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Potential Air Traffic Management CO_2 and Fuel Efficiency Performance Metrics for General ANSP Use

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1 Introduction

Air Navigation Service Providers (ANSPs) are committed to delivering real environmental and fuel efficiency benefits in the global Air Traffic Management (ATM) system throughout the world. CANSO has supported this effort by identifying and promoting appropriate metrics to measure ANSP performance. ANSPs can influence fuel efficiency through improved airspace design, and by supporting more fuel efficient trajectories. This paper focuses on the value of a consistent method to identify trajectory inefficiencies that can be measured directly by ANSPs using trajectory-based surveillance data which can identify excess distance flown and vertical flight inefficiency. The conversion to actual fuel burn figures requires further work and agreement with stakeholders including airlines and ICAO. ICAO's Fuel Savings Estimation Tool (IFSET) and EUROCONTROL's Base of Aircraft Data (BADA) lookup tables may be one mechanism for generating a consistent conversion from trajectories to fuel for international comparisons. More detailed performance models like the FAA's Aviation Environmental Design Tool (AEDT) and BADA 4 may be appropriate as they mature.

CANSO recognises that the cross border nature of the ATM system makes it vital that any environmental performance metrics adopted are internationally consistent. The adoption of ATM CO_2 performance metrics that are inconsistent across States, Functional Airspace Blocks (FABs) or regions would lead to inconsistent implementation of environmental solutions.

2 CANSO's Metrics and Methodologies Subgroup

It was for these reasons that CANSO's Environment Workgroup set up a 'Metrics and Methodologies' (M&M) subgroup in 2008, and began to analyse how best to measure ANSP fuel burn and CO_2 performance. The objectives of the group were to address the following points:

1. Seek consensus on methodologies and metrics for measuring ATM influence on aviation's CO_2 emissions
2. Describe the total system 'inefficiency' pool including:
   a. Improvement opportunities by phase of flight (taxi out, climb, cruise, and descent)
   b. Interdependencies that impact fuel efficiency including weather, excess demand, safe separation, maximising capacity
   c. How new technologies and procedures can reduce interdependencies
   d. Identifying the challenging but deliverable (near term) opportunity pool
3. Develop guidance on performance measurement methodologies for ATM's contribution to aviation CO_2 emissions.
4. Identify metrics that focus on ATM's contribution by phase of flight.
5. Identify long-term strategic opportunities for improvement and aspirational goals for reducing ATM's contribution to aviation CO_2 emissions.

This paper describes the work of the M&M subgroup and the consensus achieved across the full Environment Workgroup in identifying appropriate metrics to measure ANSP CO_2 and fuel burn performance; it is responsive to bullet points 1 through 4 above.

3
Strategic Value of Performance Metrics

Measuring ATM system performance is the first step in identifying improvement opportunities. By collecting baseline data on improvement pools by phase of flight, ANSPs can make strategic decisions on where to focus resources for improving efficiency and lowering fuel burn. As a second step at the strategic planning level, the initial measures focus on the size of the problem, such as quantifying the potential range of efficiency improvements per phase of flight. A list of possible measures is created that could be applied to each phase of flight to improve efficiency and lower fuel burn.

Lastly, applying the measures in practice by ANSPs is more challenging because of interdependencies with demand and weather that may change from one time period to another.

4
Criteria Governing ANSP Metrics

To ensure that a metric appropriately represents an ANSP's performance, that metric should conform to several criteria. The metric should:

- Capture the right ANSP behaviours with sufficient fidelity to show improvements in fuel efficiency and CO_2 reductions,
- Accurately reflect fuel burn and CO_2 performance outcomes driven by ANSP actions,
- Not be unduly affected by factors outside the ANSP's control, and
- Be transparent, measurable and auditable.

5
Survey of Current Measures related to Fuel Burn

There are a number of metrics available to depict the fuel burn and CO_2 performance of the aviation industry as a whole (or a proxy of it) such as:

Metric	Description
Excess Time Flown converted to fuel	**Measured by additional time versus an unimpeded time and converted for various aircraft types. This method can apply to the taxi phase or any flight phase as a first approximation.**
Vertical Inefficiency	**Measured by level flight segments on departure or approach as well as non-optimal cruise altitudes.**
Excess Distance Flown	**Measured in Nautical Miles (NM) or kilometres, a potential proxy for fuel burn and emissions in cruise and arrival phases. (Note, excess distance and Vertical Inefficiency can be combined.)**
Excess Fuel on Oceanic Routes	**Measured as a modelled optimum versus actual fuel burn. Requires sophisticated wind modelling.**
Percentage achievement of Continuous Climb Operations (CCO) and Continuous Descent Operations (CDO)	**A potential measure of flight in a relatively efficient mode.**
United Kingdom's (UK) National Air Traffic Services (NATS) 3 Dimensional Inefficiency (3DI) Score	**Evaluates entire trajectory for distance (horizontal) and vertical based inefficiencies within UK airspace.**

Measures of fuel efficiency outside the ANSP community often use small samples of flights and use sophisticated fuel models driven by BADA or data collected directly from the aircraft. In these measures additional data is needed outside the 3D surveillance position reports including aircraft weight, thrust, Centre of Gravity (CG), wind, etc. These models can assess fuel burn differences driven by non-ANSP issues like load factors, ferrying fuel, fleet mix, and airline specific flying practices.

