Additional taxi-in time performance indicator document

Technical documentation on the methodology for the calculation of the additional taxi-in time indicator

Overview

The Additional Taxi-In Time addresses the operational inefficiencies associated with the stand availability and congestion of the taxiway system while taxiing in. This is reflected by the accumulated (i.e. additional) time spent in the arrival taxi operations on the apron and taxiway system, including holding on the taxiway or the taxilane before parking on the stand.

This document describes the conceptual, logical and implementation independent model of the additional taxi-in time performance indicator.

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TITLE

Additional taxi-in time performance indicator document

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Abstract

This document describes the conceptual, logical and implementation independent model of the additional taxi-in time performance indicator.

Keywords

Performance indicator
Additional taxi-in time

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1 Introduction

1.1 General

This document describes the conceptual, informational, and implementation independent model of the additional taxi-in time performance indicator.

This document focuses on the analysis of additional taxi-in time. A separate document is available regarding the analysis of additional ASMA time [1] and the additional taxi-out time [2].

1.2 Purpose of the document

The purpose of this document is twofold:

- to present the concept, and underlying logical and mathematical modelling of the indicator; and
- to document the processing and use of data for the calculation of the indicator.

1.3 Scope

This document provides a technical description on the methodology used in the analysis of the additional taxi-in time performance indicator. This methodology is the result of the work by a specific working group created to review the additional times methodologies (additional ASMA and taxi-out times) and the introduction of the additional taxi-in times. This group was participated by several internal and external members between November 2021 and October 2022.

The calculation of this performance indicator by EUROCONTROL makes use of the data collected through the Airport Operator Data Flow according to the specification EUROCONTROL-SPEC-175 for data collection and processing, under the responsibility of the airports team in the OPS section of the Aviation Intelligence Unit. For the calculation of the indicator, the Airport Operator Data Flow is combined with data provided by the Network Manager.

The objective of the methodology is to measure and observe additional time spent in the taxi-in phase without highlighting specific reasons for the observed behaviour. More detailed case studies are needed to find out reasons for particular observations.

While this document focuses on the methodology itself, results for a number of airports across Europe are available in regular publications at www.ansperformance.eu.

1.4 Summary of the performance indicator information

Additional taxi-in time: Summary			
Current version status	Monitoring		
Version status and evolution	Conceptual Phase	2022	Ongoing
	Technical Development	2022	Ongoing
	Prototyping / Validation	2022	Ongoing
	Monitoring	-	-
	Target Setting		N/A
	Phase Out		N/A
Context	KPA (PRC) : Efficiency Focus Area: Airport impact on flight duration, punctuality, fuel burn and CO_2 emissions. Originator: Working Group for Additional Times		
Description	This indicator provides an approximate measure of for the average holding time during the taxi-in phase, during times that the apron and stands are congested.		
Formula and Metrics	This indicator is calculated on the basis of data availability for Actual In Block Time (AIBT) and Actual Landing Time (ALDT). The additional taxi-in time is the difference between the actual taxi-in transit time and a reference taxi-in transit time for the group of similar flights. The taxi-in additional time for the airport is the average additional taxi-in values for all flights.		
Unit	Minutes per arrival		
Used in	-		

Table 1: Performance Indicator summary

1.5 Acronyms and terminology

Term	Definition
AIBT	Actual In Block Time
AIU	Aviation Intelligence Unit
ALDT	Actual Landing Time
APDF	Airport Operator Data Flow
ARWY	Arrival Runway
ASMA	Arrival Sequencing and Metering Area
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
CODA	Central Office for Delay Analysis
CPR	Correlated Position Reports
CTFM	Current Tactical Flight Model
DRWY	Departure Runway
KPA	Key Performance Area
KPI	Key Performance Indicator
LT	Local Time
PRISME	Pan European Repository of Information Supporting the Management of EATM
PI	Performance Indicator
PRU	Performance Review Unit
QoS	Quality of Service
RWY	Runway

Table 2: Acronyms and terminology

2 Conceptual model

2.1 What we would like to measure

This conceptual indicator has been selected to measure the operational inefficiencies during the taxi-in phase associated with the congestion of the aprons and taxiways and the stand availability. This is reflected by the accumulated (i.e. additional) time spent in the on the apron and taxiways, including holding on the taxiway or the taxilane before parking on the stand.

2.2 Concept of runway optimisation

When aircraft cannot fly unimpeded 4D trajectories, there are generally three places at which queuing takes place, as illustrated in Figure 1:

- At the departure stand (pre-departure queuing to optimise network performance)
- At the departure runway (take-off queuing, e.g. runway holding)
- In the arrival terminal airspace (arrival queuing in the Arrival Sequencing and Metering Area or ASMA, using speed control, stacks, holding, extension of approach path etc.)

