International Civil Aviation Organization

Thirteenth Meeting of the Air Traffic Management Sub-Group (ATM/SG/13) of APANPIRG

Singapore, 25 – 29 August 2025

Agenda Item 5: ATM Systems (Modernization, Seamless ATM, CNS, ATFM)

PROGRESS OF THE ASIA-PACIFIC TRAJECTORY-BASED OPERATIONS PATHFINDER PROJECT

(Presented by Singapore on behalf of Hong Kong China, Indonesia, Japan, New Zealand, Singapore, Thailand, United States of America, Viet Nam, Civil Air Navigation Services Organisation (CANSO) and International Air Transport Association (IATA))

SUMMARY

This paper presents progress by the Asia-Pacific (APAC) Trajectory-Based Operations (TBO) Pathfinder Project ("Pathfinder"). Pathfinder was initiated under the APAC Air Navigation Service Provider (ANSP) Committee (AAC) to develop pathways for implementing the ICAO Global TBO concept in the region. Through the participation of ANSPs of States/Administrations and International Organisations, Pathfinder aims to: i) raise TBO awareness in the region; ii) provide greater clarity on TBO requirements through workshops / scenarios / demonstrations; and iii) analyse benefits and, develop a TBO roadmap for APAC.

1. INTRODUCTION

1.1 The Pathfinder project involves the ANSPs of China, Hong Kong China, Indonesia, Japan, New Zealand, Philippines, Singapore, Thailand, United States of America and Viet Nam, along with CANSO and IATA, who have agreed to define, develop and demonstrate the concept of operations and requirements for TBO in the APAC region. Based on the ICAO Global TBO concept, Pathfinder will allow ATM stakeholders in APAC to harmonise their planning and modernisation efforts to improve flight operations and air traffic management efficiency across the region.

1.2 ATM/SG/12 was updated that, at the kick-off meeting of Pathfinder project, three workgroups (WGs) were formed to focus on specific goals and deliverables through the 4-year project (see **Appendix A**). Since then, Project Meeting #2 was conducted from 20 – 24 January 2025 where Pathfinder members shared their plans to progress the Recommendations from the ICAO AN-Conf/14 on TBO (Recommendation 3.1/3) and FF-ICE (Recommendation 3.2/2). The three WGs also conducted breakout sessions to work on their respective deliverables.

2. DISCUSSION

2.1 The key progress made at the WG level was as follows:

WG1 – Learning and Advocacy

2.2 WG1 identified that engaging the leadership of TBO stakeholders is a key priority for supporting air navigation modernisation and securing the necessary commitments for prioritisation of resources. For 2025, WG1 would conduct a series of engagement sessions with the executive leadership by the technical experts of Pathfinder. These sessions will facilitate a common understanding of TBO, its key enablers and associated operational values, supported by a set of TBO communications material.

2.3 WG1 has completed the first edition of the TBO communications material (see **Appendix B**) and intends to use this material to support the engagements and a reference resource for APAC ATM stakeholders.

WG2 – TBO Trials and Capabilities Built-up

2.4 WG2 has developed a phased plan to test and demonstrate the primary aspects of TBO, in particular, FF-ICE/R1, FF-ICE/R2, and Connected Aircraft concept. Each phase includes the identification of operational scenarios, a series of table-top exercises, and lab demonstrations to provide greater clarity on the expected processes and procedures of TBO. Through operational scenarios, these activities aim to highlight the operational values of TBO that would benefit APAC.

2.5 In July 2025, WG2 completed the first phase via a FF-ICE/R1 lab demonstration using four operational scenarios between chosen city pairs, specifically:

a) Guam and Bangkok, via Ho Chi Minh;

b) Tokyo and Bangkok, via Hong Kong;

c) Bali and Bangkok, via Singapore; and

d) Auckland and Singapore, via Jakarta.

2.6 The scenarios explored FF-ICE/R1 trajectory creation and negotiating in response to various operational challenges such as Special Use Airspace, ATFM measures and volcanic ash. Scenarios were demonstrated in a mixed-mode environment where some ANSPs have not implemented FF-ICE/R1. Eight[1] ANSPs participated in this lab demonstration to further strengthen the concept of operations and gained insight on the technical requirements for FF-ICE/R1 implementation. Key lessons learnt were captured and shared with the participants (see **Appendix C**).

