# Arrival Management with Open Data

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***Abstract*—This document is a sample illustrating the Quarto `ieeetran` template. It includes the key elements of a scientific articles (references, equations, figures, tables, code, cross references). The template enables the generation of IEEE-formatted article from a Jupypter notebook.**

## I. Introduction

Operational efficiency is a key element of addressing aviation's contribution to climate change. Emissions may increase due to the expected growth in international air traffic until lower emitting technologies and fuels and other mitigating measures are developed and deployed .. ICAO adopted at its 41st Assembly a long-term aspirational goal for international aviation **icao2022?**. In support to the Paris Agreement, the goal is to achieve net-zero carbon emissions by 2050.

Levers for fuel reduction:

* operational efficiency

* market-based measures

* sustainable aviation fuel

* new aircraft propulsion and airframes

A wider use and pick-up of sustainable aviation fuel, and new aircraft propulsion technologies or aircraft design requires further research.

Despite the introduction of an initial market-based mechanism, immediate action to curb fuel burn and CO2 emissions rests with improvements of operational efficiency. ICAO has introduced the trajectory-based operations concept, which promises operational and environmental benefits to aviation. where the flight trajectory of an aircraft is flown as close as possible to the userpreferred route, with as little disruptions as possible through collaborative decision-making mechanism. This includes reducing potential conflicts and resolving demand/capacity imbalances earlier and more efficiently. TBO can therefore bring significant operational and environmental benefits to aviation.

The contribution of this paper comprise:

- conceptualisation of sequencing separation for arrival management and development of an open data and open software based implementation of the approach; and
- use-case application of the developed approach on a subset of airports within the European

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Extra footnote..

## II. Trajectory-Based Operations - Arrival Management

### A. header 2

## III. Data and Conceptual Approach

### A. Approach

data preparation

- trajectory data - Opensky Network, weekly downloads
- airport information - Openstreet Map

data downloaded & script development, data cleaning

*1) Trajectory Flight Phase Segmentation & Milestone:* Different approaches exists to detect and describe aircraft flight phases, e.g. recent machine learning algorithm [1]. This paper implements a heuristic approach with a focus on the detection of arrival traffic at the study airports. Figure Figure 1 shows the detected arrival flights for a single day.

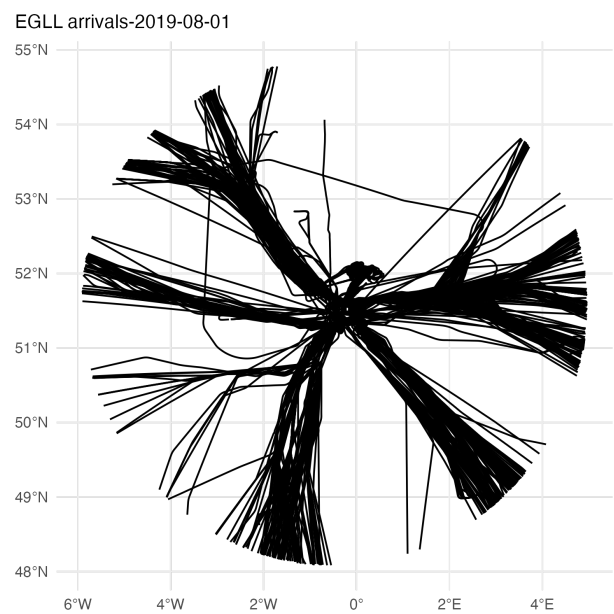


Figure 1: Arrivals at London Heathrow (EGLL) on sample day

*2) Landing Runway Identification:* The identification of the landing direction is based on a simple geospatial heuristic. Conceptually, aircraft are aligned with the runway (centerline) before landing. An aircraft is assigned to a landing runway based on the closeness of its pre-landing positions to the extended runway centerline.

### B. Generalisation of additional time in terminal airspace

The additional time in terminal airspace (c.f. ICAO KPI08, EUROCONTROL Performance Review System & European

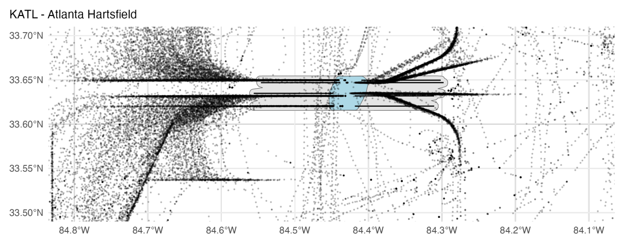


Figure 2: Arrivals at Atlanta Hartsfiled (KATL) on sample day

Single European Sky Performance Scheme) is typically expressed as the difference between the observed travel time of a flight entering the terminal area (e.g. 40NM or 100NM from the aerodrome reference point) and a respective reference time. The latter is defined as the travel time in non-congested situations. For practical reasons, the reference (or uncongested) travel times are determined based on a historical data analysis and sub-sampling the population of arrival flights per entry sector/fix, aircraft wake turbulence category and propulsion type (as a proxy of approach speed), and landing runway.

