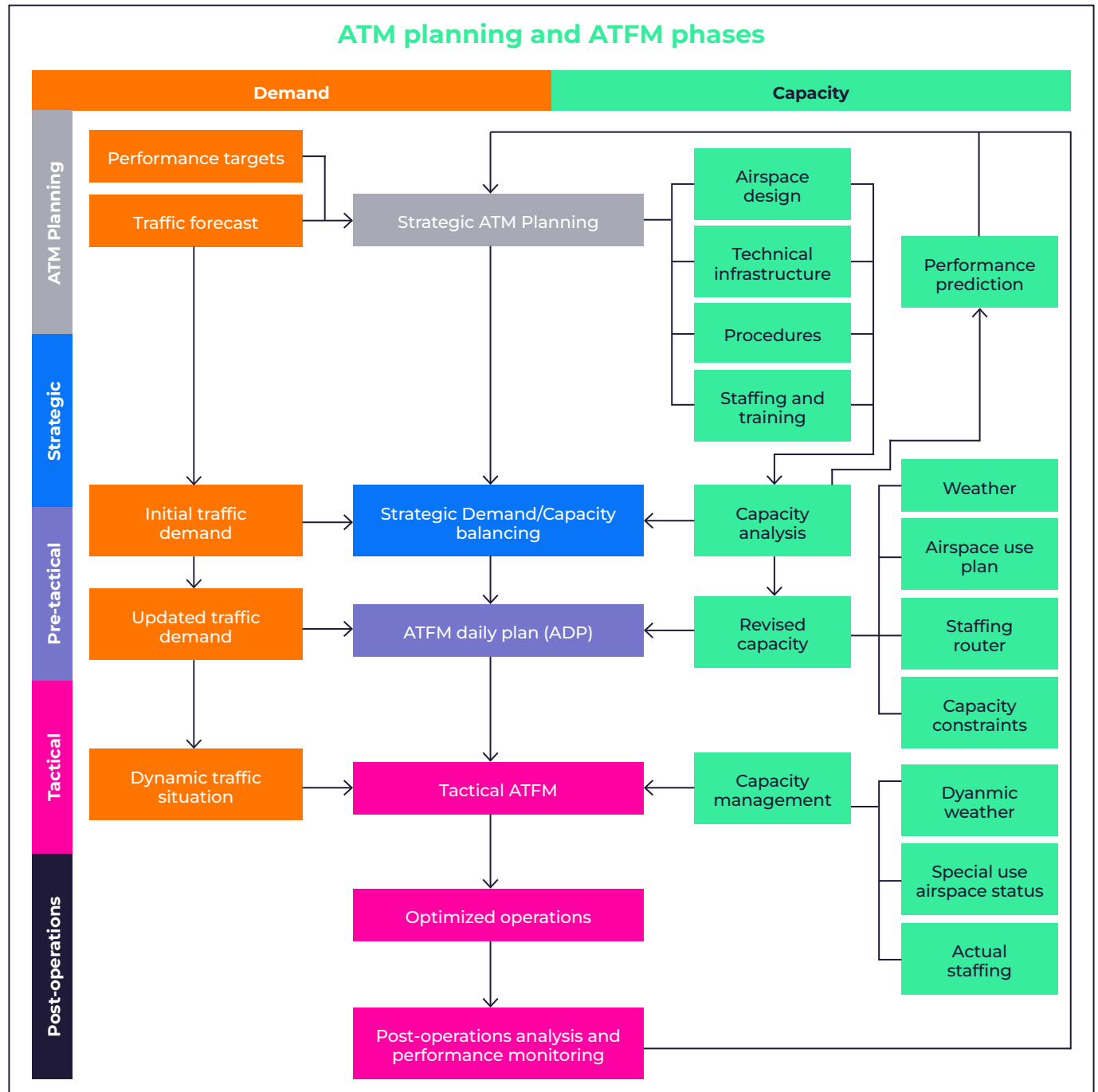
**Pre-Tactical ATFM** is defined as actions taken one day to one week before the day of operations with key activities including the development of ATFM Daily Plans (ADP) that communicate planned or expected ATFM solutions such as conditional route availability based on the Flexible Use Airspace (FUA) concept, airspace re-sectorisation, or ATFM measures in anticipation of the expected demand.

**Tactical ATFM** is defined as actions taken on the day of operations. Tactical ATFM actions aim to minimise potential demand-capacity imbalances by using ATFM measures to manage delays and improve predictability for all stakeholders in the network.



# 1. Introduction

**Figure 1**, taken from Figure II-4-1 in the *Manual on Collaborative ATFM (Doc 9971, 3<sup>rd</sup> Ed.)* provides an overview of the three ATFM operational phases, in the context of broader ATM planning and post-operations analysis. Chapter four of Part II of Doc 9971 discusses in greater detail these ATFM phases.



**Figure 1 – ATFM Operational Flow**

For more detailed discussion on ATFM implementation and operations, ICAO's *Manual on Collaborative ATFM (Doc 9971)* and CANSO's [Implementing ATFM/CDM](#) are good guiding documents on the topic.

The next chapter discusses the range of ATFM solutions and how they can be applied in these ATFM phases.

# 2. ATFM Solutions

This chapter explores the range of ATFM strategies, methods, and technologies that can be applied to optimise the available ATC capacity and/or balance the traffic demand against it.

## 2.1 The Need to Consider a Variety of ATFM Solutions

Broadly speaking there are two “categories” of ATFM solutions to balance air traffic demand and ATC capacity:

- **Capacity Optimisation Solutions**, which are solutions to optimise the available ATC capacity to meet the anticipated demand without placing undue delays or restrictions on the airspace users, and/or
- **ATFM Measures**, which are measures taken on the traffic (flights) to reduce the demand placed on the ATM resource when optimisation activities are not sufficient or not possible.

Capacity optimisation activities should be first considered when demand is exceeding capacity, as these solutions have the least impact on stakeholders. ATFM measures, on the other hand, should be implemented when solutions to optimise the capacity are not sufficient or not possible. The following sections describe ATFM solutions that can be considered under the two strategies.

## 2.2 Capacity Optimisation Solutions

Capacity Optimisation Solutions should first be considered for implementation as they tend to have least impact on stakeholders especially the Airspace Users (AUs). The section lists the most common optimisation solutions and how they can be applied.

**Table 1** - Capacity Optimisation Solutions

| Capacity Optimisation Solutions               | Constraints Addressed   | Description   |
|---|---|---|
| <b>Sectorisation</b>                          | <ul style="list-style-type: none"> <li>• Capacity Shortfall</li> <li>• Airspace Complexity</li> </ul> | The capacity of a portion of controlled airspace can be optimised by the sectorisation associated with the specific airspace and surrounding airspace(s). When faced with a specific capacity shortfall, a new airspace configuration (e.g., number of sectors or sector configuration) can increase the overall capacity through a more appropriate distribution of Air Traffic Control Officer (ATCO)’s workload.   |
| <b>Flexible Use of Airspace (FUA) Concept</b> | <ul style="list-style-type: none"> <li>• Capacity Shortfall</li> <li>• Airspace Complexity</li> </ul> | FUA is a concept in which airspace is not designated as purely for civil or military use, but rather as a continuum in which the requirements of all airspace users are accommodated to the greatest possible extent. Implementation of FUA through coordination between airspace users such as the military and/or recreational airspace users can help identify opportunities to increase airspace capacity in specific conditions.<br><br>More details on FUA can be found from ICAO <i>Manual on Civil-Military Cooperation in Air Traffic Management (Doc 10088)</i> . |

## 2. ATFM Solutions

| Capacity Optimisation Solutions  | Constraints Addressed   | Description  |
|--|---|--|
| <b>Increased ATC Unit Staffing</b>   | <ul style="list-style-type: none"> <li>Capacity Shortfall</li> <li>Airspace Complexity</li> </ul> | <p>The capacity of a portion of airspace can be optimised by the addition of assistants, planners, coordinators and/or flow controllers. The allocation of additional staff can reduce the workload of executive controllers by planning traffic and separation, coordinating with adjoining sectors/units, establishing traffic sequences and assisting with flight progress strip annotation in non-automated environments.</p>  |
| <b>Balancing Arrival and Departure Capacity (Mixed-Mode Runway Operations)</b> | <ul style="list-style-type: none"> <li>Imbalanced Arrival/Departure Demand</li> </ul>             | <p>In short periods of operation, the configuration of an aerodrome (e.g., runway usage by operations including mixed-mode operations) can impact available capacity. When a demand/capacity imbalance is identified, ATFM or ATC units should identify if a change to the operational aerodrome runway configuration can provide additional capacity to mitigate the imbalance.</p> <p>Optimising runway usage at high-demand, capacity-constrained aerodromes can be difficult, especially for mixed-mode operations where aerodromes have only one runway for both arrivals and departures. Runway sequencing tools such as Arrival Management (AMAN) and Departure Management (DMAN) or Integrated Arrival/Departure Management (IAD) can be helpful in these cases.</p> |
| <b>Increasing arrival and departure capacity at aerodromes</b>                 | <ul style="list-style-type: none"> <li>Capacity Shortfall</li> </ul>                              | <p>There are many procedures which can be applied when demand is greater than either the arrival and demand rates of the aerodromes. Some examples are: visual approaches and departures, Time-Based separation, Wake Turbulence Recategorisation (RECAT), Equivalent Lateral Spacing Operations (ELSO). Published procedures are essential for application of these capacity enhancing solutions.</p>   |