2.7 The next step for WG2 is to plan and conduct the FF-ICE/R2 table-top exercises and lab demonstrations starting Q4 2025 through 2026.

WG3 – Benefit Analysis and TBO Roadmap

2.8 WG3 has developed an initial draft of the benefit analysis report to articulate the qualitative benefits and stakeholders impacted. With the feedback obtained from the Pathfinder members, WG3 will continue to develop a methodology and identify relevant metrics to quantify the benefits of TBO.

[1] AEROTHAI, AirNav Indonesia, CAAS, FAA, HK CAD, JCAB and VATM, participated as FF-ICE/R1 capable ANSPs; Airways NZ participated as ANSPs who has not implemented FF-ICE/R1.

2.9 An initial APAC TBO roadmap was developed by WG3 with feedback from the Pathfinder members, which took reference from TBO developments at the global level, and SWIM and FF-ICE developments in the APAC region. A separate working paper on a TBO roadmap for the region has been submitted for support to ATM/SG/13, with the eventual aim for adoption by APANPIRG for inclusion into the next edition of the *Asia/Pacific Seamless ANS Plan*. The roadmap will provide States/Administrations in the region with a pathway towards the deployment of TBO in APAC.

Conclusion

2.10 For TBO to succeed and to deliver its anticipated benefits, all the parts of TBO will have to interact effectively. This starts with a common understanding of what TBO is and a description of operations within a TBO environment. TBO must be then defined, developed and deployed in a harmonised manner, with a roadmap that serves as a pathway for the region. These activities are undertaken by the three WGs of the Pathfinder project and outcomes will be shared at ICAO and other international forums to support the definition, development and deployment of TBO in the region.

3. ACTION BY THE MEETING

3.1 States/Administrations are invited to:

a) note progress and updates of the APAC TBO Pathfinder Project;

b) support their ANSPs to participate in the project to:

i) raise awareness on the operational benefits of TBO in the region, amongst the ATM stakeholders;

ii) determine operational scenarios and undertake demonstrations collaboratively to provide greater clarity on TBO requirements; and

iii) analyse regional benefits and develop a TBO roadmap for APAC; and

c) discuss any relevant matters as appropriate.

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GOALS AND DELIVERABLES OF PATHFINDER WORKGROUPS

Goals of Workgroup (WG)	Deliverables
WG1 - Learning and Advocacy • **Common understanding** of ICAO Global TBO Concept for project participants and stakeholders	D1: Engagement sessions with executives and technical leaders with TBO communications package
WG2 - TBO Trials and Capabilities Build-Up • Recognised **operational values** arising from demonstrating regional TBO scenarios • Utilised **SWIM and initial FF-ICE/R1 services** for trials	D2: Report with priority ops value documented for APAC from demos for FF-ICE, connected aircraft and TBO
WG3 - Benefit Analysis and TBO Roadmap • Determined **benefits** of regional TBO scenarios • Developed **TBO Roadmap** in line with regional needs and ICAO global developments	D3.1: Benefits Analysis Report D3.2: TBO Roadmap for APAC Seamless ANS Plan

TBO COMMUNICATIONS BROCHURE (1ST EDITION)

TBO Brochure 1st Edition (July 2025).pd

APAC TBO
PATHFINDER

Trajectory-Based Operations in the Asia Pacific region

1st Edition (July 2025)

EXECUTIVE SUMMARY

Pathway to TBO in Asia Pacific

The Asia Pacific (APAC) region presents a complex environment with significant numbers of Airspace Users (AUs) and Air Navigation Service Providers (ANSPs). It also faces growing air traffic demand and increasingly complex airspace with new airspace users. Trajectory-Based Operations (TBO) addresses these challenges by enhancing efficiency, predictability, and collaboration in Air Traffic Management (ATM).

TBO is a realisation of the ICAO Global ATM Operational Concept, providing a trajectory-centric approach to flight planning and execution. It enables better synchronisation of airspace operations, optimises flight efficiency, and aligns with global ATM modernisation efforts.

The APAC TBO Pathfinder Project aims to harmonise and accelerate the region's implementation of the ICAO global TBO concept in order to meet the anticipated growth in civil air traffic.

The Project promotes regional collaboration between ANSPs and AUs, in collaboration with Civil Air Navigation Services Organisation (CANSO) and International Air Transport Association (IATA), by identifying operational priorities to develop a TBO roadmap to align the implementation planning to improve ATM efficiency within the APAC region.