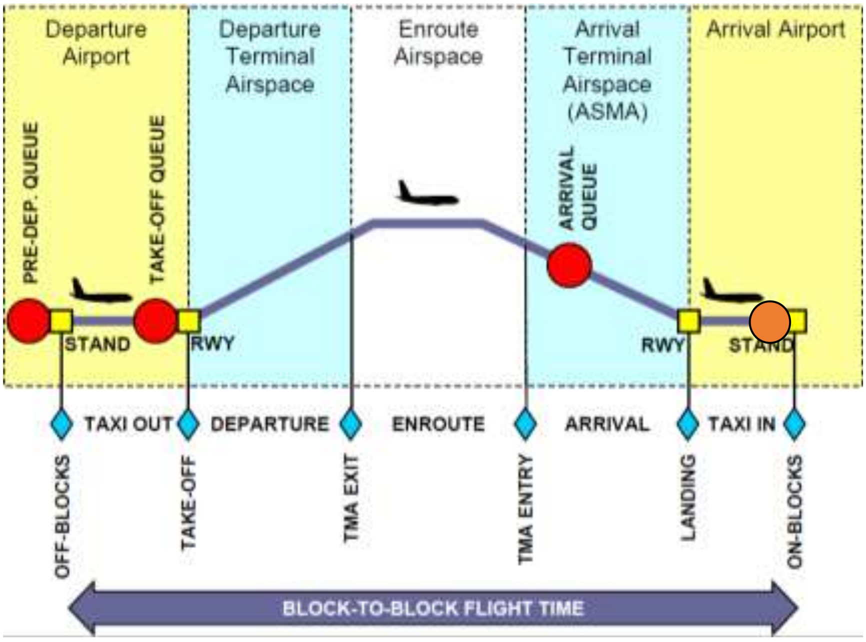

Figure 1: Outbound and Inbound Traffic Queues from a Flight Phase Perspective

Uncertainty of approach conditions (e.g. pilot performance, landing clearance time, approach speed, wind conditions) makes traffic supply to runways a stochastic phenomenon.

In order to ensure continuous traffic demand at runways and maximise runway usage, a minimum level of queuing is required. A certain amount of departure runway queuing is necessary to allow for an optimisation of departure (and arrival) management in terms of runway utilisation when demand is at or near operational capacity.

However, additional time in holding or queuing is detrimental to operations efficiency, fuel consumption and the environment. Therefore, a trade-off exists between approach efficiency and runway throughput.

Optimisation of runway utilisation may require:

1. Re-sequencing the take-off (and landing) order at the runway; and

2. 2. Buffering a sufficient number of aircraft in the queue to be able to fine tune the metering and the runway throughput (to optimise the separation of aircraft released from the queue to the runway).

In both cases some aircraft will suffer a certain penalty in terms of queuing time. Higher runway utilisation targets may require higher levels of departure (take-off) queuing in the manoeuvring area and arrival queuing in airspace. This effect can be reduced if aircraft are already delivered to the queue in the right sequence and at the required time intervals.

In addition to three places marked with a red dot in Figure 1, aircraft might also experience some queuing or holding after landing and during the taxi-in phase (orange dot in Figure 1). This is mainly due to the congestion of the aprons and taxiways or issues with the stand availability.

To reduce cost and environmental impact, the departure and arrival queuing time should be kept to the minimum needed to achieve the selected runway utilisation objectives. If possible, any departure and arrival delay that is needed for other reasons than sequencing and metering should therefore be absorbed at the departure stand through ATFM delays and local ATC pre-departure delay. If this is done properly, then measuring outbound and inbound queuing time allows assessing the "operational cost" associated with sequencing and metering in function of the selected runway utilisation objectives.

Measuring inbound queuing time in terms of additional taxi-in time makes it possible to assess the efficiency of the gate allocation and management process and, thus, the operational cost associated with unavailability of gates or congestion during taxi-in.

2.3 Conceptual approach

The additional taxi-in time indicator aims to provide a measure of the inefficiencies on the apron and taxiway system during the taxi-in phase including possible stand queuing time. The additional taxi-in time is a proxy for the level of efficiency (i.e. inefficiency) of the local operations during the taxi-in phase of a flight.

Performance in terms of additional taxi-in time is monitored on the basis of regular reporting in comparison to a nominal reference. Based on regular reporting, metrics are derived for the respective reporting month. The current measurements are compared to a nominal reference to address the level of efficiency. The reference is derived from the statistical analysis of a reference period sample. This approach is depicted in Figure 2.