## 2. ATFM Solutions

| Capacity Optimisation Solutions                              | Constraints Addressed  | Description  |
|--|--|--|
| <b>Dynamic Airspace Configuration (DAC) (Intra-Facility)</b> | <ul style="list-style-type: none"> <li>• Sector over-demand within a single Area Control Centre (ACC)</li> <li>• Inefficient sector geometry for current traffic patterns</li> <li>• ATCO workload imbalance</li> </ul>                    | <p>Intra-facility DAC focuses on optimising airspace sectorisation within a single ATC facility by either increasing the number of sectors or adjusting sector configurations without altering the boundaries between facilities. This solution involves fine-tuning the existing sector layout to ensure a balanced workload distribution among ATCOs, especially during peak traffic periods. By increasing the number of sectors, more ATCOs can be deployed, enhancing coverage and capacity. Alternatively, reconfiguring sectors allows for a more efficient distribution of traffic with the same number of ATCOs, improving capacity without additional staffing. This dynamic approach enables ATCOs to better manage the varying demands of air traffic while maintaining safe and efficient operations.</p>   |
| <b>Dynamic Airspace Configuration (DAC) (Intra-Facility)</b> | <ul style="list-style-type: none"> <li>• Uneven workload distribution across facilities</li> <li>• Cross-boundary congestions</li> <li>• Limited contingency or recovery options during airspace closures or ATC system outages</li> </ul> | <p>Inter-facility DAC refers to the reorganisation of airspace sectors across multiple ATC facilities with adjacent airspace to better balance traffic demand and available capacity. This strategy involves modifying the configuration of existing sectors and making associated adaptation and CNS data available to adjacent facility sectors to handle two use cases: (1) to manage contingencies (facility outage), or (2) to dynamically share the workload more effectively among ATCOs by leveraging available ATCO capacity in an adjacent facility.</p> <p>For the contingency use case, by adjusting the sectorisation of airspace across facilities, adjacent ATC facilities can temporarily take control over airspace of a facility that experienced an outage or “ATC-0” event to provide some level of air traffic control service.</p> <p>For workload sharing across facilities, ATC facilities can accommodate higher traffic demand and reduce congestion, thus improving overall airspace efficiency. This flexibility in airspace design allows for a more adaptable response to fluctuating demand and enhances the ability of ATC facilities to handle complex air traffic scenarios with optimised capacity utilisation.</p> <p>Operationalising inter-facility DAC will require considerations and decisions on the necessary ATCO training and currency requirements to enable such operations in both contingency and workload sharing use cases.</p> |

## 2. ATFM Solutions

### 2.3 ATFM Measures

When solutions to optimise the capacity are not sufficient or not possible, ATFM measures, which are measures taken on the traffic (flights) to reduce the demand placed on the ATM resource, may be implemented. ATFM measures work by adjusting the affected flights' operations, whether through time or lateral and vertical profiles. The section lists the most common ATFM measures and how they can be applied.

#### Time-Based ATFM Measures

These are ATFM measures that work by adjusting the time of operations of the affected flights through methods such as delay assignments.

**Table 2** - Time-Based ATFM Measures

| ATFM Measures                      | Constraints Addressed  | Description   |
|------------------------------------|--|---|
| <b>Ground Delay Program (GDP)</b>  | <ul style="list-style-type: none"> <li>• Aerodrome Arrivals</li> <li>• Aerodrome Departures</li> </ul>                           | GDP is a pre-tactical or tactical ATFM measure where aircraft are held on the ground to balance demand and capacity at a specific aerodrome. In the process, departure times known as <i>Calculated Take-Off Times (CTOT)</i> are assigned to corresponding arrival/departure slots into/ from the aerodrome where demand exceeds capacity. Compliance with the GDP is achieved through a combination of Airspace Users (AU)' actions and ATC instructions. A GDP aims to, among other things, minimise airborne delays. It is a flexible program, and its form may therefore vary depending on the needs of the ATM system. GDPs are best developed in a collaborative manner. When a GDP is scheduled to last for several hours, the likelihood of slots having to be revised increases, as conditions can change. There should therefore be a system in place to advise stakeholders of any changes to the CTOTs or to the GDP parameters. |
| <b>Airspace Flow Program (AFP)</b> | <p>Over-demand at</p> <ul style="list-style-type: none"> <li>• Airspace sectors</li> <li>• Fixes</li> <li>• Waypoints</li> </ul> | AFP is a pre-tactical or tactical ATFM measure to balance demand and capacity in a sector of airspace, a fix, or a waypoint. In the process, CTOTs and Calculated Time Over (CTOs) corresponding to available entry slots into the airspace where demand exceeds capacity are assigned to aircraft on the ground and in the air. Compliance with the AFP is achieved through a combination of AU actions and ATC instructions. An AFP aims to, among other things, minimise airborne delays by allowing AUs to absorb the delay on the ground or in the air by adjusting flight speed to meet the CTO. Consideration should be given to the extent of the airborne delay that can be absorbed. In general, an aircraft can "lose" 2-3 minutes per flight hour through speed adjustment.   |

## 2. ATFM Solutions

| ATFM Measures  | Constraints Addressed  | Description  |
|--|--|--|
| <p><b>Airspace Flow Program (AFP) (continued)</b></p>  |  | <p>It is a flexible program, and its form may therefore vary depending on the needs of the ATM system. AFPs are best developed in a collaborative manner. When an AFP is scheduled to last for several hours, the likelihood of CTOTs and CTOs having to be revised increases, as conditions could change. There should therefore be a system in place to advise stakeholders such of changes to CTOTs and CTOs as well as of any changes to the AFP parameters.</p>   |
| <p><b>Ground Stop (GSt)</b><br/> <i>Note: A GSt stops flights departing from aerodromes bound for the impacted aerodrome. To stop traffic departing from aerodrome where impact has occurred see “Departure Stop” below.</i></p> | <ul style="list-style-type: none"> <li>• Significant reduction of aerodrome arrival capacity due to adverse weather conditions, runway closures, or runway accidents/incidents</li> <li>• Prevention of extended airborne holding due to airspace sector saturation</li> <li>• Inability of an ATC facility to provide the service due to unforeseen circumstances</li> <li>• Support the application of short notice rerouting</li> </ul> | <p>Ground Stop (GSt) is a tactical ATFM measure implemented in response to an unforeseen adverse situation. Certain aircraft, such as those originating from specific departure aerodromes or those scheduled to arrive at a particular aerodrome, are mandated to remain on the ground for a designated period. This measure is used when there is a significant reduction of capacity due to adverse/severe weather conditions, facility closures, runway accidents/incidents. It is sometimes colloquially referred to as a “zero rate ATFM measure”.</p> <p>The implementation of GSt can have severe repercussions on all stakeholders, therefore implementation of alternative ATFM measures should be considered prior to the initiation of a GSt, provided that time and circumstances permit. The implementation of a GSt typically involves a combination of notifications to AU and instructions from ATC.</p> <p>Since GSt is a high-impact measure, it is normally followed by another ATFM measure such as a GDP to re-introduce traffic into the constrained resource in an orderly manner.</p> |
| <p><b>Departure Stop</b><br/> <i>Note: A Departure Stop prevents flights departing from the impacted aerodrome. For the reverse, i.e. preventing flights from arriving at an aerodrome, see GSt above.</i></p>                   | <ul style="list-style-type: none"> <li>• Severe reduction in departure capacity due to, e.g., aircraft incident, severe weather, or equipment failure</li> </ul>   | <p>In a Departure Stop, all flights departing from the constrained aerodrome are held on the ground, including – if the situation is severe enough – flights that have already commenced pushback/taxi (a return to gate). The ATCO (TWR/GND) is responsible for ensuring no aircraft depart during the Departure Stop. A Departure Stop is typically followed by a departure GDP implemented by an ATFM system or pre-departure sequencing tool.</p> <p>Should the constraint be severe, a GSt can also be issued for flights coming in from other aerodromes at the same time.</p> <p>A Departure Stop can be used during severe capacity reduction, until a less restrictive ATFM measure can be implemented.</p>   |

## 2. ATFM Solutions

| ATFM Measures   | Constraints Addressed   | Description  |
|---|---|--|
| <p><b>Minutes-in-Trail (MINIT) and Miles-in-Trail (MIT)</b></p> | <ul style="list-style-type: none"> <li>Managing the flow of traffic into a sector or airspace or over a waypoint such as an arrival fix</li> </ul>  | <p>MINIT/MIT are tactical ATFM measures expressed as the number of minutes or nautical miles (or kilometres) between each successive aircraft at an airspace boundary point. These measures are relatively simple to implement and can take immediate effect, hence are suitable for managing short-term congestions or capacity reductions. However, the implementation of these measures by the ATFM or ATC unit can impose workload on other ATC units, as compliance is achieved by a combination of flow control and tactical ATC clearances and instructions. There is also the potential for upstream network effects, with the required spacing being expanded as it traverses multiple FIRs. As such, regular usage of MINIT or MIT may indicate that more appropriate ATFM measures should be used in their places.</p>  |
| <p><b>Minimum Departure Interval (MDI)</b></p>                  | <ul style="list-style-type: none"> <li>Managing the flows of traffic departing from an aerodrome due to the constraint in the TMA, at a departure fix, or downstream sectors</li> <li>Integrating flights into an overhead stream of traffic</li> </ul> | <p>MDI is an ATFM measure that temporarily limit departure flow from an aerodrome, expressed as the minimum time interval between successive departures along similar Standard Instrument Departure (SID) routes or SID group or to a specific destination, often issued to avoid an overload of downstream sectors. MDIs can be applied to departures from a single aerodrome or multiple aerodromes.</p> <p>In MDI, the departure interval between departure flights will be declared by the ATC unit or the ATFM unit. This departure interval is then passed on to the ATCO (TWR), and it is their responsibility to ensure flights depart in accordance with the measure. MDI may only be applied to certain flights contribution to the over demand, while other flights can be exempted.</p> <p>MDIs are particularly valuable in situations when there is a need to balance the departure demand with the airspace capacity. For example, when ATFM measures like Ground Delay Programs (GDP) are imposed or when departure routes are affected by adverse weather conditions. MDIs are used as constraints in sequence optimisation to account for complex airspace dependencies.</p> |

## 2. ATFM Solutions

| ATFM Measures         | Constraints Addressed   | Description  |
|-----------------------|---|--|
| <b>Cherry Picking</b> | <ul style="list-style-type: none"> <li>Solving short peaks in traffic demand</li> </ul> | <p>A Mandatory Cherry Pick regulation (MCP) is used as a measure to solve short peaks (e.g. 1h or 1h 30min) of demand for a limited number of flights in congested resources. It consists of selecting flights and applying ATFM measures only to those flights. It may be used in combination with other measures. The delay for cherry picked flights should not exceed 20 minutes and is not normally issued to flights that already have CTOTs or are part of an A-CDM departure sequence.</p> |

### Profile-Based ATFM Measures: Lateral

These are ATFM measures that work by adjusting the planned “lateral” profiles of the affected flights through methods such as route assignments.