Strategic alignment, regional collaboration, and continued innovation are key success factors for development and implementation of TBO.

THE NEED FOR TBO

Challenges in Today's ATM

Lack of real-time updates into strategic flight plans reduces predictability in flight operations, leading to inefficiencies in fuel optimisation and flight scheduling.

Limited information exchange between AUs and ANSPs leading to inconsistencies in trajectory predictions. Without knowledge on constraints, ATM stakeholders rely on incomplete data in planning, leading to operational inefficiencies.

Airspace congestion leading to inefficiencies and delays

Decision-making based on local trajectories rather than one that is shared and collaboratively obtained, making it harder to manage flights seamlessly across borders

APAC TBO PATHFINDER

THE NEED FOR TBO

Why TBO?

TBO enhances flight operations by enabling precise trajectory management, reducing fuel consumption, minimising delays, and improving airspace utilisation. By integrating advanced planning and real-time decision-making, TBO supports **efficient, predictable, and sustainable aviation operations.**

Optimised Airspace Utilisation

- Increased throughput with precise trajectories
- Enhanced collaborative decision-making for efficiency

Improved Flight Efficiency

- More effective route management enhancing airline scheduling
- Optimised aircraft trajectories for reduced fuel consumption

Flexibility for Airspace Users

- Increased adaptability through early trajectory adjustments
- Collaborative flight route negotiations for optimised trajectory

Supporting Aviation Sustainability

- Optimised flight profiles reducing holding times and fuel burn

More Efficient ATC Operations

- Reduced tactical intervention, enabling better resource utilisation
- Streamlined airspace management with advanced planning capability

Increased Predictability & Reliability

- Enhanced reliability through timely trajectory updates
- Minimised delays with improved operational coordination

Enhanced Regional Interoperability

- Real-time data sharing for smoother traffic flow management

WHAT IS TBO?

"A Shift from Traditional ATM to a Trajectory-Based Approach"

Current ATM environment is segmented and tactical. Flight trajectories are managed reactively, often leading to inefficiencies and unpredictable operational adjustments. TBO transforms ATM by shifting towards a trajectory-centric approach, ensuring every flight is strategically planned and optimised from departure to arrival.

Understanding TBO

At its core, TBO manages a flight trajectory as a shared plan, integrating real-time data to make precise adjustments. It enables:

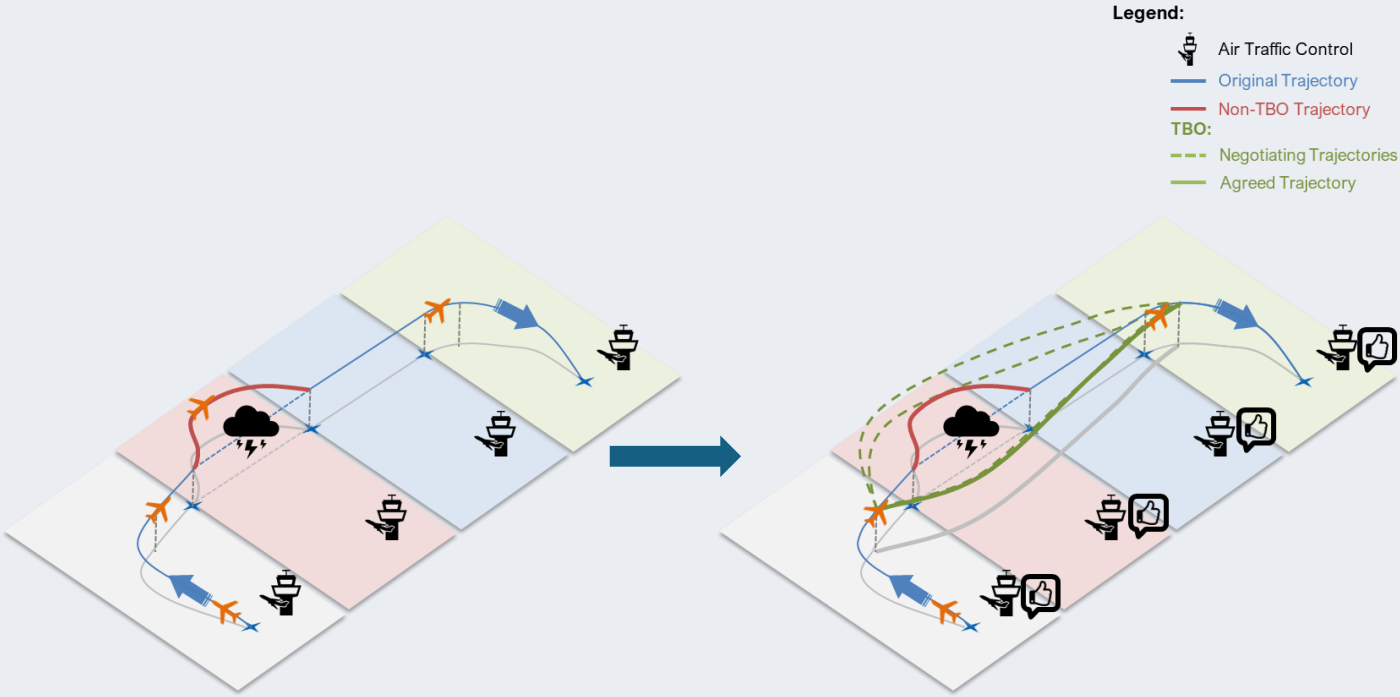
- **Sharing** of trajectory information with all relevant stakeholders for a common view
- **Managing** trajectory information through Collaborative Decision Making
- **Using** the trajectory as a unified operational plan during flight execution

