INTERNATIONAL CIVIL AVIATION ORGANIZATION

TWENTY SEVENTH MEETING OF THE ASIA/PACIFIC AIR NAVIGATION PLANNING AND IMPLEMENTATION REGIONAL GROUP (APANPIRG/27)

Bangkok, Thailand, 5 – 8 September 2016

Agenda Item 3: **Performance Framework for Regional Air Navigation Planning and Implementation**

3.6: **Other Air Navigation Matters**

PERFORMANCE BENCHMARKING FOR EFFECTIVENESS

(Presented by Singapore, United States, EUROCONTROL)

SUMMARY

Over the years, ICAO has produced several guidance documents on air traffic management (ATM) operational performance measures including those in ICAO Document 9883 (Manual on Global Performance of the Air Navigation System) and the Global Air Navigation Plan (GANP). Implementing these performance metrics involves challenges. The purpose of this paper is to demonstrate the utility of two ICAO GANP Key Performance Indicators of Additional Time in the Taxi-Out Phase and Additional Time in the Terminal Airspace in a tripartite benchmarking study by CAAS, FAA and EUROCONTROL. The procedures for determining these metrics have been harmonized to allow for a common benchmarking of the provision of air navigation services in each region. The paper also shares the experience of these groups in using these indicators and relating them to causal reasons for operational performance analyses.

1. INTRODUCTION

1.1 ICAO Document 9883, the Manual on Global Performance of the Air Navigation System, provides guidance on the Performance Based Approach (PBA) and the role of metrics for decision makers. Appendix E in particular provides examples of metrics for 11 different Key Performance Areas (KPA). The document acknowledges that more work is needed in this area and that work would be needed on the part of States to develop capabilities for measuring performance and as well as to promote the harmonized application of the performance framework across the industry.

1.2 ICAO recently released its draft version of the 2016-2030 Global Air Navigation Plan (GANP). It recommends 16 Key Performance Indicators (KPI) for Efficiency, Capacity and Predictability. In this framework, delay or additional time can be used as both an indicator of flight efficiency or as an indicator of capacity where lack of capacity leads to delay. As a supplement to the GANP, ICAO has provided more detailed description of these indicators on its website (http://www.icao.int/airnavigation/Pages/GANP-Resources.aspx). At the regional level in the Asia Pacific, a small working group (RAPMF/SWG) has been formed to establish an ATM performance measurement framework within the region.

1.3 In July 2015, the Civil Aviation Authority of Singapore (CAAS), the Federal Aviation Administration (FAA) and European Organization for the Safety of Air Navigation (EUROCONTROL) initiated a joint project to develop harmonized procedures for selected KPIs. As a start, all three parties agreed on both the Taxi-out Additional Time (KPI02) and the Additional Time in the Terminal Airspace (KPI08) indicators that are listed in the draft GANP referenced above (attached herewith in **Appendix A** for ease of reference). This effort would closely examine the complete process for producing the metrics, including grouping flights into common populations and establishing the benchmark nominal times used as the reference for computing the additional time. The data sources of each group would be examined for compatibility in determining respective traffic movement times utilized for defining the start/end times of the metrics. Singapore Changi Airport would be benchmarked in context with comparable US and European airports, similar to work performed in previous EU/US benchmarking activities.

1.4 This paper presents a summary of the work to date on the joint project with CAAS, FAA and EUROCONTROL. It will describe the data and supporting tools necessary to develop the metrics and assess interdependencies.

2. UTILITY OF METRICS

2.1 An ANSP’s investment in producing performance indicators will only make sense if it can be shown that monitoring the KPIs can enhance the management of the air traffic and which would lead to performance improvements. KPIs should be clear and point decision makers to the constraints that affect operational performance.

2.2 This paper highlights two metrics that assess the KPA for Efficiency by measuring the additional time over an un-impeded reference time in the departure and arrival phases of a flight. This is a form of a delay measure not tied to airline schedules which may include additional block time that can mask delay. Nonetheless, for the departure and arrival phases, the performance of air navigation services represents a major driver for additional times given local operating principles and procedures.

2.3 These metrics can be used to identify constraints in the system or level of service by ANSPs. By grouping flights by common operating condition (see paragraph 3.3 below), flight groupings with high additional time provide indications of operating conditions that are the most constrained and show a certain level of inefficiency. While the performance indicators are typically aggregated on a yearly level for high-level decision making, these indicators can also be provided by time of year or time of day to support a targeted operational analysis of constraints. For example, such breakdowns can quantify the magnitude of the constraints due to traffic seasonality, airline schedule peaks, or support the procedural design of approach / departure configurations.

2.4 There is also utility in calculating the indicators using harmonized procedures. Common procedures allow ANSPs to reduce cost in verifying elements of each other’s data extraction systems and metric computation procedures. A harmonized application and approach to establishing the performance metrics enables the benchmarking of performance among airports and gauge if performance improvements were possible given that they are demonstrated at comparable airports.

3. BASIC DATA AND SUPPORTING TOOLS

3.1 One item fundamental to these performance indicators is the ability to obtain key times for flights. For taxi-out metric, this includes the time leaving the gate area (i.e. actual off-block time) and the runway take-off time. For the terminal arrival area, this could be the time entering into terminal arrival airspace and the time of landing on the runway. The time entering terminal arrival airspace is approximated by a 100NM circle from the arrival airport for this joint project.

3.2 Another component of measuring additional time in the taxi-out and terminal arrival phase is developing a reference time that is representative of an "un-impeded" flight. For taxi-out, this would be a flight that would taxi at a normal speed without stopping until it reaches the runway holding point, lines up on the runway, and executes the take-off roll without delay. For the terminal arrival area, a benchmark ideal flight is one that could proceed to the runway with minimal time spent on downwind or converging with other traffic. Figures 1 and 2 illustrate the overall process for Taxi-Out and additional time in the terminal airspace.