**Table 3** - Profile-Based ATFM Measures: Lateral

| ATFM Measures    | Constraints Addressed  | Description  |
|------------------|--|--|
| <b>Rerouting</b> | <ul style="list-style-type: none"> <li>Reduce traffic demand placed on an ATS route or an airspace sector</li> </ul> | <p>Rerouting is an ATFM measure to reduce traffic demand from certain portions of the airspace by moving traffic demand away laterally.</p> <p>During alternative or advisory routing scenarios, the routes are made available to AUs on an optional basis to reduce air traffic demand from certain portions of airspace. It is important to note that where such ‘optional’ routing scenarios are not taken up by airspace users, mandatory ATFM measures will normally be required.</p> <p>Rerouting scenarios or ‘playbooks’ are composed of a set of collaboratively developed, published, predefined routes to address reoccurring route scenarios. The set of options is an assistance tool that allows efficient route coordination during periods of system constraint.</p> <p>Appendix B provides additional detail on the applications of this measure, including cross-boundary rerouting and rerouting to avoid an AFP.</p> |

## 2. ATFM Solutions

| ATFM Measures                                  | Constraints Addressed   | Description  |
|--|---|--|
| <b>Coded Departure Routes</b>                  | <ul style="list-style-type: none"> <li>Unavailability of departure routes due to weather or over-demand</li> </ul>  | <p>In a Coded Departure Route application, AUs and ANSP can coordinate and publish alternate routes from origin to destination, which can then be loaded onto a Flight Management System (FMS) by the AUs and can be cleared by the ATCO.</p>  |
| <b>Pre-Coordinated/ Playbook Routes</b>        | <ul style="list-style-type: none"> <li>Pre-coordinated rerouting to mitigate weather impact or demand/capacity imbalances in ATS routes or airspace sector</li> </ul> | <p>Pre-Coordinated or Playbook routes allow a set agreed weather or volume mitigation routes to be published in advance, thus enabling AUs and ATC facilities to implement them.</p>   |
| <b>Fix Balancing</b>                           | <ul style="list-style-type: none"> <li>Distribute demand across departure/arrival fixes</li> </ul>  | <p>Fix balancing is a measure whereby the aircraft is assigned a different arrival or departure fix than the one indicated in the flight plan. This measure is usually applied during flight and aims to distribute demand across different fixes and to avoid imposing airborne delays/holding. This can also be used, for example, during periods of convective meteorological conditions where a standard instrument arrival (STAR) or a standard instrument departure (SID) is unusable.</p> |
| <b>Severe Weather Avoidance Program (SWAP)</b> | <ul style="list-style-type: none"> <li>Plans that can be implemented when aerodromes or airspace is impacted by convective weather</li> </ul>                         | <p>Plans that are pre-coordinated and published as the basis for tactical implementation. Allows for selection of individual components of the SWAP based on actual or forecasted weather.</p>   |

## 2. ATFM Solutions

### Profile-Based ATFM Measures: Vertical

These are ATFM measures that work by adjusting the planned “vertical” profiles of the affected flights through methods such as flight level limitations or assignments.

**Table 4** - Profile-Based ATFM Measures: Vertical

| ATFM Measures        | Constraints Addressed  | Description  |
|----------------------|--|--|
| <b>Level Capping</b> | <ul style="list-style-type: none"><li>• Reduce traffic demand placed on an airspace sector</li></ul>   | Level Capping scenarios are carried out by means of flight level restrictions limiting climb or descent to avoid constrained portions of airspace.   |
| <b>Tunnelling</b>    | <ul style="list-style-type: none"><li>• Keep flights clear of constrained airspace</li><li>• Avoid conflicting flows of traffic and holding patterns</li></ul> | In Tunnelling, a flight will be requested to commence descent prior to its ideal Top of Descent (TOD) point to avoid congested or constrained airspace. While implemented tactically, AUs need to be coordinated with via CDM methods to ensure fuel planning and awareness. |

### 2.4 Additional Tools and Strategies

In addition to the two (2) categories of ATFM solutions (capacity optimisation and ATFM measures), there are other tools and strategies that can be employed by ATFM units and ATC units to manage the imbalance between traffic demand and ATC capacity. These tools and strategies are listed below.

#### Additional ATC/ATFM Tools

These are additional tools that can enhance traffic synchronisation and management, and can be used in conjunction with, in addition to, or in some cases instead of ATFM solutions to enhance traffic flow efficiency while minimising adverse impacts on stakeholders.

## 2. ATFM Solutions

**Table 5 - Additional ATC/ATFM Tools**

| ATC/ATFM Tools                         | Constraints Addressed   | Description   |
|--|---|---|
| <p><b>Departure Manager (DMAN)</b></p> | <ul style="list-style-type: none"> <li>• Ground congestions and ground holding</li> </ul> | <p>A Departure Manager (DMAN) is a tool used at airports to plan, sequence, and optimise aircraft departures in a safe and efficient way. Its goal is to balance demand with available runway capacity and constraints inside the terminal airspace while minimising delays and unnecessary taxiing. DMAN creates a calculated take-off sequence and Target Take-Off Times (TTOTs) by considering multiple constraints, including ATFM requirements such as CTOTs, and issue them to aircraft to be complied with. This tool enables ATC to manage and implement ATFM requirements, whilst ensuring runway capacity is optimised.</p> <p>DMAN is a crucial element in an Airport Collaborative Decision Making (A-CDM) process when implemented, and high degree of technology integration is required between A-CDM system, ATFM systems, and other systems employed by the Aerodrome Operators. More detail on the integration of ATFM and A-CDM, including the crucial role DMAN plays, can be found at <a href="#">CANSO Guide on ATFM/A-CDM Integration</a>.</p> |
| <p><b>Arrival Manager (AMAN)</b></p>   | <ul style="list-style-type: none"> <li>• Congested or competing arrival flows</li> </ul>  | <p>An Arrival Manager (AMAN) is an ATFM and ATC decision-support tool used to plan, sequence, and optimise arriving aircraft so they reach the runway in a smooth, predictable flow. It allows for prediction of estimated arrival times of flights well in advance, thus provides a correctly spaced sequence and smoother transitions from enroute to terminal airspace. AMAN assigns airborne or ground-based delays to flights to ensure they are properly sequenced to each runway. AMAN reduces the need for holding patterns, radar vectoring, speed control and minimises fuel burn, delays, and environmental impacts and is key to meeting runway capacity targets. AMAN is considered both an ATFM and traffic synchronisation tool.</p>   |

## 2. ATFM Solutions

| ATC/ATFM Tools                           | Constraints Addressed | Description  |
|--|-----------------------|--|
| <p><b>Integrated AMAN/DMAN (IAD)</b></p> |                       | <p>While individual AMAN and DMAN systems plan in isolation, generating pure arrival or departure sequences for the given runways, Integrated AMAN/DMAN (IAD) systems bring those two domains together.</p> <p>For example, ANSPs often want to offload arrivals to the departure runway or the other way around while managing traffic peaks. Or, in other situations, the runways are used in mixed-mode operations altogether. An IAD system synchronises the arrival and departure traffic flows and the respective sequences on the runway system. To enhance situational awareness and efficiency, the integrated planning of arrivals and departures demands a joint planning process between Tower and Approach controllers. Both units jointly plan and agree on the most suitable use of the runway resource. Successful IAD implementations often employ a phased planning approach based on different time horizons and data uncertainties. This approach starts with flow-controlled planning early on, allowing more flexibility, and transitions to more refined planning as data uncertainties decrease.</p> |

### Additional Strategies

These are strategies that can supplement the implementation of ATFM solutions and can significantly enhance the effectiveness of ATFM solutions and ATC/ATFM tools.