Fuel burn is highly dependent on these factors, but viewed from an ANSP standpoint the focus is more about delivering more efficient tracks and height profiles; the actual fuel burn and emissions of a given aircraft is primarily a function of airline decisions about aircraft type, weight, speed, route planned and cost index or business model. It was for this reason that the M&M subgroup decided to explore the possibility of using a proxy for fuel burn and CO_2 performance that more closely reflected factors within ANSP control.

Key Consensus Point: While fuel burn and CO2-based performance metrics are of interest, they have the potential to be unduly affected by factors beyond ANSP influence (e.g. airline behaviour) and therefore they may not, if taken in isolation, reflect ANSP actions to reduce fuel burn and emissions.

6 ATM CO_2 Specific Metrics

One way of viewing the ATM system is that from a purely ANSP perspective, inefficiencies may accrue either as vertical deviation from the optimum or as an unintended route extension. Although ANSPs attempt to minimise deviation from the optimum point-to-point flight trajectory at optimum speed and altitude, there are good reasons to do so, such as:

— Maintaining safe separation from other aircraft and airspace users,
— Absorption of necessary delay when airborne demand exceeds capacity,
— Noise abatement procedures in terminal manoeuvring areas (TMAs),
— Existence of military and other use airspace,
— Weather, including wind direction in TMA operations,
— Unplanned activities including medical priority flights, VIP aircraft and in-flight emergencies.

However, there are also potential ATM-related inefficiencies – elements of the system that preclude more efficient flight profiles and routings. These inefficiencies typically result from legacy airspace designs that have evolved in response to ongoing airport development and due to the historic interactions of routes and profiles of aircraft in the ATM system. When these inefficiencies are identified, an airspace redesign should be considered to remove the inefficiencies, wherever possible. Part of the airspace improvements could include the implementation of Area Navigation (RNAV) and Required Navigation Performance (RNP) capable routes to optimise arrival and departure streams. ANSPs can also address where necessary delay is absorbed, through arrival metering and speed control in the cruise phase of flight, to reduce terminal congestion. In summary, ANSPs can collaborate with airlines and airports to achieve the following fuel efficiencies:

— airspace and procedure design to optimise the profiles and tracks delivered in their airspace systems,
— air traffic controller decision-making aids (e.g. decision support tools),
— better environmental awareness across ANSP operational and support communities,

- collaboration between airports, airlines and ANSPs on fuel efficient aircraft movements to minimise or eliminate delay during arrival and departure procedures, and airport taxiing operations.

Over the past three years the M&M subgroup has played a role in driving convergence in the way ANSP environmental performance is measured. The performance metrics and measures applied in the U.S./Europe ATM Operational Performance Comparison were developed with direct input from the M&M subgroup. In this work, 39 European Civil Aviation Conference (ECAC) ANSPs are measured with a common approach. At the same time NATS has been improving its environmental measures in consultation with its regulator and airline customers. Other ANSPs like Airservices Australia; GACA, the ANSP of the Kingdom of Saudi Arabia; Airways, New Zealand's ANSP; South Africa's ANSP, ATNS SA; AeroThai; and the Civil Aviation Authority of Singapore (CAAS) have an active interest in environmental metrics.

The group found the current, most commonly quoted metric is that of horizontal route extension outside the terminal area. Measures for vertical inefficiency in cruise are improving with better surveillance data and modelling. Terminal area inefficiency can be measured both as a function of track extension and vertical segments with sufficient quality surveillance data. Improving terminal fuel inefficiency requires improved arrival predictability and delay absorption – mainly moving delay to higher altitudes and using speed reduction to absorb necessary time, or keeping delay at the gate with the engines off for departure aircraft.

The CANSO group strongly supports the measuring of trajectory inefficiencies that incorporate the horizontal and vertical trajectory throughout the flight, as a means of determining opportunities to improve fuel efficiency. In addition, taxi delays can be measured using the Airline Service Quality Performance (ASQP) data set that contains the scheduled and actual pushback times, actual take-off time, actual landing time, and scheduled and actual gate arrival times. This is often referred to as 'Out, Off, On, In' (OOOI) data. When available, airport surveillance data can also be used to measure taxi delays. This phase of flight method using radar data has been used in the U.S/Europe Operational Performance Comparison report mentioned above. Attachment 1 provided a comprehensive guide for estimating ATM efficiency pools by phase of flight.