Figure 1 – Grouping of Flights for Additional Taxi-Out Time

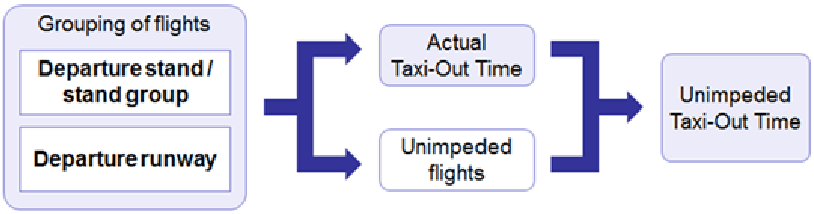
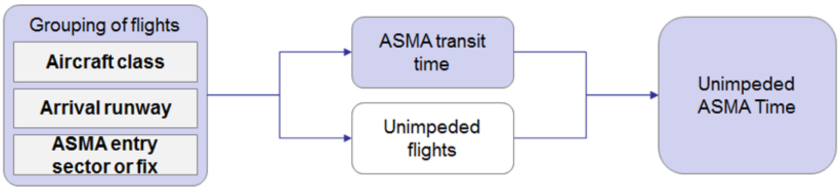


Figure 2 – Grouping of Flights for Addition Time in Terminal Area



3.3 Obtaining these times for each flight is theoretically possible but can be labor intensive. For this reason, the study team grouped arriving flights by common population (approach fix, arrival runway, and aircraft wake turbulence category) and departing flights by another common population (gate groups and departure runway) and assessed the distribution of travel times. Within each population, flights between the 5th-15th percentiles in terms of travel time were averaged to obtain a nominal flight time or taxi-out time that could be considered representative of un-impeded reference times. Figures 3 and 4 below show examples of the harmonized flights groups used for both taxi-out and terminal arrival flight efficiency. Figure 3 shows gate area clusters and Figure 4 shows the approach fix/bearing groupings.

Figure 3 – Harmonized Gate Area/Runway Groupings for Additional Taxi-Out Time

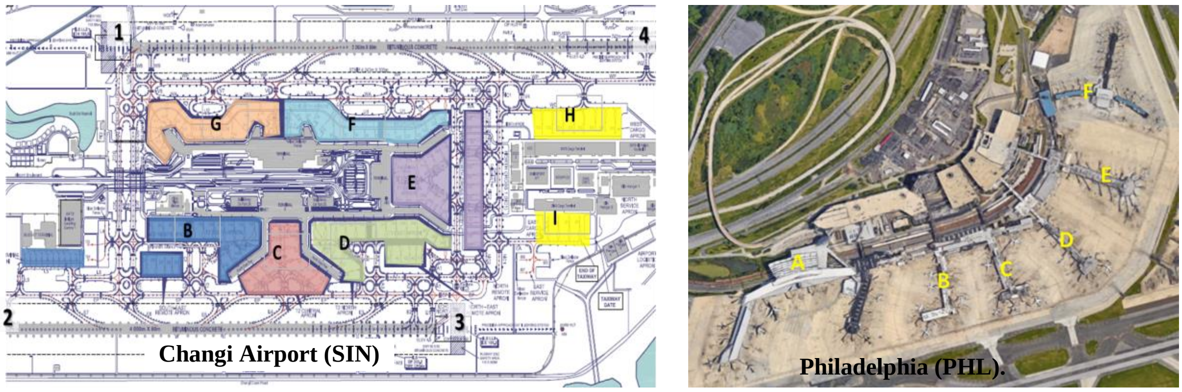
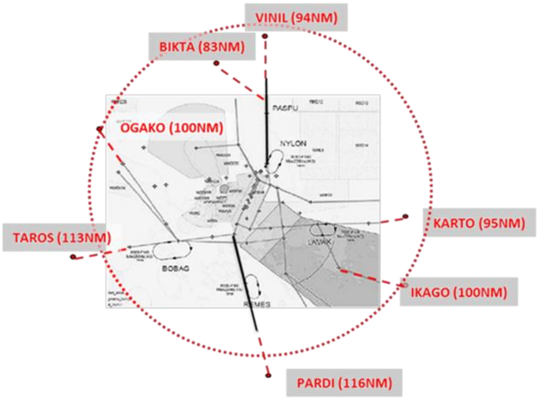
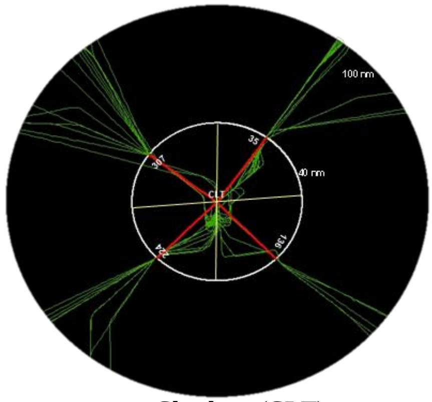


Figure 4 – Harmonized Approach Fix/Runway Groupings for Addition Time in Terminal Area



Arrivals into Changi Airport (SIN)



Charlotte (CLT)

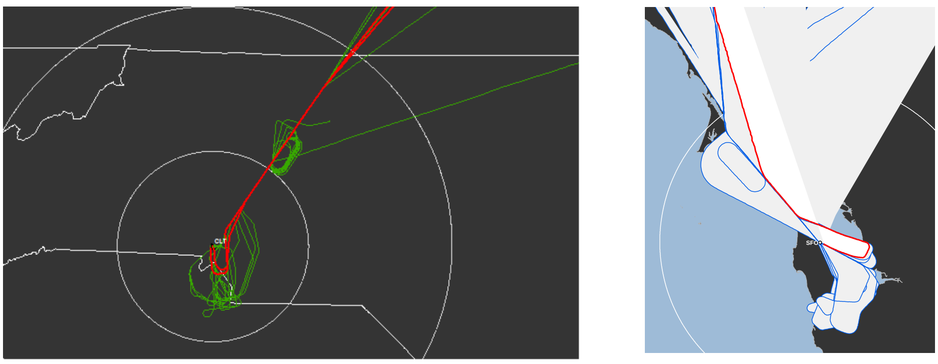
3.4 In order to derive the values of the performance indicators, the data required for determining the additional taxi-out time includes off-block time; take-off time; gate; and departure runway. Similarly, the data required for determining the additional time in terminal airspace includes time of entering the terminal airspace or over entry fix at approximately 100NM from the arriving airport; landing time; aircraft wake turbulence category; and arrival runway.

4. BENEFITS OF PERFORMANCE BENCHMARKING

4.1 Having a common methodology allows the parties to have a common reference to compare the performance of each airport. This allows ANSPs to have more reference points from the performance of comparable airports and assess their own performance or differences in operating principles or procedures.