**Table 6** - Additional Strategies

| Strategies   | Constraints Addressed   | Description  |
|--|---|--|
| <p><b>Improved Data, Predictions, and Modeling</b></p> | <ul style="list-style-type: none"> <li>• Unreliable or incomplete situational data</li> <li>• Low predictability of demand-capacity balance</li> <li>• Inaccurate weather or performance forecasts</li> </ul> | <p>Improved data, predictions, and modeling play a crucial role in optimising ATFM and can significantly enhance ATFM measures. Accurate and timely data on weather conditions, traffic demands, updated aircraft position, airspace constraints, and flight performance, when integrated into predictive models, allow for a more effective understanding of potential congestion points. This data-driven approach enables ATC systems to anticipate demand surges, optimise flight trajectories, and provide early insights into potential demand and capacity imbalances, leading to informed decision-making. These enhancements can be critical in formulating pre-emptive strategies that help avoid congestion before implementing specific ATFM measures.</p> |

## 2. ATFM Solutions

| Strategies                           | Constraints Addressed   | Description   |
|--------------------------------------|---|---|
| <b>Integrated ATFM</b>               | <ul style="list-style-type: none"> <li>• Fragmented coordination among ATFM, ATS, and airport units</li> <li>• Lack of common situational awareness across sectors or FIRs</li> <li>• Uneven distribution of delay among network nodes</li> </ul> | <p>Integrated ATFM is vital for managing congestion effectively across different sectors of the airspace. This integration involves coordinating and sharing information between all ATM facilities (including the ATFM units, Towers, ACCs, and Terminal, inside your FIR and regional FIRs), aerodromes, and other stakeholders, which can significantly improve flow management. By considering departure times (e.g, CTOT), A-CDM data (if implemented and available), arrival times, any airspace meter points (e.g., CTO) (if used) with en-route constraints and aerodrome capacity; integrated ATFM minimises the need for extended delays to be taken at any one particular point (e.g., GDPs) and can better inform overall flight planning and mitigation strategies. This allows for more dynamic and timely adjustments to air traffic flows, ensuring that all stakeholders, including airspace users and ATCs, are synchronised on real-time operations.</p> |
| <b>Recovery Phase Prioritisation</b> | <ul style="list-style-type: none"> <li>• To prioritise flights that have been impacted by an operational disruption (eg. Diverted flights)</li> </ul>   | <p>System or process that allows an agreed set of flights to receive priority in the recovery phase of constraint, which can be implemented via automation or manually. For example, flights that have been diverted may receive priority when returning to their original destination.</p>   |
| <b>Long-Range ATFM (LR-ATFM)</b>     | <ul style="list-style-type: none"> <li>• Demand and capacity imbalance in airspace or at an aerodrome and needs to manage long-range incoming traffic not conventionally covered in a GDP</li> </ul>  | <p>LR-ATFM is an ATFM concept to include airborne long-range flights into an ATFM measure to distribute the allocated delay between long range and short haul flights.</p> <p>LR-ATFM can be used after a demand and capacity has been identified in a resource several hours in advance. While not yet departed short/medium-haul flights will be subject to a GDP and will be issued with a CTOT, long-haul inbound aircraft already airborne will be issued with a Calculated Time Over (CTO) for a FIR/ sector boundary waypoint or fix. This is typically done by an automated system as calculation of times of multiple flights can be complicated. The amount of delay that can be allocated to airborne aircraft is restricted to what can be realistically achieved through speed reduction of the flight.</p>  |

## 2. ATFM Solutions

| Strategies                            | Constraints Addressed | Description   |
|---------------------------------------|-----------------------|---|
| Long-Range ATFM (LR-ATFM) (continued) |                       | <p>Transmission of the CTO to upstream flights can be done via the SWIM network and can be delivered to the flight crew by ATCOs using VHF/HF or Controller-Pilot-Data-Link Communications. The flight crew will then adjust the cruise strategy to meet the CTO. This enables more equitable distribution of delay and prevents airborne holding in TMAs.</p> <p>More information on LR-ATFM can be found in <a href="#">CANSO White Paper on Long-Range ATFM Concept</a>.</p> |

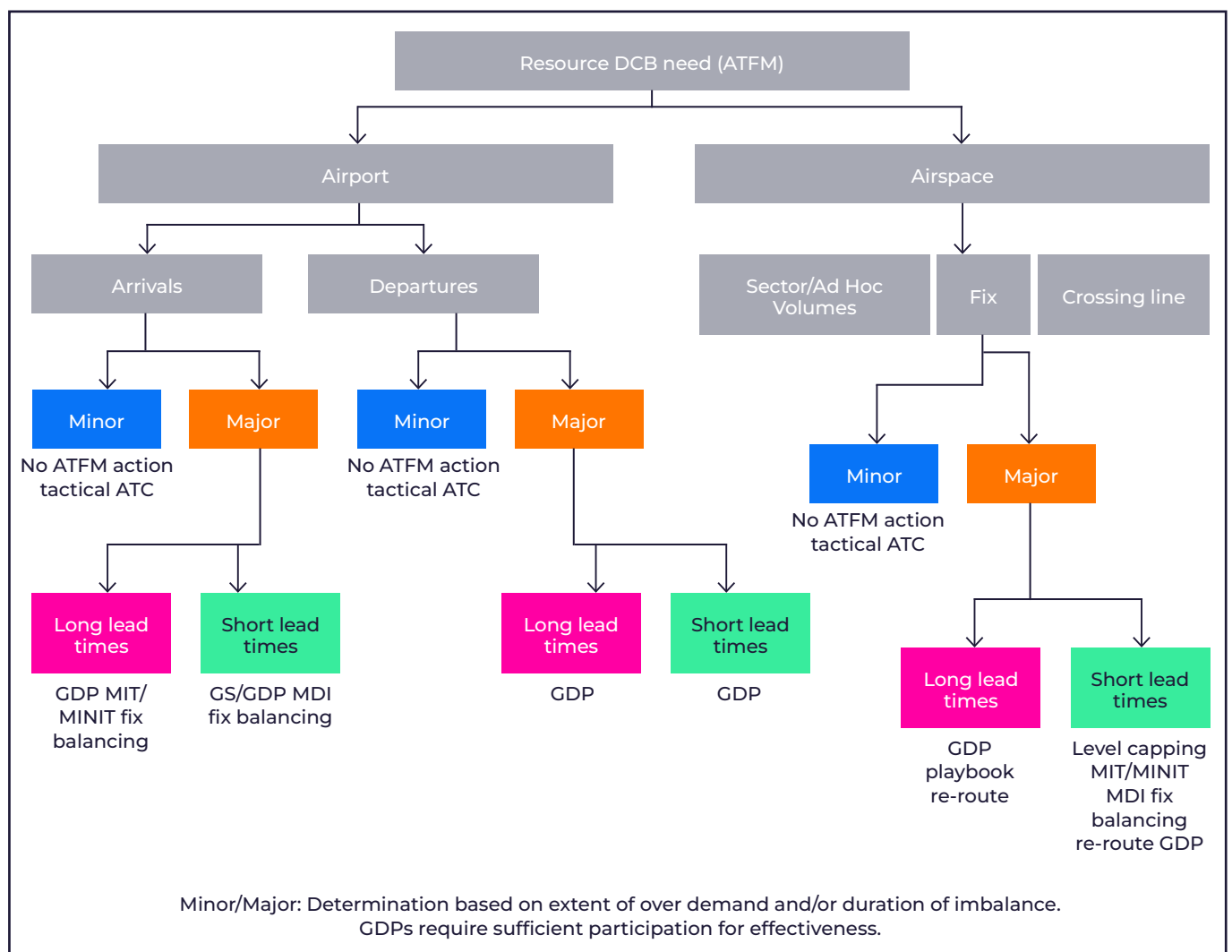
### 2.5 Additional Explanation of Selected ATFM Solutions

In addition to the description included in the tables in this chapter, Appendix B provides additional explanation, including considerations, examples, and cautions on some selected ATFM solutions more commonly used. This helps enhance an understanding on how these solutions can be utilised, and what to look out for when using them.

# 3. Identifying Applicable Solution(s) to Implement

This chapter provides recommendations on the process and considerations when selecting appropriate ATFM solutions to employ.

In selecting appropriate ATFM solution(s) to implement, ATFM Managers must assess the operational situation, available capacity, and predicted demand. Coordination with affected ACCs, Flow Management Positions (FMPs), and stakeholders is essential to ensure transparency, predictability, and equitable distribution of delay. Continuous monitoring and post-operational analysis will help to determine if the selected solution(s) can effectively support performance improvement and promote network efficiency. Figure 2, taken from Figure II-4-3 in the *Manual on Collaborative ATFM (Doc 9971, 3rd Ed.)*, gives an example of a selection process of some of the more common ATFM measures.



**Figure 2** – Selection of ATFM Measures

Recommendations on the process and considerations are further elaborated below.

# 3. Identifying Applicable Solution(s) to Implement

## 3.1 Selection Guidance

Effective ATFM depends not only on the availability of solutions but on the appropriate selection and timely application of the most suitable option. The choice of ATFM solutions should always aim to achieve demand–capacity balance with minimum overall impact on Airspace Users and the wider ATM network. ATFM Managers must evaluate several factors before determining which measure to apply; these factors are provided here.

### Availability of Alternative Capacity

Before implementing an ATFM measure, ATFM Managers should explore opportunities to increase or optimise available capacity:

- Adjust sector configurations or staffing plans
- Coordinate with adjacent sectors or FIRs to redistribute traffic
- Optimise runway configurations or departure sequencing

If additional capacity cannot be created, then an appropriate ATFM measure should be applied to balance demand.

### Nature and Duration of the Constraint

- **Short-term constraints** (e.g., temporary weather events, short staffing, or equipment outages) may be best managed through tactical measures such as Miles-in-Trail restrictions or Level Capping.
- **Longer-term constraints** (e.g., aerodrome closures, prolonged weather conditions, or planned maintenance) often require more impactful ATFM measures, such as Ground Delay Programs or Rerouting. Understanding whether the issue is transient or sustained allows for proportional, targeted intervention.

### Network-Wide Impact

Every ATFM measure affects not only the regulated airspace but also other parts of the network. ATFM Managers should assess potential downstream and upstream consequences, such as:

- Shifted congestion to adjacent sectors or aerodromes
- Increased flight times or fuel burn due to rerouting
- Impacts on connecting flights or hub operations

Coordination through the adjoining ATFM Units, FMP and stakeholders ensures that measures contribute to overall network efficiency, not isolated problem-solving.