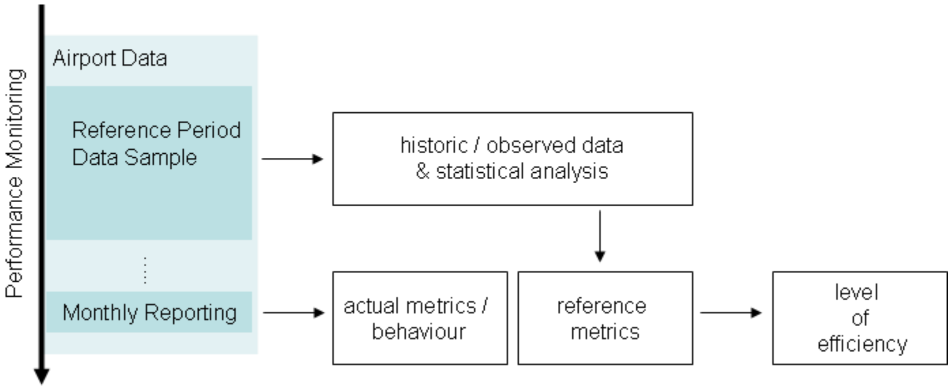

Figure 2: Performance Measurement Approach

The indicator is defined as the difference between the taxi-in transit time (actual taxi-in time) and the reference taxi-in transit time.

$$Actual\ TaxiIn\ Time = Reference\ TaxiIn\ Time + Additional\ TaxiIn\ Time$$

The reference times intend to reflect the required time to perform the taxi-in procedures assuming no inefficiency (i.e. no holding during the taxi-in or no holding on the taxilane waiting to park) and are determined based on a statistical analysis of historic data observed at the airport (last 12 months), for groupings of similar flights expected to have similar taxi-in times. The additional taxi-in time is a measure for the extent of which the actual taxi-in time exceeds the reference.

3 Methodology

This section describes the underlying logical modelling and drives the implementation of the additional taxi-in time algorithm.

3.1 Approach and assumptions

The purpose of the **additional taxi-in time** indicator is to provide an approximate measure of the average queuing time during the taxi-in phase for the arrival traffic flow, usually observed during times that the airport is congested.

Taking into account the timestamp data available, taxi-in time is defined as the time elapsing between the Actual Landing Time (ALDT) and the Actual In-Block Time (AIBT). The additional time is measured as the additional time beyond a reference taxi-in time, which is a statistically determined time based on actual taxi-in times recorded for a certain reference period.

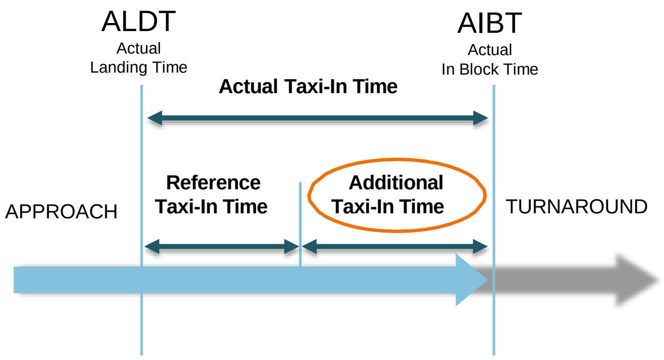

Figure 3: Conceptual approach for Additional Taxi-In Time

Systemic factors are assumed to be captured in the nominal reference; they do not significantly influence the metric: including the part of the arrival runway occupancy time between touchdown and runway exit

This indicator excludes influence of runway in use or arrival stand: a separate reference is calculated for each combination of these factors, so they are included in both the transit times of the flights under analysis and the flights used to calculate the reference transit times; therefore this does not show up in the additional time which is the difference between each flight under analysis and the corresponding reference time.

3.2 Grouping of flights

The reference taxi-in times are, as mentioned in 3.1, statistically determined based on actual taxi-in times recorded for the flights arriving at an airport during a certain reference period. Each reference time calculation requires then a sample of flights for analysis. This sample is obtained by establishing groups of flights that are expected to follow similar taxi-in routes and therefore have similar optimal transit times.. This is done through groups with the same combination of arrival runway and arrival stand.

The aircraft class or aircraft type could also have an impact on the taxi speeds and therefore the transit times. Nevertheless this additional factor breaks down the sample into more groups, reducing consequently the sample size for each group, but not having significant impact in the results.

Since the sample size is key for the calculation of realistic reference times, the aircraft class is not used as a factor in the grouping of the flights.

For each airport, flights are then grouped by combos with the same arrival runway and arrival stand. Each grouping of flights with the same combo will have a reference transit time associated.

3.3 Overview of the logical model of the Additional and Reference Taxi-in Times

This section focuses on the algorithm for the calculation of the additional taxi-in time indicator from a logical point of view. The additional taxi-in time calculation for a given airport in a given "month i" is depicted below and explained in the next section 3.4.