4.2 A fundamental concept of performance benchmarking and/or driving performance improvements is establishing a commitment through identifying performance targets. When setting performance targets for their airports, the performance of comparable airports represents an invaluable input to balance historic performance with realistic performance expectations. In Figure 5 below, actual trajectories (shown in green and blue) can be compared with the benchmark (shown in red) to identify scenarios with high additional time and assess them for mitigation.

Figure 5 – Quantifying Additional Time above Benchmark



4.3 The problems of an airport can be surfaced through the comparison of other operational parameters and constraints of each airport. Areas where each airport has an operational edge can also surface in benchmarking, showing potential best practices for other airports from which to learn. Consequently, ANSPs can implement appropriate performance enhancement measures through an information-based decision-making process.

5. ACTION BY THE MEETING

5.1 The meeting is invited to:

a) Note how the harmonized procedures developed as part of this multi-region benchmark study allow States to produce the recommended metrics in the ICAO GANP;

b) Note the observed benefits of joint benchmarking using these metrics as identified in Section 4;

c) Assess the joint benchmarking activity for use in promoting common KPIs for the Asia Pacific Region; and

d) Adapt or modify these procedures to more fully support benchmarking within Asia Pacific while keeping the workload on metrics practical.

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Description of the potential performance indicators presented in the GANP 2016

Note: these indicators, definitions and descriptions are used by different States and organizations that already have published performance information. They are provided for information and might differ from indicators and definitions contained in existing ICAO documentation.

Table 1 below provides an overview of each indicator. A description in greater level of details can be found in the following pages.

Table 1 Potential key performance indicators (KPIs) definition

Flight phase or event	ID	Name	Definition
Off-blocks (OUT)	**KPI01**	Departure punctuality	Percentage of flights departing from the gate on-time (compared to schedule) [avg. per traffic flow, per airport or per cluster of airports]
Taxi-out	**KPI02**	Taxi-out additional time	Actual taxi-out time compared to an unimpeded taxi-out time [avg. per airport or per cluster of airports]
Take-off (OFF)	**KPI03**	ATFM slot adherence	Percentage of flights taking off within their assigned ATFM slot (Calculated Take-Off Time Compliance) [avg. per airport or per cluster of airports]
En-route	**KPI04**	Filed flight plan en-route extension	Flight planned en-route distance compared to a reference ideal trajectory distance [avg. per traffic flow or airspace volume]
	KPI05	Actual en-route extension	Actual en-route distance flown compared to a reference ideal distance [avg. per traffic flow or airspace volume]
	KPI06	En-route airspace capacity	The maximum number of movements an airspace volume will accept under normal conditions in a given time period (also called declared capacity) [per airspace volume]
	KPI07	En-route ATFM delay	ATFM delay attributed to flow restrictions in a given en-route airspace volume [avg. per airspace volume]
Descent & terminal area arrival	**KPI08**	Additional time in terminal airspace	Actual terminal airspace transit time compared to an unimpeded time [avg. per airport or per cluster of airports]
Landing (ON)	**KPI09**	Airport peak arrival capacity	The highest number of landings an airport can accept in a one-hour time frame (also called declared arrival capacity, or airport acceptance rate) [per airport]
	KPI10	Airport peak arrival throughput	The 95th percentile of the hourly number of landings recorded at an airport, in the “rolling” hours sorted from the least busy to the busiest hour [per airport]
	KPI11	Airport arrival capacity utilization	Airport arrival throughput (accommodated demand) compared to arrival capacity or demand, whichever is lower [per airport]
	KPI12	Airport/Terminal ATFM delay	ATFM delay attributed to arrival flow restrictions at a given airport and/or associated terminal airspace volume [avg. per airport or per cluster of airports]
Taxi-in	**KPI13**	Taxi-in additional time	Actual taxi-in time compared to unimpeded taxi-in time [avg. per airport or per cluster of airports]
In-blocks (IN)	**KPI14**	Arrival punctuality	Percentage of flights arriving at the gate on-time (compared to schedule) [avg. per traffic flow, per airport or per cluster of airports]

Per flight phase or gate-to-gate	**KPI15**	Flight time variability	Distribution of the flight (phase) duration around the average value [avg. per airport or per traffic flow]
	KPI16	Additional fuel burn	Additional flight time/distance converted to estimated additional fuel burn attributable to ATM [avg. per flight, airport or per airspace volume]

Detailed descriptions of potential key performance indicators

KPI ID	**KPI01**
KPI Name	**Departure punctuality**
Definition	Percentage of flights departing from the gate on-time (compared to schedule)
Measurement Units	% of scheduled flights
Variants	Variant 1 – departure punctuality within 5 minutes of scheduled departure time Variant 2 – departure punctuality within 15 minutes of scheduled departure time
Operations measured	Departures of scheduled flights
Object(s) characterized	The KPI is typically computed for individual airports, or clusters of airports (selection/grouping based on size and/or geography)
Utility of the KPI	This is an airspace user and passenger focused KPI: departure punctuality gives an overall indication of the service quality experienced by passengers, and the ability of the airlines to execute their schedule at a given departure location.
Parameters	On-time threshold (maximum positive or negative deviation from scheduled departure time) which defines whether a flight is counted as on-time or not. Recommended values: 5 minutes and 15 minutes.
Data requirement	For each departing scheduled flight: - Scheduled departure time (STD) - Actual off-block time (AOBT)
Data feed providers	Schedule database(s), airports, airlines and/or ANSPs
Formula / algorithm	At the level of individual flights: 1. Exclude non-scheduled departures 2. Categorize each scheduled departure as on-time or not At aggregated level: 3. Compute the KPI: number of on-time departures divided by total number of scheduled departures
References & examples of use	Comparison of ATM-Related Operational Performance: U.S./Europe (June 2014)