### Equity and Predictability

ATFM measures must be applied fairly and transparently, ensuring equitable treatment of all airspace users. Predictability is critical to airline and aerodrome operations; therefore, early notification, consistent CTOT and CTO allocation procedures, and adherence to published parameters are essential. ATFM Managers should aim to provide operators with stable and timely information to support effective flight planning.

### Safety and Workload Considerations

Safety remains the overriding priority in ATFM decision-making. Measures should reduce controller workload, avoid sector overload, and maintain manageable traffic complexity. Any solution that risks compromising safety or creating additional coordination burden must be avoided, even if it appears to improve efficiency metrics.

### Continuous Assessment and Review

ATFM Managers should continuously monitor the performance and effectiveness of applied measures. When conditions improve or demand decreases, restrictions should be adjusted or cancelled promptly to restore normal operations. Post-operational and data analysis support future decision-making and contribute to ongoing ATFM performance improvement.

# 3. Identifying Applicable Solution(s) to Implement

## 3.2 ATFM Measure Selection Matrix

Table 7 provides examples of ATFM measure selection matrix. This matrix serves as an operational quick-reference tool. ATFM Managers should:

- Identify the constraint type and expected duration
- Select the measure that achieves demand–capacity balance with minimal disruption
- Coordinate the implementation measure with affected ACCs, FMPs and stakeholders
- Monitor the measure’s effectiveness and adjust or cancel it as soon as conditions allow

Note that this is not an exhaustive list.

**Table 7** - Example ATFM Measure Selection Matrix

| <b>Operational Scenario/Constraint</b>   | <b>Likely Term</b> | <b>Primary Objective</b>                  | <b>Recommended ATFM Measure(s)</b>  | <b>Notes/ Considerations</b>   |
|--|--------------------|---|---|--|
| <b>Weather affecting arrival aerodrome (e.g., thunderstorms, low visibility, strong winds)</b> | Short/medium       | Regulate arrival flow                     | <b>Ground Delay Program (GDP); possible Miles-in-Trail (MINIT) or Level Capping</b> | Coordinate with the affected aerodrome and adjacent ACCs; issue early GDP to minimise airborne holding |
| <b>Runway closure or aerodrome capacity reduction (e.g., maintenance, incident)</b>            | Medium/long term   | Manage reduced arrival/departure capacity | <b>Ground Delay Program (GDP); Departure Slot Allocation</b>                        | Consider coordination with aerodrome operator and AU for updated slot planning                         |
| <b>Runway closure or aerodrome capacity reduction (e.g., maintenance, incident)</b>            | Medium/long term   | Manage reduced arrival/departure capacity | <b>Ground Delay Program (GDP); Departure Slot Allocation</b>                        | Consider coordination with aerodrome operator and AU for updated slot planning                         |
| <b>Sector overload due to high demand</b>  | Short              | Maintain sector workload within capacity  | <b>Miles-in-Trail (MIT/ MINIT); Level Capping; possible Rerouting</b>               | Monitor demand trends; apply regulation dynamically and cancel when load decreases                     |
| <b>Airspace restriction (e.g., military activity, temporary segregated area)</b>               | Short/medium       | Redistribute demand to unaffected routes  | <b>Rerouting Measures; possibly Level Capping</b>                                   | Issue alternative route proposals; coordinate with adjacent sectors and FMPs                           |

# 3. Identifying Applicable Solution(s) to Implement

| Operational Scenario/Constraint   | Likely Term    | Primary Objective                    | Recommended ATFM Measure(s)                          | Notes/ Considerations  |
|---|----------------|--------------------------------------|--|--|
| Equipment outage or reduced ATC staffing  | Short/medium   | Reduce traffic complexity and demand | Ground Delay Program (GDP); MIT/MINIT Restrictions   | Ensure equitable treatment of flights; reassess regularly as capacity returns      |
| En-route weather deviation (e.g., convective activity, turbulence zones)            | Short/tactical | Maintain safety and flow continuity  | Rerouting Measures; Level Capping                    | Tactical coordination between ACCs essential to maintain separation and efficiency |
| Aerodrome departure congestion (e.g., ramp congestion, delayed turnarounds)         | Short term     | Smooth departure peaks               | Departure Slot Allocation; MIT/MINIT                 | Coordinate with Aerodrome Operations Centre (APOC) and Tower                       |
| Special event or major airspace activity (e.g., large sporting event, VIP movement) | Long Term      | Preemptively manage network impact   | Strategic ATFM Planning; Rerouting; Pre-tactical GDP | Apply measures in advance with wide stakeholder coordination and NOTAM publication |

## 3.3 Case Studies in the Use of ATFM Solutions

In aviation, disruptions caused by special events and unforeseen circumstances have been an inevitable part of the air transportation system. Unique challenges from natural disasters, State events, space or military operations can occur and disrupt air traffic management on any given day. ATFM solutions are often selected and implemented to manage these types of events, both planned and unplanned.

CANSO has developed a reference document that brings together case studies examining how ANSPs have planned for and managed several types of special events and disruptions ranging from large-scale planned airspace closures to unplanned weather phenomena. This document can be a helpful reference for ATFM Managers in learning how other ANSPs have selected and used ATFM solutions and can be read in conjunction with this toolkit.

The document can be accessed via <https://canso.org/publication/planning-for-the-expected-and-unexpected/>.

# 3. Identifying Applicable Solution(s) to Implement

## 3.4 Applicability of ATFM measures for New Entrants

As “New Entrants” are developed and integrated into aviation airspace, there is a need to consider the applicability of ATFM tools.

New entrants are defined as new types of airspace users (vehicles) that operate in airspace. These are driven by innovation and new technologies. Examples of new entrants include:

- **Piloted and Autonomous air taxis:** Typically intended for urban areas to transport passengers to airports, who then transfer to traditional aviation flights. This is an evolving area as technologies and strategies are being proven, and initial implementations are occurring.
- **Hypersonic aircraft:** New vehicle types that have reduced sonic boom and improved economics that allow for air speeds greater than the speed of sound. Normal operations are at altitudes above those used by traditional aviation, however the transition to/from normal aviation speeds may need airspace segregation.
- **Unmanned aerial systems/vehicles:** There are multiple models and uses for UAS/UAVs. Many of these do not impact traditional aviation such as low altitude systems that remain near to the surface.
- **High altitude platforms/systems:** New systems that operate at altitudes above traditional aviation and may last for many days or even months. These can include platforms that provide internet service to remote areas, photo survey missions, and atmospheric research platforms.
- **Package/medicine delivery drones:** An emerging technology that is being implemented in multiple parts of the world currently, typically remains below traditional aviation altitudes.

- **New types of space vehicles:** New methodologies and concepts of rapid development have resulted in many new types of space vehicles. While they are at traditional aviation altitudes for a very short period, the speeds are incompatible with aviation, resulting in the need to dedicate airspace to space operations. As new space vehicles are developed, there can be risks to aviation until the space vehicles become proven, and the repeatability of the operation is known. As space vehicle technology and design is proven and reliable, the risk to aviation is greatly reduced and the impacts are lessened. A major focus of ATFM and ATM is to develop tools and processes to better integrate aviation and space operations. Further information on space operations can be found in the document published by CANSO: [Considerations for Managing Space Operations – CANSO](#).

Details of new entrants to aviation vary depending on the specifics of each new entrant. As the new entrant technology matures and operational needs are clarified, ATFM measures may be needed to mitigate the impacts of these new types of operations.

## 3.5 Summary: Considerations in ATFM Solution Selection

The selection of an ATFM solution requires a balance of operational judgment, coordination, and data-driven analysis. By following these guiding principles, ATFM Managers ensure that ATFM actions maintain network safety, minimise disruption, and promote the efficient use of available capacity.

# 4. Key Principles and Conclusion

Multiple solutions can be implemented to address imbalances between capacity and demand within the air traffic management network. The initial priority for ATFM Managers is to increase or optimise the capacity of the constrained resource wherever possible. When capacity optimisation is not feasible, a range of ATFM measures can be employed to reconcile demand with available capacity.