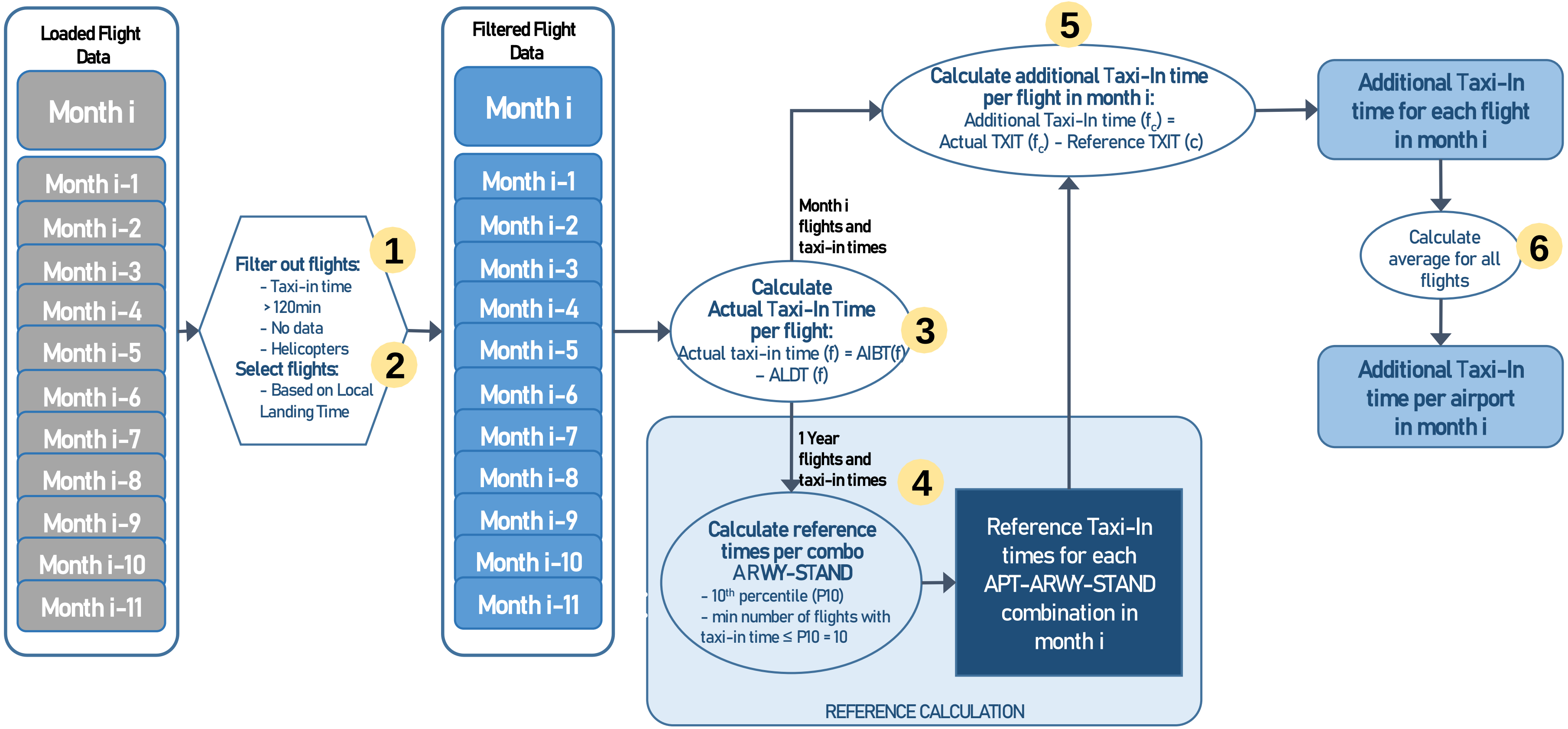

Figure 4: Logical steps for the monthly Additional Taxi-in Time calculation

3.4 Calculation of the Additional Taxi-in Time

The computation of the indicator for a given airport is based on six consecutive steps as shown in Figure 4:

1. Starting with all the loaded flight data in the system, filter out the flights with some missing data (e.g. no runway information, no stand information or no in-block time), flights with taxi-in time longer than 120 min and helicopters.
2. For the analysis of month i, select the arrivals of the last year based on the runway time in local time, that is [month i-11:month i] (e.g. for month Nov-22, take all arrivals landing between 01-Dec-21-00:00:00 until 30-Nov-22-23:59:59 inclusive, in local time).