KPI ID	KPI02
KPI Name	**Taxi-out additional time**
Definition	Actual taxi-out time compared to an unimpeded/reference taxi-out time
Measurement Units	Minutes/flight
Variants	Variant 1 – basic (computed without departure gate and runway data) Variant 2 – advanced (computed with departure gate and runway data)
Operations measured	The duration of the taxi-out phase of departing flights
Object(s) characterized	The KPI is typically computed for individual airports, or clusters of airports (selection/grouping based on size and/or geography)
Utility of the KPI	This KPI is intended to give an indication of the efficiency of the departure phase operations on the surface of an aerodrome. This may include the average queuing that is taking place in front of the departure runways, non-optimal taxi routing and intermediate aircraft stops during taxi-out. The KPI is also typically used to estimate excess taxi-out fuel consumption and associated emissions (for the Environment KPA). The KPI is designed to filter out the effect of physical airport layout while focusing on the responsibility of ATM to optimize the outbound traffic flow from gate to take-off.
Parameters	Unimpeded/reference taxi-out time: - Recommended approach for the basic variant of the KPI: a single value at airport level, e.g. the 20th percentile of actual taxi times recorded at an airport, sorted from the shortest to the longest - Recommended approach for the advanced variant of the KPI: a separate value for each gate/runway combination, e.g. the average actual taxi-out time recorded during periods of non-congestion (needs to be periodically reassessed)
Data requirement	For each departing flight: - Actual off-block time (AOBT) - Actual take-off time (ATOT) In addition for the advanced KPI variant: - Departure gate ID - Take-off runway ID
Data feed providers	Airports (airport operations, A-CDM), airlines (OOOI data), ADS-B data providers and/or ANSPs
Formula / algorithm	At the level of individual flights: 1. Select departing flights, exclude helicopters 2. Compute actual taxi-out duration: ATOT minus AOBT 3. Compute additional taxi-out time: actual taxi-out duration minus unimpeded taxi-out time At aggregated level: 4. Compute the KPI: sum of additional taxi-out times divided by number of IFR departures
References & examples of use	Comparison of ATM-Related Operational Performance: U.S./Europe (June 2014) PRC Performance Review Report (EUROCONTROL 2015) Single European Sky Performance Scheme CANSO Recommended KPIs for Measuring ANSP Operational Performance (2015)

KPI ID	KPI03
KPI Name	**ATFM slot adherence**
Definition	Percentage of flights taking off within their assigned ATFM slot (Calculated Take-Off Time Compliance)
Measurement Units	% of flights subject to flow restrictions
Variants	None
Operations measured	The take-off of IFR flights subject to flow restrictions
Object(s) characterized	The KPI is typically computed for individual airports, or clusters of airports (selection/grouping based on size and/or geography)
Utility of the KPI	This KPI gives an indication of the capability of an airport to contribute to ATFM effectiveness by delivering outbound traffic in a predictable manner to the departure runway, in compliance with assigned ATFM slots.
Parameters	Size of the ATFM slot: the period between 5 minutes before and 10 minutes after the CTOT.
Data requirement	For each departing IFR flight subject to an ATFM regulation: - Calculated Take-Off Time (CTOT) - Actual take-off time (ATOT)
Data feed providers	Airports, ATFM service
Formula / algorithm	At the level of individual flights: 1. Exclude flights not subject to an ATFM regulation 2. Categorize each departing flight as compliant with its ATFM slot or not At aggregated level: 3. Compute the KPI: number of compliant departures divided by total number of departing flights subject to an ATFM regulation
References & examples of use	Single European Sky Performance Scheme CANSO Recommended KPIs for Measuring ANSP Operational Performance (2015)

KPI ID	KPI04
KPI Name	**Filed flight plan en-route extension**
Definition	Flight planned en-route distance compared to a reference ideal distance
Measurement Units	% excess distance
Variants	Variant 1, using a 40 NM cylinder around the departure and destination airport as the start/end of en-route airspace Variant 2, using a 40 NM cylinder around the departure airport and a 100 NM cylinder around the destination airport as the start/end of en-route airspace
Operations measured	The planned en-route distance, as selected during the preparation of flight plans
Object(s) characterized	The KPI can be computed for any volume of en-route airspace; this implies that it can be computed at State level (covering the FIRs of a State)
Utility of the KPI	This KPI measures the en-route horizontal flight (in)efficiency contained in a set of filed flight plans crossing an airspace volume. Its value is influenced by route network design, route & airspace availability, airspace user choice (e.g. to ensure safety, to minimize cost and to take into account wind and weather) and airspace user constraints (e.g. overflight permits, aircraft limitations). A significant gap between this KPI and the Actual en-Route Extension KPI indicates that many flights are not flown along the planned route, which should trigger an analysis of why this is happening.
Parameters	A '*Measured area'* is defined for which the KPI is computed. For example a State. A '*Reference area*' is defined as a (sub)regional boundary considered, containing all '*Measured areas'*, for example States within the same ICAO Region. Departure terminal area proxy: a cylinder with 40 NM radius around the departure airport. Destination terminal area proxy: a cylinder with 40 NM radius around the destination airport (variant 1). For variant 2 the radius is 100 NM.
Data requirement	For each flight plan: - Departure airport (Point A) - Destination airport (Point B) - Entry point in the '*Reference area'* (Point O) - Exit point from the '*Reference area'* (Point D) - Entry points in the '*Measured areas'* (Points N) - Exit points from the '*Measured areas'* (Points X) - Planned distance for each NX portion of the flight
Data feed providers	ANSPs
Formula / algorithm	For the horizontal trajectory of each flight, different parts (trajectory portions) are considered (see Figure 1 for the example of a flight departing outside the '*Reference Area*' and overflying a measured State; Figure 2 for the example of a domestic flight within a measured State): 1) The part of the flight which is within the reference area (segment OD). If airports A and/or B are located within the reference area, the points O and/or D are placed on the airport reference point (ARP). 2) The part of the flight for which the State level indicator is computed (between points N and X). If points A and/or B (the airports) are located within the measured State, the points N and/or X are placed on the 40 NM circle (variant 1) around the airport reference point as shown in Figure 2, to exclude terminal route efficiency from the indicator.