## 4.1 Key Principles in ATFM Solution Implementations

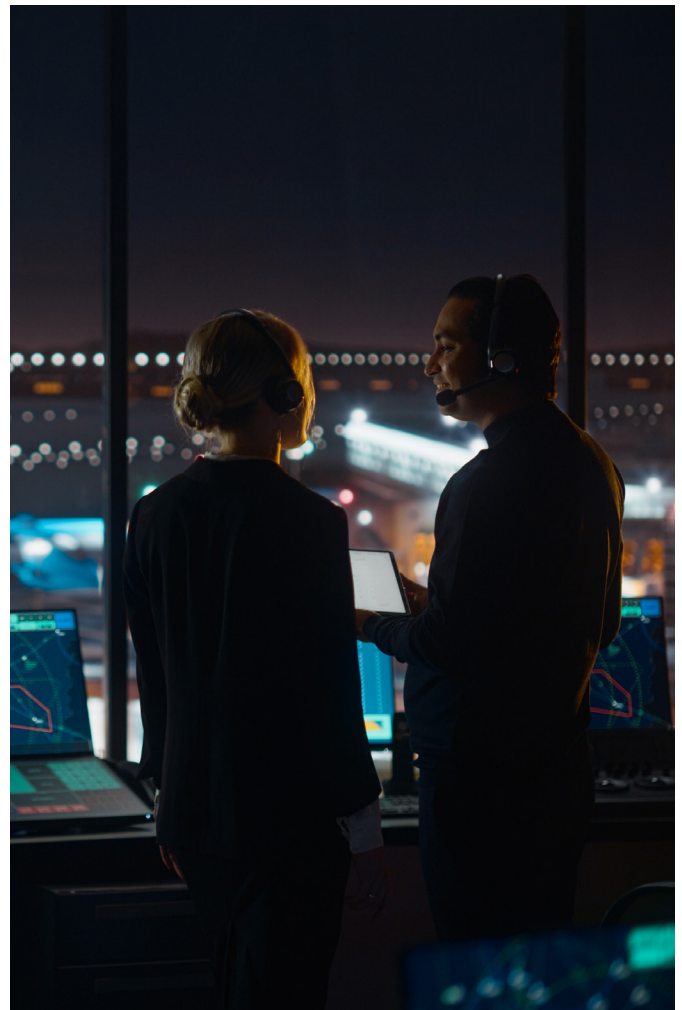
Effective ATFM relies on sound judgment, proactive planning, and close coordination across all operational stakeholders. The following principles underpin every ATFM decision and action:

- **Safety First:** Safety is the fundamental priority in all ATFM decisions. Every solution must maintain or enhance safety margins within the air traffic management system.
- **Efficiency and Predictability:** Flow Managers should aim to optimise the use of available capacity while minimising delays, fuel consumption, and environmental impact. Predictable operations benefit both service providers and airspace users.
- **Equity and Transparency:** All ATFM measures must be applied in a fair and transparent manner, ensuring equal treatment of all flights based on objective, published criteria.
- **Collaboration and Coordination:** Continuous communication and coordination with Air Traffic Service unit FMPs, airspace users, and other stakeholders are essential to achieve balanced and coordinated outcomes.
- **Timeliness and Adaptability:** Decisions should be made in a timely manner and remain flexible to evolving operational circumstances. Measures should be reviewed and adjusted as conditions change to restore normal operations as soon as practicable.
- **Performance Improvement:** Post-operations analysis and feedback should be used to refine processes, validate decision-making, and improve future ATFM performance.

## 4.2 Conclusion

ATFM Managers have access to a comprehensive toolkit of ATFM solutions, each designed to manage specific operational scenarios. The effectiveness of ATFM relies on selecting and applying the most appropriate measure for the situation at hand. Choosing an unsuitable measure may result in unnecessary delays, reduced efficiency, or failure to adequately resolve the underlying imbalance.

It is anticipated that ATFM Managers who utilise this consolidated “toolkit” — which clearly outlines ATFM solutions and their appropriate applications — will achieve more consistent, efficient, and effective ATFM outcomes across all phases of operation.



# 5. Additional Resources

Apart from the information provided in this document, there are many additional resources available on ATFM implementation, operations, and solutions. These resources include ICAO and CANSO documents as well as research publications by academic institutions. A non-exhaustive list of useful additional resources are provided below.

## 5.1 ICAO and CANSO References

- ICAO. Annex 11 to the Convention on International Civil Aviation: Air Traffic Services. 15th Edition, Amendment 53. ICAO. November 2024.
- ICAO. Procedures for Air Navigation Services – Air Traffic Management (PANS-ATM, Doc 4444). 16th Edition, Amendment 12. ICAO. November 2024.
- ICAO. Manual on Collaborative Air Traffic Flow Management (Doc 9971). 3rd Edition. ICAO. 2018.
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## 5.2 Research Publications

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- de Jonge, H., Tuinstra, E. and Seljée, R., 2005, June. Outbound punctuality sequencing by collaborative departure planning. In *6th USA/Europe ATM 2005 Seminar*.
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# Appendix A: ATFM Implementation from Around the World

ATFM is implemented differently in various parts of the world, reflecting the various operational needs, geographical and geopolitical landscapes, and operating environments in which States/ANSPs operate. In implementing ATFM, one of the first steps a State or ANSP should take is to understand their environment and determine the appropriate ATFM Concept of Operation (CONOPS).

In developing an ATFM CONOPS, the ICAO Manual on Collaborative ATFM (Doc 9971) recommends establishing it in terms of the “Geographical Dimension” and “Types of ATFM” to be implemented.

## Geographical Dimension of ATFM

The term “geographical dimension” here refers to the scope of traffic to be included in the ATFM solutions, which ranges from an ATFM solution that captures only domestic flights to an ATFM solution that encompasses international flights through sub-region or regional agreements. Broadly speaking, the geographical dimension of ATFM can be divided into domestic, cross-border, and regional ATFM.

**Domestic ATFM** refers to an ATFM implementation in which *only domestic flights* are captured in the ATFM solutions implemented by the ATFM service provider (ANSP). Other international flights are either excluded from the calculation or exempted from the solutions. This type of implementation does not require cross-border agreement but will be effective only if a large enough portion of the traffic demand is domestic. Experience and best practices indicate that a minimum of 70% participation of flights in an ATFM solution is required for it to be effective, and as such, domestic ATFM implementation are normally implemented where domestic traffic makes up most of the demand, e.g., the United States and Australia.

**Cross-Border ATFM** refers to an ATFM implementation in which *short-range international flights from immediate neighbors or within a sub-regional group are also included in the ATFM solutions in addition to domestic ones*. This type of geographical dimension helps supplement the amount of traffic participating in the ATFM solutions in places where domestic traffic alone does not suffice. The implementation of ATFM in the United States, through collaboration with Canada, demonstrates this type of geographical dimension.

**Regional ATFM** refers to an ATFM implementation where flights beyond domestic or immediate neighbors need to be included in the ATFM solutions to manage demand-capacity imbalances. This

implementation, which is essentially a cross-border ATFM implemented at the regional scale, aims to maximise the efficiency of ATFM operations across the areas of multiple ANSPs in the region, and requires regional collaboration and/or agreement. This type of implementation is especially useful for regions with many small FIRs and large contingents of intra-regional traffic demand, such as Europe, Asia-Pacific, and the Middle East.

**Inter-regional ATFM** refers to an ATFM implementation where flights beyond the region need to be included in the ATFM solutions to manage demand-capacity imbalances. This implementation, which is essentially LR-ATFM is implemented at the inter-regional scale, aims to maximise the efficiency of ATFM operations across regions, and requires inter-regional collaboration and/or agreement.

## Types of ATFM: Centralised vs Distributed

Apart from the geographical dimension, the “type” of ATFM operations specifies how the operations are executed. Broadly speaking, two “types” of ATFM operations are implemented globally –centralised and distributed.

**Centralised ATFM** refers to an ATFM implementation whereby a single ATFM unit is responsible for demand-capacity balancing within its area of responsibility. Conventionally, this ATFM unit is established by an ANSP and is responsible for managing the demand-capacity balancing within the ANSP’s FIR(s). This type of implementation is the most recommended one for States/ANSPs implementing domestic ATFM, to enable the most optimised management of traffic demand considering all the constraints within the FIR. This type of operation can also be extended to cross-border/regional ATFM.

# Appendix A: ATFM Implementation from Around the World

However, formal agreement can be established among the sub-regional or regional States to establish a regional ATFM center responsible for all the areas within the region.

**Distributed ATFM** refers to an ATFM implementation whereby several ATFM units, each responsible for their own area of responsibility (e.g. an FIR), form a “network” in which ATFM solutions implemented to manage traffic demand in one ATFM unit’s area of responsibility can include traffic coming from another unit’s area. The exchanging of ATFM information and measures among ATFM units and other stakeholders are based on interconnected information-sharing framework and the facilitation of compliance with the ATFM solutions are based on a common set of agreed principles. This type of operation is best implemented when a sub-region or a region requires collaborative ATFM implementation, but the (sub)-regional environment is not suitable for the establishment of a regional ATFM center.

## Examples of ATFM Models Implemented

Based on the geographical dimensions and types of ATFM, three main models of ATFM have been implemented to date – domestic, regional-centralised, and regional-distributed. Below are examples of how these models are used in different parts of the world.

### Domestic ATFM Concept United States

In the US, the Federal Aviation Administration (FAA) oversees a large proportion of the globe’s airspace with large oceanic airspace on either side of the country, allowing for the flexible handling of enroute traffic around constraints such as weather. ATFM in the US National Airspace System (NAS) is applied at major aerodromes, in surrounding terminal airspace, and in enroute airspace to manage constraints and congestion caused by weather, traffic overloads, and emergency situations, and is managed nationally by the Air Traffic Control System Command Center (ATCSCC). The US ATFM system

uses many ATFM tools including Miles/Minutes in Trail, AFP, GDP, GSt, Required Routes, Time-Based Metering/Scheduling, and several others, known collectively as Traffic Management Initiatives (TMI). GDPs and AFPs are managed by the distribution of Estimated Departure Clearance Times (EDCT- this is the equivalent of an CTOT) to aircraft subjected to the ATFM measure<sup>1</sup>. GDPs focus on allocating ground delays to flights that are destined for congested or capacity-constrained aerodromes, thereby holding them at their aerodrome of origin to help reduce the amount of fuel consumption and CO2 emissions that would otherwise be required through airborne holding at the destination. AFPs work in a similar way by allocating EDCTs to flights destined for severely congested or weather-affected airspace. Other tactical ATFM solutions such as minutes-in-trail, miles-in-trail, level capping, and re-routing are also used, as well as occasional airborne holding when the delays per aircraft are expected to be minimal.