NATS has also developed, with peer review from the M&M group and others in the aviation industry, a metric that seeks to reflect the vertical and horizontal inefficiencies in flights. This is a proxy for CO_2 as smoother vertical and more direct lateral profiles deliver fuel burn and emissions reductions compared to stepped climbs, descents and deviations from lateral point to point tracks. The NATS metric is called the 3 Dimensional Inefficiency (3Di) Score. Eurocontrol Performance Review Unit (PRU), FAA and Airservices Australia are also considering the use of vertical and lateral elements of flight profiles in their flight efficiency work. The NATS 3Di method was recently approved by the UK Civil Aviation Authority (CAA) as a method to set targets and financially incentivise improved fuel efficiency in NATS airspace and is described in detail in Attachment 2.

Key Consensus Point: A measure of ANSP CO_2 and fuel burn performance should take account of both vertical and horizontal elements of flight

The M&M subgroup promotes a structured approach to measuring trajectory efficiency by identifying vertical and horizontal (or time) inefficiencies. The key to the success of this approach is ANSPs having access to trajectory data for flights in their airspace. In most cases ANSPs must work with their neighbours to share trajectory data and focus on optimising cross border efficiencies. CANSO recommends that the sharing of post-operational data is a good first step in the fuel efficiency improvement process. Analysis of efficiency by phase of flight improves the understanding of how to make improvements.

7
Issues Requiring Further Consideration

This document has sought to set out the work of the CANSO ENVWG Metrics and Methodologies subgroup in identifying ANSP relevant CO_2 performance metrics, focusing on key areas of consensus. While consensus has been achieved in some areas representing significant progress in terms of ANSP CO_2 performance measurement, this work has also identified other areas requiring further consideration such as:

— Analysis of the proper weighting for vertical and horizontal efficiency. In the phase of flight method documented by CANSO, horizontal and vertical inefficiencies are calculated separately. When converting these inefficiencies to fuel, BADA tables are used. In the US/ Europe ATM Operations Performance Comparison, a single representative aircraft is assumed so that performance differences are not driven by aircraft mix. The NATS 3Di score builds this relationship through sophisticated modelling using KERMIT (a NATS developed fuel modelling tool). It is important to understand the relationship between horizontal and vertical efficiency as tradeoffs are necessary. In effect, both excess distance and horizontal segments are converted to time which is then converted to fuel.
— Clarification of the link between ANSP proxy measures of fuel burn and CO2 performance (i.e. those incorporating measures of vertical and horizontal inefficiency) and CO_2 based measures. Specifically, what is the relationship between track extension and CO_2 per flight or between 3Di scores and CO_2? Is there a relationship that we could derive statistically?
— Most “inefficiency” is the direct result of a constraint or interdependency. How can we better understand the impact of constraints and interdependencies across ANSPs and in different airspace? How should we include:
  — The impact of new demand on the system? New demand can be expected to result in increased track and profile inefficiency in a constrained system. How do we take account of this as ANSPs?
  — Normalising efficiency data for weather? Do we need to? Some weather effects could form part of the benefits pool, like use of time-based spacing on approach in bad weather – this would be an ANSP led improvement that we could be driving for.
  — Other factors driving level segments and excess distance not in an ANSP’s control?

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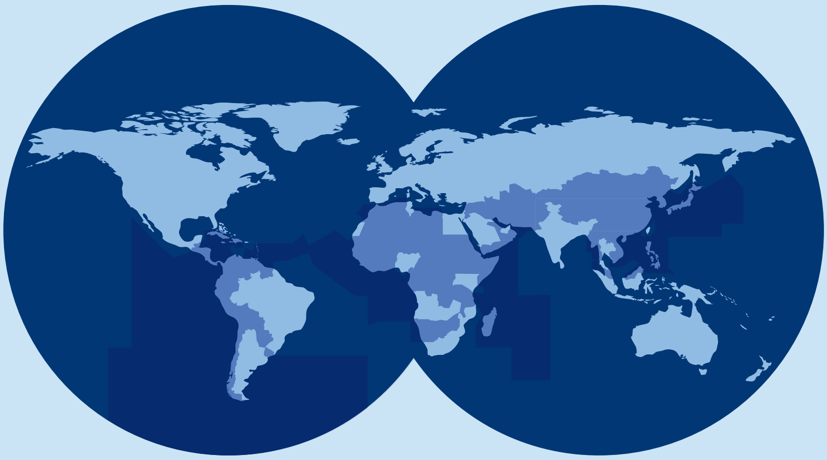
CANSO members are responsible for supporting over 85% of world air traffic, and through our Workgroups, members share information and develop new policies, with the ultimate aim of improving air navigation services on the ground and in the air. CANSO also represents its members' views in major regulatory and industry forums, including at ICAO, where we have official Observer status. For more information on joining CANSO, visit www.canso.org/joiningcanso.



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