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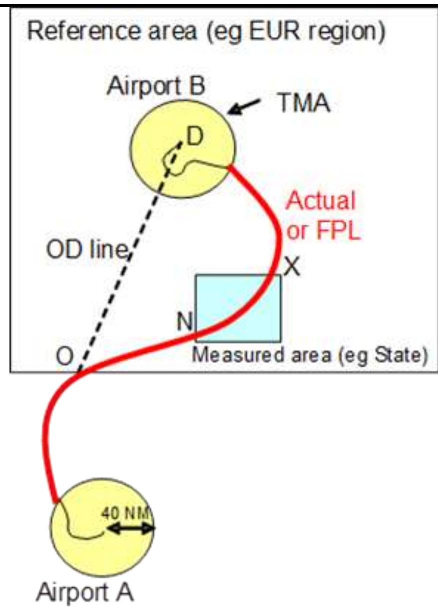

Figure 1 - Significant points and trajectory segments (example 1)
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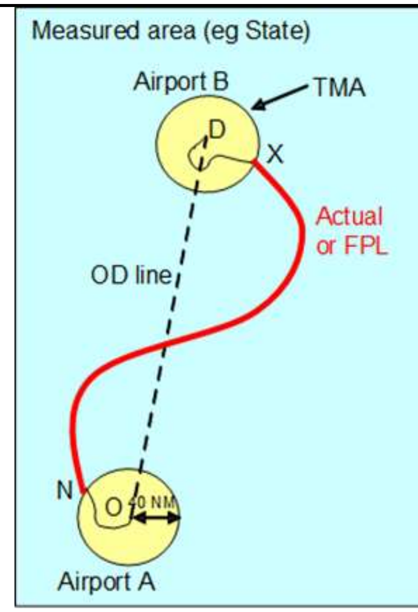

Figure 2 - Significant points and trajectory segments (example 2)
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Between points N and X, three quantities can be computed: the planned distance (length of flight plan trajectory), the local direct distance (great circle distance between N and X, not required for this indicator), and the contribution of the trajectory between N and X to the completion of the great circle distance between O and D. This contribution is called the “achieved distance”. The formula for computing this is based on four great circle distances interconnecting the points O, N, X and D: achieved distance = [(OX-ON)+(DN-DX)]/2.

When a given flight traverses multiple States, the sum of the planned distance in each State equals the total planned distance from O to D. Likewise the sum of all achieved distances equals the direct distance from O to D.
The extra distance for a portion NX of a given flight is the difference between the actual/flight planned distance and the achieved distance. The total extra distance observed within a measured area (e.g. a State) over a given time period is the sum of the planned distances across all traversing flights, minus the sum of the achieved distances across all traversing flights.

The KPI is computed as the total extra distance divided by total achieved distance, expressed as a percentage.
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<td>References & examples of use</td>
<td>ICAO EUR Doc 030 EUR Region Performance Framework Document (July 2013)
Comparison of ATM-Related Operational Performance: U.S./Europe (June 2014)
PRC Performance Review Report (EUROCONTROL 2015)
Single European Sky Performance Scheme
CANSO Recommended KPIs for Measuring ANSP Operational Performance (2015)</td>
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KPI ID	**KPI05**
KPI Name	**Actual en-route extension**
Definition	Actual en-route distance flown compared to a reference ideal distance
Measurement Units	% excess distance
Variants	Variant 1, using a 40 NM cylinder around the departure and destination airport as the start/end of en-route airspace Variant 2, using a 40 NM cylinder around the departure airport and a 100 NM cylinder around the destination airport as the start/end of en-route airspace
Operations measured	The actual distance flown by flights in en-route airspace
Object(s) characterized	The KPI can be computed for a traffic flow or a volume of en-route airspace; this implies that it can be computed at State level (covering the FIRs of a State)
Utility of the KPI	This KPI measures the en-route horizontal flight (in)efficiency as actually flown, of a set of IFR flights crossing an airspace volume. Its value is influenced by route network design, route & airspace availability, airspace user choice (e.g. to ensure safety, to minimize cost and to take into account wind and weather) and airspace user constraints (e.g. overflight permits, aircraft limitations), and tactical ATC interventions modifying the trajectory (e.g. reroutings and 'direct to' clearances). The KPI is also typically used to estimate the excess fuel consumption and associated emissions (for the Environment KPA) attributed to horizontal flight inefficiency.
Parameters	Identical to the parameters of the 'Filed Flight Plan en-Route Extension' KPI.
Data requirement	For each actual flight trajectory: - Departure airport (Point A) - Destination airport (Point B) - Entry point in the 'Reference Area' (Point O) - Exit point from the 'Reference Area' (Point D) - Entry points in the 'Measured Areas' (Points N) - Exit points from the 'Measured Areas' (Point X) - Distance flown for each NX portion of the actual flight trajectory, derived from surveillance data (radar, ADS-B…).
Data feed providers	ANSPs, ADS-B data providers
Formula / algorithm	Identical to the formula/algorithm of the 'Filed Flight Plan en-Route Extension' KPI.
References & examples of use	ICAO EUR Doc 030 EUR Region Performance Framework Document (July 2013) Comparison of ATM-Related Operational Performance: U.S./Europe (June 2014) PRC Performance Review Report (EUROCONTROL 2015) Single European Sky Performance Scheme CANSO Recommended KPIs for Measuring ANSP Operational Performance (2015)

KPI ID	KPI06
KPI Name	**En-route airspace capacity**
Definition	The maximum number of movements an airspace volume will accept under normal conditions in a given time period (also called declared capacity)
Measurement Units	Movements/hr
Variants	None
Operations measured	The nominal capability of an ANSP to deliver ATM services to IFR traffic in a given volume of en-route airspace.
Object(s) characterized	The KPI is typically used at the level of individual sectors (sector capacity) or en-route facilities (ACC capacity)
Utility of the KPI	The KPI measures an upper bound on the allowable throughput of an en-route facility or sector. Declared capacities are used in real time traffic flow management as well as for measuring and monitoring service delivery and efficiency. Some ANSPs may prefer not to declare capacities, and only have these capacities declared daily based on known/current operational factors. Declaring capacities provides an important reference for understanding the total system performance under normal operating conditions and provides a basis to work from when determining the impact of operational factors limiting capacity.
Parameters	None
Data requirement	Declared capacities are determined by the ANSP, and are dependent on traffic pattern and sector configuration. Some ANSPs determine the capacity at facility level using a simulation tool: a given traffic pattern is iteratively grown, until the annual ATFM delay per flight reaches a predetermined maximum acceptable value. The throughput at which this occurs is the airspace capacity.
Data feed providers	ANSPs
Formula / algorithm	At the level of an individual en-route facility: 1. Select highest value from the set of declared capacities (the maximum configuration capacity) 2. Compute the KPI: convert the value to an hourly movement rate, if the declaration is at smaller time intervals
References & examples of use	CANSO Recommended KPIs for Measuring ANSP Operational Performance (2015)