The FAA ATCSCC conducts ATFM using a suite of tools in the Traffic Flow Management System (TFMS). Flight Schedule Monitor (FSM) is one tool and is used to monitor aerodrome demand-capacity balances, model GDP, GSt, and AFP initiatives, and evaluate ATFM alternatives. GDPs are modeled in the FSM tool, and arrival slots are allocated to aircraft based on identified capacity and flight times. The FSM creates a collaborative environment between the ANSP (FAA) and airspace users and allows airspace users to apply their business models by allowing the flight operators to substitute their own flights within the GDP or AFP. Required Routes and many other functions are housed in the Traffic Situation Display (TSD) part of TFMS.



<sup>1</sup> TEDCT is similar to the Calculated Take-Off Time (CTOT), which is the term used in Doc 9971 to refer to a take-off slot assigned to aircraft subjected to the Ground Delay Program (GDP).

# Appendix A: ATFM Implementation from Around the World

## Australia

Domestic ATFM model is implemented in Australia and managed by Airservices Australia. Airservices Australia serves two FIRs, collectively making up 11% of the world's airspace. In Australia, the aeronautical information publication (AIP) Enroute Supplement Australia (ERSA) defines the ATFM phases as strategic, generally occurring more than one day prior to day of operations, pre-tactical occurring on the day prior to operations, and tactical occurring on the day of operations. Key ATFM activities in Australia include strategic planning facilitated by slot coordination through the independent Aerodrome Coordination Australia (ACA), pre-tactical planning through the planning and implementation of the GDP managed by the Airservices Australia Network Operations Centre (NOC), and tactical aircraft sequencing facilitated by air traffic controllers and dedicated ATM systems at key aerodromes during the tactical ATFM phase.

The two key ATFM systems used in Australia are the **ATFM system** and an **AMAN system**. The ATFM system facilitates Ground Delay Program requirements, and the AMAN supports arrival sequence management.

The **ATFM system** software monitors demand-capacity imbalances across the Australian aerodromes and airspace network and implements an ATFM measure (GDP) when required. Key information such as runway availability, forecast conditions, and aerodrome acceptance rates are used to determine aerodrome capacity, while traffic demand is determined through real-time updates to schedule data via flight plans and surveillance data. Any demand that exceeds the determined capacity is then converted into ground delays in the form of a Calculated Take-Off Time (CTOT). The ATFM system currently allows airspace user collaboration through the web based CDM platform, which allows airspace users to optimise their fleet utilisation through internal slot swapping and external slot exchange functionality through a web client.

An AMAN is an estimated time of arrival (ETA)-based software that calculates the arrival sequence for flights into key aerodromes using key information such as flight position and speed, runway operation mode, meteorological conditions, and aerodrome acceptance rates. Information from the AMAN is then utilised

by ATCOs for sequencing activities including speed control, vectoring, or airborne holding to achieve safe and orderly arrival traffic flow into the aerodrome.

## Regional-Centralised ATFM Concept

The European ATFM network is an example of a regional-centralised ATFM system. The concept arises from a dense set of national ATM systems that provides limited flexibility when dynamic flow management is required to avoid congested sectors. The European ATFM network is made up of high-level airspace management by *EUROCONTROL's Network Manager Operations Centre (NMOC)* and national-level airspace management by individual ANSPs; with solutions typically comprising complex combinations of ground holding and airborne holding to balance between the efficiency of operations and equity of delay distribution.

At NMOC, key activities during the ATFM phases include strategic planning through the development of a Network Operations Plan (NOP) and pre-tactical planning with a focus on collaborative decision Making (CDM) with all airspace users, culminating in ATFM Daily Plans or Initial Network Plans being communicated through an industry portal. Subsequently in the tactical phase, collaborative flow management planning is executed by the EUROCONTROL Network Manager, resulting in the tactical application of ATFM measures - GDPs - in the form of *Calculated Take-Off Times (CTOTs)* - are issued to airspace users whose planned flights are expected to transit constrained or congested airspace, thereby distributing the demand more evenly throughout the network.

The facilitating system for ATFM used by EUROCONTROL Network Manager is the *Enhanced Tactical Flow Management System (ETFMS)*. The ETFMS has two key functions: the assessment of flight plan information and the calculation of traffic demand for every sector in the Network Manager's area of responsibility; and the computer-assisted allocation and distribution of ATFM slots (CTOTs) to all participating airspace users. The ETFMS utilises flight activation and monitoring, and flight profile calculation functions to accurately assess demand-capacity imbalances and to allocate the ATFM slots, with the aim of reducing potential airborne delays in the congested airspace.

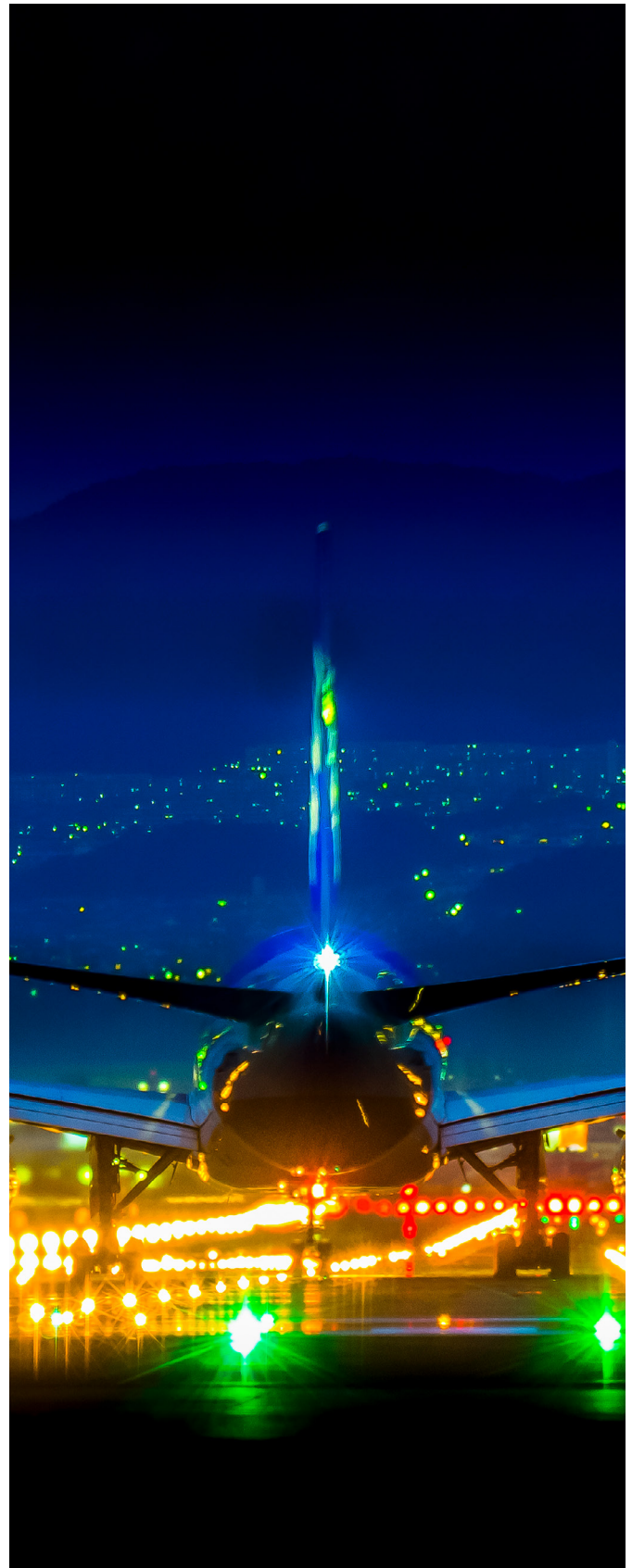
# Appendix A: ATFM Implementation from Around the World

## Regional-Distributed ATFM Concept

In places where a region-wide agreement for a centralised ATFM centre such as EUROCONTROL Network Manager is not possible, a different ATFM concept has emerged. This is known as the regional-distributed ATFM concept, which is employed in parts of Asia-Pacific and (separately) Latin America and the Caribbean and Middle East. The concept, first introduced in Asia-Pacific as the Distributed Multi-Nodal ATFM Network concept, is based on a network of ANSPs leading independent ATFM operations within their areas of responsibility and connected to other ANSPs and stakeholders through effective information sharing and collaborative decision-making mechanisms. This is achieved with two operational bases:

- **Common Operating Procedures** that guide how cross-border ATFM measures – such as a Calculated Take-Off Time (CTOT) distribution in a Ground Delay Program (GDP) – are to be used within the network; and
- **An Interconnected Information Sharing Framework** that establishes mechanism and protocols for efficient ATFM information exchange among stakeholders in the network, thereby allowing key information – such as CTOTs – to be delivered to the right place and at the right time for effective compliance facilitation.

These operational bases allow an ANSP to independently implement ATFM measures to manage both domestic and international traffic into resources where demand is exceeding capacity within their area of responsibility, while other ANSPs and stakeholders in the network can effectively comply with the measures based on the common operating procedures. This concept therefore removes the requirement for a centralised ATFM unit providing the service for the entire region but retains ANSPs' independence in managing their own ATM resources, a concept suitable for several regions' geopolitical environments.



# Appendix B: Additional Explanation of Selected ATFM Solutions

This Appendix provides additional explanation, including considerations, examples, and cautions on some selected ATFM solutions more commonly used. This helps enhance an understanding of how these solutions can be utilised, and what to look out for when using them.

## Aerodrome arrival and departure capacity increase

**Type:** Manual

**Phase of Flight:** Arrival and Departure

**ATCO workload:** Medium

There are many procedures which can be applied to increase capacity when demand is greater than either the arrival and demand rates of the aerodromes. Some examples are – not an exhaustive list:

- [Visual approaches and departures](#),
- [Time-Based separation](#),
- [Wake Turbulence Recategorisation \(RECAT\)](#),

Published procedures are essential for application of these capacity enhancing solutions.