Evolution of ATM: From Traditional ATM to TBO

Traditional ATM	TBO Approach
Segmented control by ATC	Continuous trajectory management, minimising impact of disruptions
Tactical, reactive adjustments	Strategic, pre-planned trajectory optimisation
Limited data-sharing	Transparent information exchange via SWIM and FF-ICE
Voiced-based clearance	Digital trajectory negotiations and clearances with ADS-C and CPDLC
Restricted collaboration between stakeholders	Collaborative decision-making between ANSPs, AUs, airports, MET services and other ATM stakeholders

WHAT IS TBO?

Visualising TBO



Today in a non-TBO environment

Full TBO environment

In traditional air traffic management, aircraft encountering adverse weather would rely on immediate rerouting from their current ATC unit. While this addresses the immediate weather concern, it often results in **suboptimal flight paths** when considering the entire journey.

A TBO environment transforms this approach through **enhanced stakeholder collaboration** and **information sharing**. Aircraft receives advance notice of potential weather disruptions to their planned trajectory, enabling them to **proactively coordinate** with all ATC units along their route. This collaborative process allows the aircraft to **negotiate alternative trajectories** that account for weather avoidance while considering the operational constraints of each ATC unit. Through this negotiation, several potential trajectories are evaluated until a mutually acceptable solution emerges. The final agreed trajectory is then communicated to all stakeholders, resulting in a more **efficient overall flight path**.

WHAT IS TBO?

TBO Building Blocks

TBO is enabled by:

SWIM

System Wide Information Management (SWIM)

Provides a network-centric infrastructure that facilitates the sharing of information among all stakeholders, including air traffic controllers, airspace users, aerodrome operators, and meteorological services.

FF-ICE

Flight and Flow Information for a Collaborative Environment (FF-ICE)

Enables stakeholders to collaboratively plan and optimise flight trajectories before departure and throughout the trajectory lifetime by considering various factors such as airspace capacity, weather conditions, and airspace users' preferences. FF-ICE also enables post-departure trajectory negotiation and re-planning to respond to airspace constraints changes, and ensures all stakeholders are informed of the updated trajectory.

CA

Connected Aircraft (CA)

Enables information exchange between flight deck and relevant aviation system participants including AUs (e.g. flight crew and OCC), ANSPs, aerodrome operators and other third-party information suppliers (e.g. meteorological services) through the use of performance-based links.

STAKEHOLDER INVOLVEMENT & REGIONAL COLLABORATION

Stakeholders and Their Roles

Aviation Authorities

Modernise regulatory framework to facilitate adoption of advanced technologies

Aerodrome Operators

Leverage TBO for optimised ground operations

ANSPs

Manage trajectory-based requests to ensure safe and efficient traffic flows

Airspace Users

Leverage TBO for optimised flight efficiency.

Regional and Global Organisations

Provide global TBO guidance and align regional implementations

Importance of Cross Border Harmonisation

Given APAC's diverse operational landscape, regional collaboration is essential for a harmonised TBO implementation, ensuring interoperability and consistency of trajectories within and across the region.