KPI ID	**KPI07**
KPI Name	**En-route ATFM delay**
Definition	ATFM delay attributed to flow restrictions in a given en-route airspace volume
Measurement Units	Minutes/flight
Variants	None
Operations measured	The management of (temporary) capacity shortfalls in en-route airspace due to high demand and/or capacity reductions for a variety of reasons, resulting in the allocation of ATFM delay
Object(s) characterized	The KPI can be computed for any volume of en-route airspace which participates in the ATFM process
Utility of the KPI	This KPI is a time aggregation of the ATFM delay generated by flow restrictions which are established to protect a given volume of en-route airspace against demand/capacity imbalances. These flow restrictions (also called ATFM regulations) normally have a delay cause associated with them. This allows the KPI to be disaggregated by cause, which allows better diagnosis of the reasons for demand/capacity imbalances. Typically, the KPI is used to check whether ANSPs provide the capacity needed to cope with demand.
Parameters	None
Data requirement	For each IFR flight: - Estimated Take-off Time (ETOT) computed from the last filed flight plan - Calculated Take-off Time (CTOT) - ID of the flow restriction generating the ATFM delay - Airspace volume associated with the flow restriction - Delay code associated with the flow restriction
Data feed providers	ATFM
Formula / algorithm	At the level of individual flights: 1. Select the flights crossing the volume of en-route airspace 2. Select the subset of flights which are affected by the flow restrictions in this airspace 3. Compute ATFM delay: CTOT minus ETOT At aggregated level: 4. Compute the KPI: sum of ATFM delays divided by number of IFR flights crossing the airspace
References & examples of use	ICAO EUR Doc 030 EUR Region Performance Framework Document (July 2013) Comparison of ATM-Related Operational Performance: U.S./Europe (June 2014) PRC Performance Review Report (EUROCONTROL 2015) Single European Sky Performance Scheme CANSO Recommended KPIs for Measuring ANSP Operational Performance (2015)

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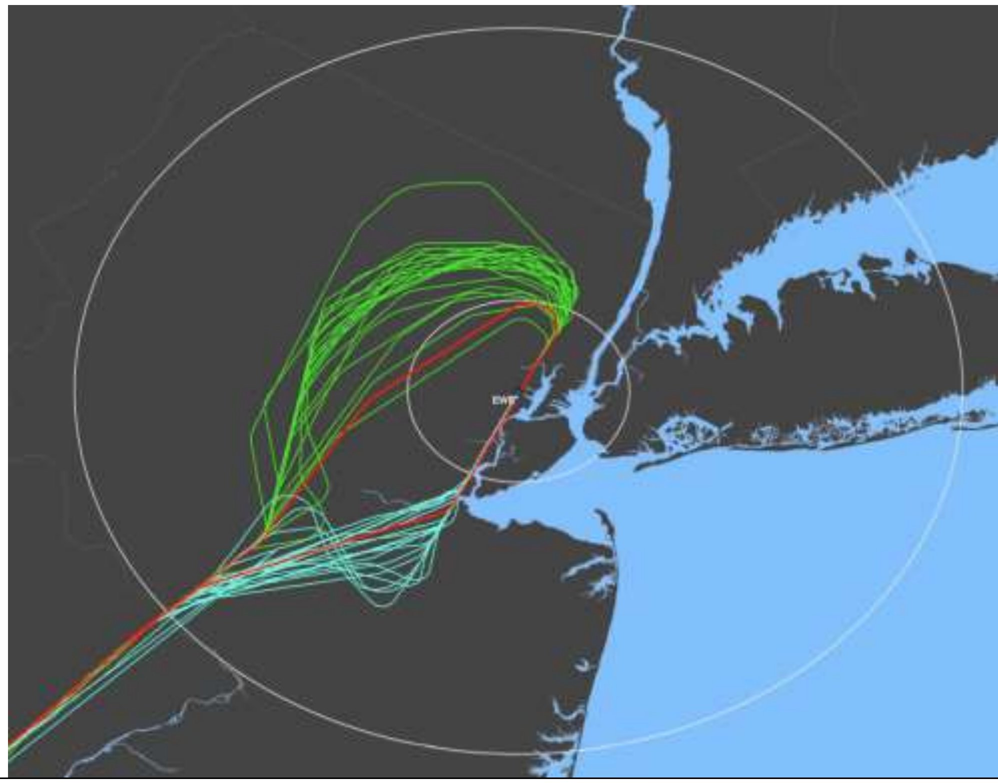
<tr><th>KPI ID</th><th>KPI08</th></tr>
<tr><th>KPI Name</th><th>Additional time in terminal airspace</th></tr>
<tr><td>Definition</td><td>Actual terminal airspace transit time compared to an unimpeded time.

Actual trajectories are generally longer in time and distance due to path stretching and/or holding patterns. In the example below the unimpeded trajectories are shown in red, and the actual trajectories in green and blue.

</td></tr>
<tr><td>Measurement Units</td><td>Minutes/flight</td></tr>
<tr><td>Variants</td><td>Variants are possible depending on the chosen size of terminal airspace (40 NM or 100 NM cylinder) and the richness of the data feed: basic (without arrival runway ID) or advanced (with arrival runway ID)
Variants with 100 NM cylinder are useful if airports have holding patterns outside the 40 NM cylinder
The use of generic cylinders abstracts local specifics in terms of approach airspace design (e.g. TMA) and ensures comparability across different airports.
<table>
<tr><th></th><th>40 NM cylinder</th><th>100 NM cylinder</th></tr>
<tr><td>Advanced data feed</td><td>Variant A40</td><td>Variant A100</td></tr>
<tr><td>Basic data feed</td><td>Variant B40</td><td>Variant B100</td></tr>
</table></td></tr>
<tr><td>Operations measured</td><td>The terminal airspace transit time during the arrival flight phase</td></tr>
<tr><td>Object(s) characterized</td><td>The KPI is typically computed for individual airports, or clusters of airports (selection/grouping based on size and/or geography)</td></tr>
<tr><td>Utility of the KPI</td><td>This KPI is intended to give an indication of the average queuing that is taking place in terminal airspace. This queuing is the result of sequencing and metering. The KPI captures the extent to which arriving flights are subjected to speed reductions, path extensions and holding patterns to absorb the queuing time. The KPI is also typically used to estimate excess fuel consumption and associated emissions (for the Environment KPA) attributable to horizontal flight inefficiency in terminal airspace. The KPI is designed to filter out the</td></tr>
</table>