## Airspace Flow Programs (AFPs)

**Type:** Automated

**Phase of Flight:** En Route

**Applied by:** Departure, Arrival

**ATCO workload:** Medium

AFPs are designed to address demand and capacity imbalances in specific areas of airspace, rather than at individual aerodromes. Much like GDP are used for an aerodrome, AFPs can be used to provide similar capacity management for an airspace (sector, FIR, or Special Use Area (SUA), waypoint, fix). They are beneficial when demand is or is expected to exceed capacity, adverse weather, limited airspace availability, or other capacity-reducing factors are expected to impact a significant region, potentially affecting multiple flights across a wide area. AFPs allow ANSPs to proactively manage demand by issuing ground-based (CTOT), time-based flow restrictions (CTO) or adjusting flight routing options, ensuring that demand and capacity is balanced.

Implementing AFPs can provide strategic benefits by minimising delays and enhancing predictability for airspace users and passengers. Key elements of AFPs include setting parameters for affected airspace, monitoring real-time traffic flows, and coordinating

with stakeholders and adjacent ANSPs. By using tools such as collaborative decision-making (CDM), traffic flow prediction systems, and advanced communication platforms, AFPs help to dynamically balance demand with available capacity, reducing delays and maintaining safety while maximising airspace efficiency.

For example, an ANSP has a sector with a capacity of 55 flights per hour. A loss of radio frequencies causes the capacity to be reduced to 40 per hour. Therefore, a reduction of 15 flights per hour is necessary. A delay program to balance demand and capacity by delaying specific flights that are predicted in that sector either by holding them on the ground (CTOT) or issuing an airborne restriction (CTO) is implemented, creating the necessary demand reduction. Air traffic controllers and airspace users work collaboratively to assign and manage the delays by ensuring the flights depart on their assigned CTOT or a CTO should the flight already be airborne. The CTO is the time the flight is expected to cross a sector boundary. The flight crew are expected to adjust their trajectory to cross the sector at the CTO issued.

## Arrival Manager (AMAN)

**Type:** Automated

**Phase of Flight:** Enroute Transition to TMA

**Applied by:** Enroute

**ATCO workload:** Medium

The AMAN is a tool that optimises the sequencing and scheduling of arriving aircraft at aerodromes. By predicting the arrival times of flights well in advance, AMAN ensures smoother transitions from en-route to terminal airspace. AMAN tools provide a scheduled landing time for each arriving flight and then assign airborne or ground-based delays to flights to ensure they are properly sequenced to a runway. It assists ATCOs in managing arrival demand against available runway capacity by creating efficient, orderly arrival sequences. This facilitates continuous descent operation (CDO), reduces the need for holding patterns and minimises radar vectoring, speed control (in the TMA) fuel burn, delays, and environmental impacts.

# Appendix B: Additional Explanation of Selected ATFM Solutions

Implementing AMAN can enhance operational efficiency and safety. AMAN integrates surveillance data from en-route and terminal control systems, enabling controllers to issue early speed adjustments or holding instructions for inbound flights. By ensuring that aircraft arrive at an optimal time, the tool helps balance runway use and air traffic workload. Incorporating collaborative decision-making (CDM) processes with AUs and other stakeholders further strengthens the effectiveness of AMAN, ensuring alignment between operational goals and real-time traffic conditions. The ATCOs workload is focused on ensuring that flights meet their meter fix time (issued by the AMAN system), usually within plus or minus one minute. This could necessitate the ATCO assigning speed controls, vectoring, or holding aircraft when the required delay cannot be achieved by speed control or vectoring.

## Long-Range ATFM (LR-ATFM)

**Type:** Automated

**Phase of Flight:** En Route, Enroute Transition to TMA, Arrivals, Departures

**Applied by:** Enroute

**ATCO workload:** Medium

Long-Range ATFM is the integration of ATFM solutions to deliver a collaboratively balanced flow of long-haul and short haul aircraft to an aerodrome, a waypoint, or a sector of an airspace. LR-ATFM is a process that enhances the capabilities of ATFM by enabling ATFM managers to assign specific times for aircraft to reach designated waypoints during their en-route phase of flight. It ensures orderly traffic flow and optimal use of airspace capacity by synchronising aircraft movements based on predicted and Estimated Times over (ETO) at FIR/sector boundaries, waypoints or fixes. Flight can be issued with CTO (the delay should never be more than three minutes per flight hour) and is particularly useful when inbound international long-range flights that are difficult to manage with the issuance of a CTOT (could be airborne already). The concept allows an issuing ATFMU to issue CTOs to upstream flights. This is a valuable tool to balance demand and capacity by delaying flights enroute enabling a fairer distribution of delays and potentially preventing holding aircraft inside a TMA at uneconomic flight levels.

## Ground Stop (GSt)

**Type:** Automated

**Phase of Flight:** Arrival

**Applied by:** Departure

**ATCO workload:** Medium to High

A GSt is a key ATFM Measure designed to address immediate and localised constraints in the air traffic system. It will temporarily halt departures at their origin aerodrome, preventing further strain on already saturated en-route sectors or destination aerodromes. ATCOs play a vital role in executing GSt by coordinating closely with ATFM units to ensure that departures comply with the restriction. This process involves issuing clear instructions to airspace users and ensuring that aircraft remain at their gates or holding areas until it is safe to proceed. ATCOs provide real-time updates to flight crews and aerodrome operations, aligning tactical actions with ATFM objectives.

By effectively implementing GSt, ATCOs help prevent cascading delays, airspace congestion, and safety risks, particularly during unexpected disruptions such as severe weather or equipment failures. They also maintain communication with adjacent control centers to monitor downstream and upstream impacts and prepare for the safe resumption of operations. Ground Stops are often complemented by reroutes, airborne holding, or Miles-in-Trail (MIT) ATFM Measures, making ATCOs the essential bridge between ATFM plans and operational execution. This coordination ensures that demand is restored gradually and safely, reducing the operational and economic impacts of these interventions. A typical ground stop approach might be to always issue a GSt for one hour. This allows instantly stopping adding traffic to a demand exceeding capacity problem. Then, approaching the end of the initial one hour, evaluate if the GSt needs to be extended or canceled.

GSt is a valuable tool to immediately stop adding demand and allow stakeholders an opportunity to collaborate on the situation and analyse alternative ATFM measures or other options to resolve the situation. They are also very useful when you are not certain what time an issue may take place. For instance, you know the winds are going to shift at an aerodrome and this will reduce the arrival rate, but you do not know exactly when this will occur.

# Appendix B: Additional Explanation of Selected ATFM Solutions

You can avoid undue delays to flights by waiting for the winds to shift, issuing a ground stop, and then collaborating on a more appropriate solution. Normally a GDP is implemented subsequently to a GST to manage the recovery from the GST.

The impact to ATCOs can vary based on the conditions and the length and scope of the GST. For instance, if the GST cannot be lifted for a long duration, this creates the possibility of congestion at aerodromes that are holding these flights, or if flights are released too early, they may have to divert to an alternate aerodrome upon arrival.

## Priority Handling Diversion Recovery

**Type:** Manual, Semi-Automated

**Phase of Flight:** En Route

**ATCO workload:** Low

In a situation where diversions have occurred, once recovery can begin, the diverted flights should have priority over non-diverted, or regularly scheduled flights. This can be supported by ATFM automation, shared situational awareness tools, of which flights diverted so ATC can prioritise those recover flights, or manual methods that accomplish the same result.

## Required Routes/Rerouting

**Type:** Manual, Semi-Automated

**Phase of Flight:** En Route

**ATCO workload:** Moderate

Implementing required routes can be a very powerful tool in the ATFM toolbox but requires several other tools for efficient implementation.

## Concept

When constraints are present, providing structure to flow of traffic can be an efficient means of increasing capacity. If the flows are organised and flow to each airport are consistent, there is more predictability and controller workload is reduced, increasing capacity and safety. The required route needs to be coordinated across all Area Control Centres (ACCs) involved and other TMMs such as MIT may be required in addition to a required route. The coordination of required routes can be time consuming and there are several tools that can reduce the time needed to implement a required route.

## Enablers

- **Precoordinated Route Playbook:** A set of alternate routes that have been coordinated and agreed to by all of the involved ATS elements. These are typically updated on AIRAC cycles and are published to ATS and Flight Operators.
- **Coded Departure Route (CDR):** An automation technique where a short alphanumeric code is used for standard alternate routes. The CDRs can match the Playbook Routes and ATCOs can easily adjust the filed flight plan route to match the reroute by use of a CDR.
- **International Route Coordination** is another form of Precoordinated Route Playbook, which allows two or more ANSPs to collaborate on alternate routes that will work for them, and are included in the Precoordinated Route Playbook.

## Implementation

When a weather, equipment, staffing or other constraint becomes known or forecasted, Required Routes can be built based on the Precoordinated Route Playbook enabler. Required routes can either be a full implementation of a playbook route, a partial implementation (only some of the departure and destination aerodromes are included), or the required route can be built without using the route playbook, but the coordination is often longer.

Automation Support for Required Routes can include notification of the required route to ATS and Airspace Users, monitoring of compliance with the Required Route, tools to assist ATS in correcting existing filed flight plan to conform with the Required Route. Typically Required Routes only apply to future flights, as for extensive reroutes, the airborne flights likely do not have adequate fuel, but in some circumstances airborne Required Routes is possible and desired.

## Required Routes & AFPs

Sometimes an Airspace Flow Program delay can be avoided by routing around the constraint. When too many airspace users choose to route around an AFP, Required Routes may be needed to manage the increased flows routing out of the delay.