This notion of additional time can be generalised for every subset of points within the arrival airspace. On the basis of historic data, the travel time between such a set of points can be determined and compared to the flight time of an uncongested trajectory.

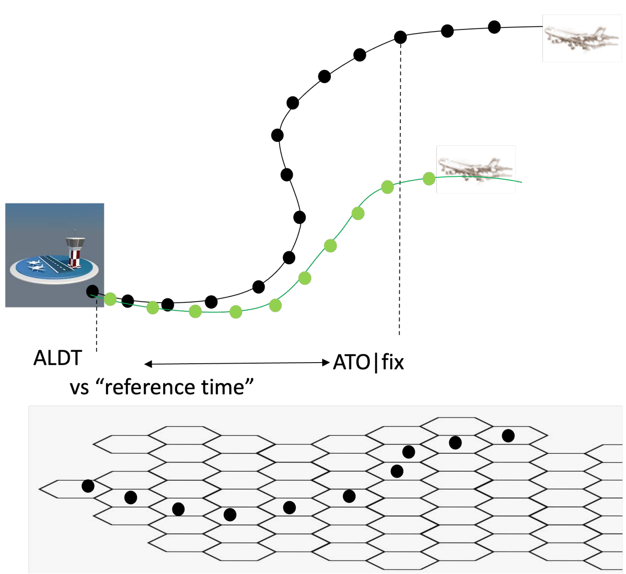


Figure 3: Spacing deviation concept

For practical reasons, this paper discretises the arrival airspace into cells. In particular, we are using hexogonal cells and the H3-indexing system [2]. Uber originally developed the Hexagonal Hierarchical Geospatial Indexing System (H3) as a grid system for supporting the optimisation of ride planning (and associated pricing and dispatch) and for visualisation purposes. H3 is available as an open-source library written in C and with bindings in several languages. We use hexagon-cells of resolution 8 with an average edge length of 0.5314 km.

### C. *Arrival Sequencing - Spacing Deviation*

Let us consider a pair of consecutive landing aircraft denoted leader and trailer, with $s$ being their temporal spacing (inter-arrival time). From an operational perspective, highly efficient operations will maximise the utilisation of the available runway (system) capacity. Accordingly, we can assume that during peak times the temporal spacing at landing $s$ accounts for the operational concept applied at the airport, and only comprises a minimal spacing error. Potential error sources include additional safety margins applied by the air traffic controller (or aircrew when landing under visual flight rules), variations of the arrival spacing due to reduction of airspeed during the flare. We consider the observed temporal spacing $s_{ij}$ as a lower bound for safe operations.

Using the constant time delay principle, the spacing deviation (or spacing error) at time t considers the current position of trailer at time $t$, and the past position of leader at time $t-s$. Based on our approach, the spacing deviation is defined as the temporal difference between the respective reference times for the position of the leader and trailer:

$$spacingdeviation(t) = ref\_time(trailer_{(t)}) - ref\_time(leader_{(t-s)})$$

## IV. Case Study - Results

### A. *Data Sampling*

At the time of writing no global open flight table exists. For this study, we validated the sample with reference data available to the Performance Review Unit. Under the EUROCONTROL Performance Review System, airport operators report movement data on a monthly basis [3].

## V. Conclusions

This paper aimed at exploring a data-driven approach to measuring arrival management based on open data.

## Reproducibility

This paper has been built with the R/RStudio ecosystem. The draft manuscript and its supporting data preparatory steps are archived at https://github.com/rainer-rq-koelle/paper-2023-ICNS.

The script to download the weekly global datasets are included. The cleaned trajectory data is stored at: «tbd».

## Acknowledgment and Disclaimer

The authors thank the comments by XX YY ZZ.

The views expressed are the authors' own and do not represent a policy or position of EUROCONTROL .

## References

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[3] EUROCONTROL, “Eurocontrol Specification for Operational ANS Performance Monitoring - Airport Operator Data Flow.” 2019 [Online]. Available: https://www.eurocontrol.int/publication/eurocontrol-specification-operational-ans-performance-monitoring