	operational variability of terminal airspace transit time (e.g. due to wind, aircraft speed and length of the approach procedure, such as the difference between a straight-in approach and a downwind arrival) while focusing on the responsibility of ATM to optimize the inbound traffic flow from terminal airspace entry to landing.
Parameters	Destination terminal area proxy (also called Arrival Sequencing and Metering Area – ASMA): a cylinder with 40 NM radius around the destination airport. For variants A100 and B100 the radius is 100 NM. For the advanced variants only: list of terminal airspace entry segments (used to group flights entering the cylinder from ± the same direction) Unimpeded terminal airspace transit time: – Recommended approach for the basic variants of the KPI: a single value at airport level = the 20th percentile of actual terminal airspace transit times recorded at an airport, sorted from the shortest to the longest – Recommended approach for the advanced variants of the KPI: a separate value for each entry segment/landing runway combination = the average terminal airspace transit time recorded during periods of non-congestion (needs to be periodically reassessed)
Data requirement	For each arriving flight: - Terminal airspace entry time, computed from surveillance data (radar, ADS-B…) - Actual landing time (ALDT) In addition for the advanced KPI variants: - Terminal airspace entry segment, computed from surveillance data (radar, ADS-B…) - Landing runway ID
Data feed providers	Airlines (OOOI data), airports, ADS-B data providers and/or ANSPs
Formula / algorithm	At the level of individual flights: 1. Select arrivals, exclude helicopters 2. Compute actual terminal airspace transit time: ALDT minus terminal airspace entry time 3. Compute additional terminal airspace transit time: actual terminal airspace transit time minus unimpeded terminal airspace transit time At aggregated level: 4. Compute the KPI: sum of additional terminal airspace transit times divided by number of IFR arrivals
References & examples of use	Comparison of ATM-Related Operational Performance: U.S./Europe (June 2014) PRC Performance Review Report (EUROCONTROL 2015) Single European Sky Performance Scheme CANSO Recommended KPIs for Measuring ANSP Operational Performance (2015)

KPI ID	KPI09
KPI Name	**Airport peak arrival capacity**
Definition	The highest number of landings an airport can accept in a one-hour time frame (also called declared arrival capacity, or airport acceptance rate)
Measurement Units	Number of landings / hour
Variants	None
Operations measured	The capacity declaration of an airport
Object(s) characterized	The KPI is computed for individual airports
Utility of the KPI	This KPI indicates the highest landing rate that an airport will accept, using the most favorable runway configuration under optimum operational conditions. The runways may or may not be the most constraining factor for airport capacity: at some airports the most constraining factor may be the terminal airspace, the taxiways, the number of gates, passenger handling capacity etc. The KPI is typically used for scheduling and ATFM purposes, and to develop capacity investment plans.
Parameters	None
Data requirement	Scheduling parameters for slot controlled airports Airport Acceptance Rates (AAR)
Data feed providers	Airports
Formula / algorithm	At the level of an individual airport: 1. Select highest value from the set of declared arrival capacities 2. Compute the KPI: convert the value to an hourly landing rate, if the declaration is at smaller time intervals
References & examples of use	Comparison of ATM-Related Operational Performance: U.S./Europe (June 2014) CANSO Recommended KPIs for Measuring ANSP Operational Performance (2015)

KPI ID	KPI10
KPI Name	**Airport peak arrival throughput**
Definition	The 95th percentile of the hourly number of landings recorded at an airport, in the "rolling" hours sorted from the least busy to the busiest hour
Measurement Units	Number of landings / hour
Variants	Variant 1: IFR arrivals only Variant 2: IFR + VFR arrivals (relevant for airports with a high percentage of VFR traffic)
Operations measured	The actual number of landings at an airport
Object(s) characterized	The KPI is computed for individual airports
Utility of the KPI	This KPI gives an indication of "busy-hour" landing rates at an airport, as recorded during a given time period. For congested airports, this throughput is an indication of the effectively realized capacity; for uncongested airports it is a measure of demand.
Parameters	Time interval for "rolling" hours. Recommended value: 15 minutes. The percentile chosen to exclude outliers. Recommended value: 95th percentile.
Data requirement	For each arriving flight: - Actual landing time (ALDT)
Data feed providers	Airports
Formula / algorithm	At the level of individual flights: 1. Select arrivals, exclude helicopters At the level of individual "rolling" hours: 2. Convert the set of landings to hourly landing rates by "rolling" hour 3. Sort the "rolling" hours from the least busy to the busiest hour 4. Compute the KPI: it equals the landing rate value of the 95th percentile of the "rolling" hours
References & examples of use	Comparison of ATM-Related Operational Performance: U.S./Europe (June 2014)

KPI ID	KPI11
KPI Name	**Airport arrival capacity utilization**
Definition	Airport arrival throughput (accommodated demand) compared to arrival capacity or demand, whichever is lower
Measurement Units	%
Variants	Variant 1: IFR arrivals only
Operations measured	The number of unaccommodated landings at an airport
Object(s) characterized	The KPI is computed for individual airports
Utility of the KPI	This KPI assesses how effectively arrival capacity is managed by the ANSP. It is a measure of accommodated demand, compared to the available capacity of the airport, irrespective of the delay incurred by arriving traffic. Seen in another way, it captures the “missed” arrival slots. At congested airports, the KPI relates the throughput to the declared capacity. At uncongested airports (or airports without declared capacity) the KPI relates the throughput to the unconstrained demand based on flight plans.
Parameters	Time interval at which to perform the most granular calculations. Recommended value: 15 minutes.
Data requirement	For each arriving flight: - Actual landing time (ALDT) - Estimated landing time (ELDT) (from flight plan) For each time interval: - Declared landing capacity of the airport
Data feed providers	Airports
Formula / algorithm	For each time interval: 1. Compute the throughput: count the number of actual landings based on ALDT 2. Compute the demand: count the number of estimated landings based on ELDT 3a. if demand >= capacity: utilization = throughput / capacity 3b. if demand < capacity: utilization = throughput / demand At aggregated level (longer time periods): 4. Compute the KPI: sum(utilization*demand) / sum(demand)
References & examples of use	CANSO Recommended KPIs for Measuring ANSP Operational Performance (2015)