   For the month i+1 we will recalculate again the reference taxi-in times based on the last year- through a new selection of the flights.
3. Calculate, for each departure flight f, the taxi-in time, as the time between the actual landing time (*ALDT(f)*) and the actual in-block time (*AIBT (f)*).

$$TaxiIn\ time\ (f) = AIBT\ (f) - ALDT\ (f)$$

4. The reference times are calculated based on the entire year of data as obtained in step 1, 2 and 3. One reference value is calculated for each group of similar flights (same combo arrival runway – stand) in a separate process that is explained in the next section.
5. Calculation of the additional time for each flight based on the reference time of similar flights (that is, the reference calculated for the combo ARWY – STAND to which this flight belongs). Therefore, for a flight f_c using a combo *c* with a certain ARWY – STAND through subtraction of the combo's reference time from the actual taxi-in time of each flight.

$$Additional\ TaxiIn\ time\ (f_c) = TaxiIn\ time\ (f_c) - \ TaxiIn\ reference\ time\ (c)$$

   As explained in the next section, the sample size might not allow to calculate a reference time for certain combos. In that case, it will not be possible to calculate the additional taxi-in time for the flights using those combos ARWY – STAND and these flights will not be taken into account in the final computation.
6. Calculation of the average additional taxi-in time for the airport in month i as the average of the additional taxi-in times of all n flights f (regardless of their combo) from month i with a valid calculated additional time. [min/departure].

$$Average\ additional\ TaxiIn\ time\ (month\ i) = \frac{\sum_{f=1}^{n} Additional\ TaxiIn\ time\ (f)}{n}$$

3.5 Calculation of the Reference Taxi-in Times

The objective of the reference times is to identify what would be the *optimal while possible* time to taxi-in from a given runway to a given stand without any holding, i.e. if the operation was unimpeded.

The calculation of these reference times is done as an approximation via a statistical analysis of a reference sample. This reference sample is specific for each airport and each month. As shown in Figure 4, the period considered as the sample for the reference calculation is the last year of traffic departing from that airport up to and including the month of operations under analysis. The reference sample is therefore dynamic: a rolling year of traffic data, filtered and selected according to local time.

The computation of the reference times for a given airport in a given month is based on step 4 as shown in Figure 4 which includes steps 4a and 4b as depicted in Figure 5:

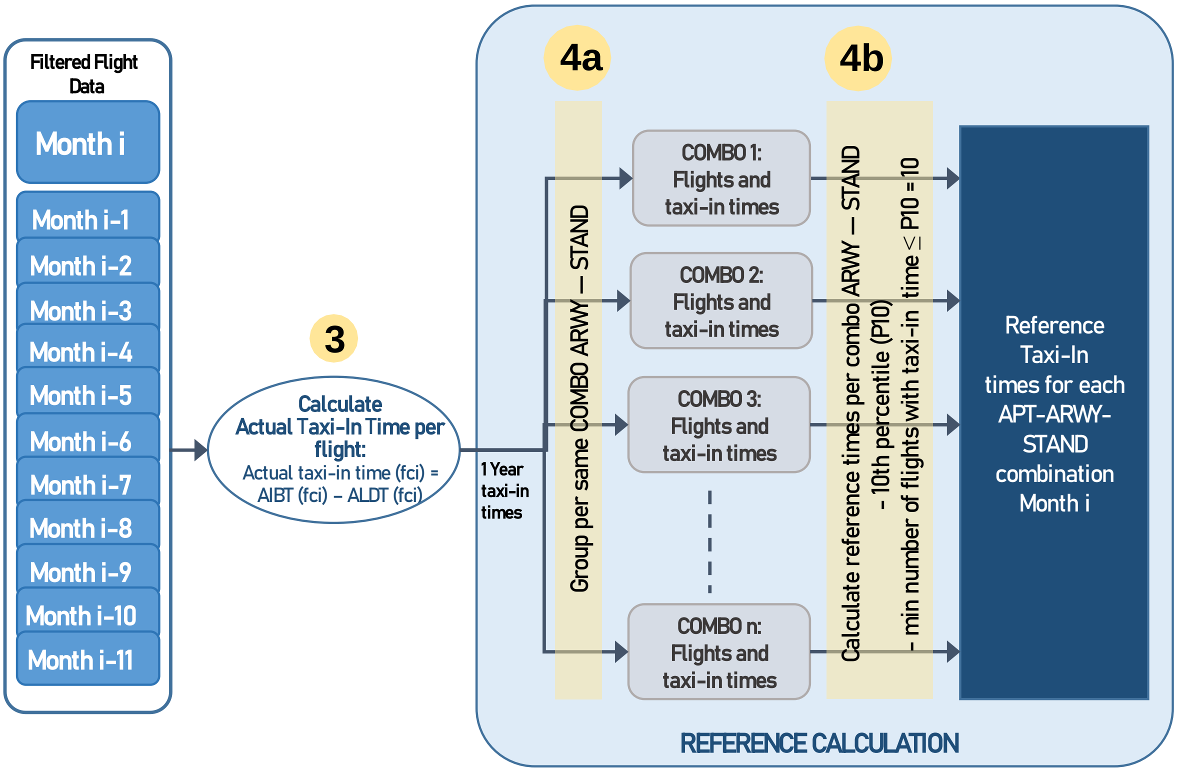

Figure 5: Steps of the Reference Taxi-in Times calculation

Starting with the full set of data for the year, and after steps 1 to 3 in Figure 4, we obtain the sample of 1 year of departing flights with their taxi-in times (TXIT) with their arrival runway and stand.