CHALLENGES & OPPORTUNITIES FOR ASIA PACIFIC

Challenges

Several ATM initiatives have successfully demonstrated the positive impacts of TBO and its building blocks on airspace efficiency. APAC can leverage insights from these initiatives to shape its implementation strategy.

A major challenge in APAC is the lack of a coordinated mandate for TBO implementation. While full regional harmonisation may be challenging due to varying levels of ATM infrastructure maturity and national priorities, collaborative efforts can help drive ANSPs' and Aus' alignment, ensuring progressive adoption of TBO and its building blocks.

Benefits of Regional Coordinated Approach for TBO Implementation

Sharing of Best Practices & Lessons Learnt

- Lowering implementation risk
- Minimising duplicate efforts

Validation Through Collaboration

- Conduct collaborative trials and demonstrations
- Identify harmonisation requirements
- Build confidence in new processes
- Sharing resources and capabilities

Ensuring System Interoperability

- Jointly identify and develop key building blocks
- Leverage collective technical expertise
- Establish common standards across borders

Synchronise Regional Progress

- Create regional timelines
- Develop roadmaps to align implementation

APAC TBO PATHFINDER PROJECT

About

The APAC TBO Pathfinder Project is an initiative to define, develop and demonstrate the ConOps and requirements for TBO in the APAC region.

Through collaborative efforts to identify operational values and prioritisation of operational scenarios at the regional level, the Project provides clarity on the expected operational processes and benefits, and will develop a roadmap as a pathway to operationalise TBO in the APAC region.

In collaboration with CANSO and IATA, it allows ANSPs and AUs to harmonise their planning and modernisation efforts and improve flight and overall ATM efficiency across the region.

Key Milestones

Define

Define ConOps for TBO in APAC

Demonstrate

Demonstrate TBO processes and validate operational workflows and scenarios by utilising the key TBO building blocks

Develop

Develop TBO roadmap for APAC

Expected Benefits for Pathfinder Members

- Improved and common understanding of TBO and its benefits
- Greater familiarity with operational processes and readiness to implement TBO and its building blocks
- Contribute to the APAC TBO roadmap for harmonised TBO implementation within APAC

APAC TBO PATHFINDER

NEXT STEPS

Why Leadership is Critical?

Successful adoption of TBO in APAC requires:

- Strategic alignment on plans across key ATM stakeholders such as ANSPs, AUs and regulators
- Collaboration and engagements within and across the region
- Investment in key building blocks of TBO including SWIM, FF-ICE and Connected Aircraft

Communications with ATM stakeholders including leadership buy-in at an early stage is pivotal.

Next Steps

1

Support the APAC TBO Pathfinder Project

- Champion Pathfinder project within your organisation
- Allocate resources for active participation in Pathfinder activities

2

Lead Strategic Implementation

- Support harmonisation of operational processes
- Align capability development roadmap within your organisation with regional TBO objectives
- Prioritise investments in interoperable technologies and systems

TBO is not just an innovation. It is a necessary transformation for APAC's ATM modernisation. Strong commitment from all ATM stakeholders to champion TBO implementation can drive APAC's shift towards modernised airspace efficiency, enhanced ATM predictability, and strengthened regional collaboration.

"Together, APAC is charting our way forward"

KEY LESSONS LEARNT

Strategic

- Early engagement and broader participation of regional stakeholders are essential to
  - ≫ Understand benefits and necessary changes
  - ≫ Identify common system requirements
  - ≫ Harmonize regional FF-ICE procedures

SWIM

- Foundational SWIM capabilities should be established not only for FF-ICE operations but also to support the sharing of constraint/restriction information among stakeholders
- To enhance system integration and consistency, a globally or regionally standardized common set of message headers is required
- An established message format based on standardized information exchange model (e.g. AIXM) is essential for the effective exchange of constraint/restriction information
- Early involvement of network experts is essential to support system integration

FF-ICE

- Mixed-mode FF-ICE operation is feasible; however, the operational approach needs further detail
- When available, FF-ICE templates should be used
- The required response/action in the event of a message validation error should be clearly defined
- Detailed constraint/restriction information should be provided when a planning status is non-concur and a filing status is not acceptable
- There is a discrepancy on the GUFI specified in Doc 9965 Vol. II and the FIXM schema
- To enable automation of data validation, inclusion of a flight plan version should be mandatory in flight data responses.