4.a This sample is then broken-down into the different samples with flights and taxi-in times for each possible combo at the airport given its runways and stands (step 4a in Figure 6).

4.b For each one of these samples of flights, the reference time for that combo ARWY – STAND is calculated as the **10th percentile** of those taxi-in times:

$$TaxiIn\ Reference\ time_{combo\ j} = 10th\ percentile\ (TaxiIn\ times)_{combo\ j}$$

The 10^{th} percentile is estimated to provide the best approach to the optimal (while possible) transit times in the distribution of all taxi-in times for a given combo (Figure 6).

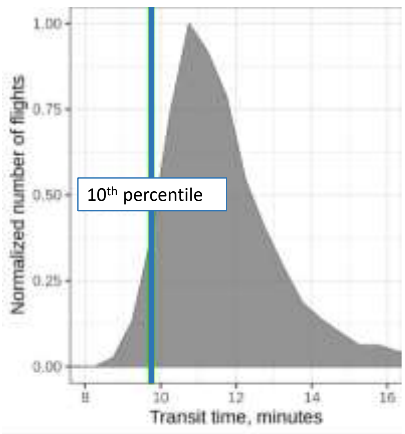

Figure 6: Reference as the 10^{th} percentile of the transit times

For a calculated reference time to be considered valid and representative the *optimal while possible* taxi-in times for a certain combo ARWY – STAND, there must be at least 10 flights in the sample with a taxi-in time equal or shorter than the calculated reference time.

$$(\text{Minimum number of flights with TaxiIn time } \leq 10\text{th percentile})_{combo\ j} = 10$$

Combos where the sample size is too small and this condition is not met will not have any taxi-in reference time assigned.

4 Error description

The error in the results depends on the accuracy and precision of the available data. The time stamps used for the calculation use the format HH:MM:SS, so the highest precision is seconds. Nevertheless, in some cases the data provided might be limited to a HH:MM format, so in those cases the precision is lower.

The precision in the collection of the AIBT (Actual In-Block Time) is key in the calculation of the taxi-in times. This event should reflect as much as possible when the aircraft stops moving once parked at the stand.

5 Factors not considered

There are other factors in addition to the specific taxi-in procedure that can have an impact on the taxi-in times. These factors are inherently included in both the reference sample and the flights under analysis in month i, but they are not considered in the grouping of the flights, so there is no specific reference time calculated for the different conditions resulting from these factors.

- Different taxi-in routes. The data does not include the path followed by the aircraft during the taxi-in phase nor the runway exit used by the aicraft. The reference is therefore calculated assuming always the same or similar path from the runway to the stand.
- Aircraft taxiing speed. The data does not include the speed at which the aircraft is taxiing in. The reference is calculated for all flights for a given combo runway-stand regardless of their actual speed.
- Special events affecting the taxi-in procedures, which might require a specific reference sample (e.g. construction works on certain apron areas).

The reason for not considering these factors is the lack of the required information in the dataset. However, even if the dataset would inform about the runway exit, taxi-route or speed, the number of factors to be considered in the combos should be kept to a minimum in order to keep a reasonable sample size that would allow for a more reliable result from the statistical analysis based on a percentile approach.

Considering more factors would increase the possible combinations and therefore reduce the number of flights in each combination, which would have a detrimental effect in the reliability of the statistical result.

6 Implementation and regular monitoring

In the implementation of the regular calculation of the additional taxi-in times it is required to establish in parallel a monitoring routine of certain elements to ensure the quality of the result.

6.1 Implementation of the monitoring of additional times

This methodology requires as described in Figure 4 a complete year of data, i.e. rolling 12 months up to and including the month of operations under analysis. Nevertheless, during the first year of data provision the reference sample cannot reach the required 12 months. In that case the reference sample to be used is the traffic sample available to date. Figure 7 illustrates an example where the data provision starts in May, and the reference sample would increase from 1 to 12 months in the first year, and then continue the rolling year.

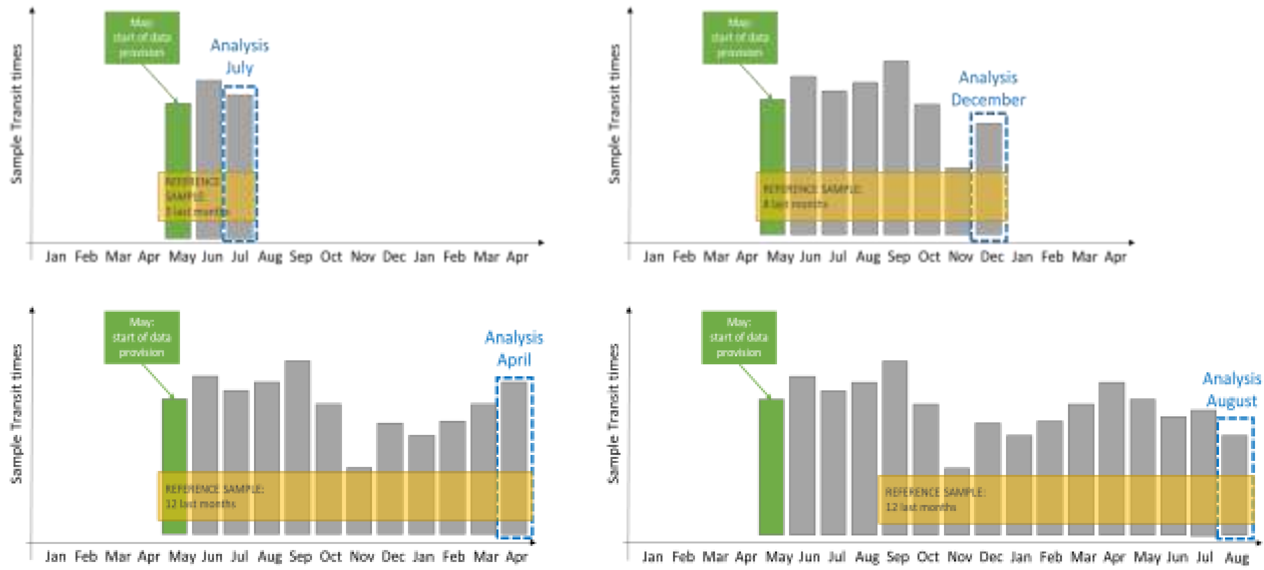

Figure 7: Incremental increase of the size of the reference sample until reaching 1 year

6.2 Evolution of the taxi-in reference times

The taxi-in reference times, as described in 3.4. are calculated every month based on the past rolling year traffic sample. The reason to implement a rolling reference sample is to automatically adapt to changing situations and keep in this way an up to date reference. Nevertheless it is necessary to monitor the evolution of the reference times to identify possible issues in the data provision and calculations.

6.3 Share of flights without a valid reference transit time

As observed in section 3.5, the calculated taxi-in reference time for a given combo ARWY—STAND is not considered valid when the size of the traffic sample using that combo in the reference year is not big enough to show at least 10 flights with a transit time equal or shorter than the 10^{th} percentile.

Flights belonging to combos for which there is no valid reference will consequently have neither reference nor additional time and will not be considered in the analysis. The share of these flights in comparison with the total number of flights under analysis (that is, the second data set of Month i after the filtering and selection done in steps 1 and 2) should be monitored to identify possible issues in the data provision (e.g. a change in the naming of the stands) and possible needs for specific action.

6.4 Special cases

In some cases the analysis for a given airport must be adapted to its specific conditions or events. The following are only example of possible special cases:

- Runway denomination change: when a runway denomination changes, the data using the previous runway denomination can be combined with the new data to extend the reference sample. This way, both runway denominations can be considered in the same combos and increase the sample size.
- Special events: in case of special events affecting the normal operation at the airport (works on the apron, trials, implementation periods, new runway, closure of runways and/or aprons, etc) a focused analysis may use a specific reference sample or filter of the flights/dates to be considered. This is more intended for deep-dive analysis than for regular monitoring.

Any deviation from the standard filtering or choice of reference sample (as described in Figure 4) should be published together with the results of the analysis to ensure transparency and reproducibility.

7 Source data

7.1 Main and secondary data sources

The additional taxi-in time indicator is calculated by AIU/OPS in EUROCONTROL using data provided by the airport operators and the Network Manager:

- The airport operators provide, through the APDF (Airport Operator Data Flow: EUROCONTROL-SPEC-175) the actual in-block times, the actual landing times, the runways and the stands used by the arrivals.

Name	Source	Alternative Source
Departure airport	Airports (APDF)	ANSPs
Actual landing time	Airports (APDF)	ANSPs or Network Manager
Actual In-block time	Airports (APDF)	
Arrival Runway	Airports (APDF)	
Arrival Stand	Airports (APDF)	

Table 3: Data Sources

Note: The Network Manager data flow also provides the actual landing times. Given the quality assurance measures defined for the airport operator data flow, Network Manager data flow based timestamps will only be used for complementing the airport operator data flow.

8 Quality management

8.1 The Airport Operator Data Flow process

The airport operator data flow (APDF) comprises all data collection, processing, and performance indicator calculation sub-processes. Reporting entities (i.e. airport operators) submit their data to EUROCONTROL on a monthly basis and in compliance with the APDF data specification.

Several activities are performed in the data flow process, involving different actors, until performance reports are published. As a summary, a high level overview of the activities can be found below (Figure 8):

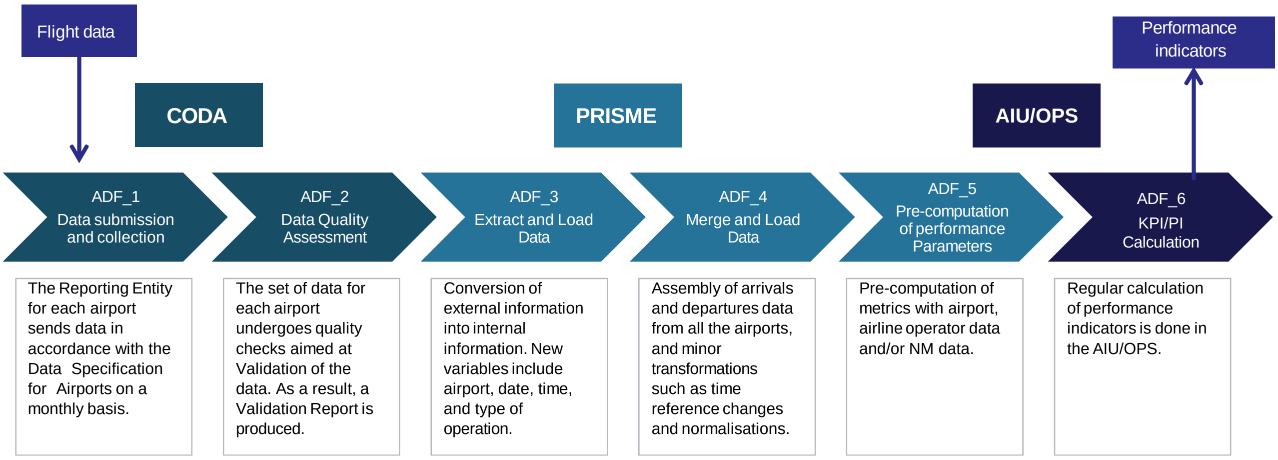

Figure 8: Airport Data Flow process scheme including activities and actors involved.

The airport operator data flow can be conceptualised as stages or sub-processes:

- APDF_1 – Data Collection
- APDF_2 – Data Validation
- APDF_3 – Data Extraction, Transformation and Loading
- APDF_4 – Data Merging
- APDF_5 – Pre-Computation of performance parameters
- APDF_6 – Calculation of Performance Indicators

Each of the sub-processes are governed by quality assurance measures. The AIU/OPS assumes responsibility for the whole flow in terms of quality assurance. Data collection and initial validation is also performed by AIU/OPS. Once the data is loaded, the data processes within the EUROCONTROL data warehouse are managed by PRISME. In the final stage, AIU/OPS extracts the relevant data and computes the performance metrics and indicators.

APDF related documentation is available in EUROCONTROL-SPEC-175.

8.2 Quality Assurance Framework

Quality assessment on airport data flow process is focused towards implementing a Quality Assurance Framework based on the ISO 9001 standard. The airport operator data flow process includes several data processing activities, starting from the moment flight information is provided by the reporting entity until performance reports are released.

Standard Operating Procedures for all these sub-processes have been established and is quality controlled.

8.3 Data Quality Checks

For the APDF the following quality areas have been identified. Quality controls in support of these quality areas are implemented and regularly monitored as part of the aforementioned APDF sub-processes (Figure 9).

Mapping	Mapping consists of checking the format of submitted data and ensuring that the data to be stored in PRISME follow the same coding convention
Completeness	This process checks the number of operated flights, and the amount of not null values for the main fields in the airport data (e.g., OOOI, STA, STD)
Matching	A set of filters is applied to search among flights submitted by the airport operators/air carriers and find the exact flight matches in the NM database
Data Accuracy Validation	This quality check mainly assesses the quality of OOOI data (Off Block, Take Off, Landing, In Block) through a set of acceptability criteria.

Figure 9: Quality Performance Areas and corresponding Quality Indicators.

More detail on these quality checks can be found in the Airport Data Flow Data Specifications (EUROCONTROL-SPEC-175).

9 References

[1] EUROCONTROL, “Additional ASMA time performance indicator document,” 2023.

[2] EUROCONTROL, “Additional taxi-out time performance indicator document,” 2023.

10 Revision History

Edition	Description	Comment
00-01	New draft – all pages	New document
01-00	Final draft after consultation	Minor editorial changes