KPI ID	**KPI12**
KPI Name	**Airport/Terminal ATFM delay**
Definition	ATFM delay attributed to arrival flow restrictions at a given airport and/or associated terminal airspace volume
Measurement Units	Minutes/flight
Variants	None
Operations measured	The management of (temporary) capacity shortfalls at and around destination airports due to high demand and/or capacity reductions for a variety of reasons, resulting in the allocation of ATFM delay
Object(s) characterized	The KPI is typically computed for individual airports, or clusters of airports (selection/grouping based on size and/or geography)
Utility of the KPI	This KPI is a time aggregation of the ATFM delay generated by flow restrictions which are established to protect a destination airport or its terminal area against demand/capacity imbalances. If a terminal area covers multiple airports, each individual flight delay is attributed to the corresponding destination airport. These flow restrictions (also called ATFM regulations) normally have a delay cause associated with them. This allows the KPI to be disaggregated by cause, which allows better diagnosis of the reasons for demand/capacity imbalances. Typically, the KPI is used as a proxy to check whether airports and ANSPs provide the capacity needed to cope with demand.
Parameters	None
Data requirement	For each IFR flight: - Estimated Take-off Time (ETOT) computed from the last filed flight plan - Calculated Take-off Time (CTOT) - ID of the flow restriction generating the ATFM delay - Airport or terminal airspace volume associated with the flow restriction - Delay code associated with the flow restriction
Data feed providers	ATFM
Formula / algorithm	At the level of individual flights: 1. Select the flights arriving at this airport 2. Select the subset of flights which are affected by the flow restrictions at this airport or its terminal airspace 3. Compute ATFM delay: CTOT minus ETOT At aggregated level: 4. Compute the KPI: sum of ATFM delays divided by number of arrivals at the airport
References & examples of use	ICAO EUR Doc 030 EUR Region Performance Framework Document (July 2013) PRC Performance Review Report (EUROCONTROL 2015) Single European Sky Performance Scheme CANSO Recommended KPIs for Measuring ANSP Operational Performance (2015)

KPI ID	KPI13
KPI Name	**Taxi-in additional time**
Definition	Actual taxi-in time compared to an unimpeded/reference taxi-in time
Measurement Units	Minutes/flight
Variants	Variant 1 – basic (computed without landing runway and arrival gate data) Variant 2 – advanced (computed with landing runway and arrival gate data)
Operations measured	The duration of the taxi-in phase of arriving flights
Object(s) characterized	The KPI is typically computed for individual airports, or clusters of airports (selection/grouping based on size and/or geography)
Utility of the KPI	This KPI is intended to give an indication of the various taxi-in inefficiencies that occur after landing. Its value may be influenced by unavailability of the arrival gate and effects such as non-optimal taxi routing and intermediate aircraft stops during taxi-in. The KPI is also typically used to estimate excess taxi-in fuel consumption and associated emissions (for the Environment KPA). The KPI is designed to filter out the effect of physical airport layout while focusing on the responsibility of the airport to provide parking space and ATM to optimize the inbound traffic flow from landing to in-blocks.
Parameters	Unimpeded/reference taxi-in time: − Recommended approach for the basic variant of the KPI: a single value at airport level, e.g. the 20th percentile of actual taxi times recorded at an airport, sorted from the shortest to the longest − Recommended approach for the advanced variant of the KPI: a separate value for each runway/gate combination, e.g. the average actual taxi-in time recorded during periods of non-congestion (needs to be periodically reassessed)
Data requirement	For each arriving flight: - Actual landing time (ALDT) - Actual in-block time (AIBT) In addition for the advanced KPI variant: - Landing runway ID - Arrival gate ID
Data feed providers	Airports (airport operations), airlines (OOOI data), ADS-B data providers and/or ANSPs
Formula / algorithm	At the level of individual flights: 1. Select arriving flights, exclude helicopters 2. Compute actual taxi-in duration: ALDT minus AIBT 3. Compute additional taxi-in time: actual taxi-in duration minus unimpeded taxi-in time At aggregated level: 4. Compute the KPI: sum of additional taxi-in times divided by number of IFR arrivals
References & examples of use	Comparison of ATM-Related Operational Performance: U.S./Europe (June 2014) PRC Performance Review Report (EUROCONTROL 2015) CANSO Recommended KPIs for Measuring ANSP Operational Performance (2015)

KPI ID	KPI14
KPI Name	**Arrival punctuality**
Definition	Percentage of flights arriving at the gate on-time (compared to schedule)
Measurement Units	% of scheduled flights
Variants	Variant 1 – arrival punctuality within 5 minutes of scheduled arrival time Variant 2 – arrival punctuality within 15 minutes of scheduled departure time
Operations measured	IFR arrivals of scheduled airlines
Object(s) characterized	The KPI is typically computed for traffic flows, individual airports, or clusters of airports (selection/grouping based on size and/or geography)
Utility of the KPI	This is an airspace user and passenger focused KPI: arrival punctuality gives an overall indication of the service quality experienced by passengers, and the ability of the airlines to execute their schedule at a given destination.
Parameters	On-time threshold (maximum positive or negative deviation from scheduled arrival time) which defines whether a flight is counted as on-time or not. Recommended values: 5 minutes and 15 minutes.
Data requirement	For each arriving scheduled flight: - Scheduled departure time (STA) - Actual in-block time (AIBT)
Data feed providers	Schedule database(s), airports, airlines and/or ANSPs
Formula / algorithm	At the level of individual flights: 1. Exclude non-scheduled arrivals 2. Categorize each scheduled arrival as on-time or not At aggregated level: 3. Compute the KPI: number of on-time arrivals divided by total number of scheduled arrivals
References & examples of use	Comparison of ATM-Related Operational Performance: U.S./Europe (June 2014)

KPI ID	KPI15
KPI Name	**Flight time variability**
Definition	Distribution of the flight (phase) duration around the average value
Measurement Units	Minutes/flight
Variants	Different parameter values possible (see ‘Parameters’)
Operations measured	scheduled flights with the same flight ID on a given airport-pair (flight XYZ123 from A to B): the gate-to-gate duration, and at more detailed level the duration of the individual flight phases (taxi-out, airborne, taxi-in)
Object(s) characterized	The KPI is typically computed for the scheduled traffic flows interconnecting a given cluster of airports (two or more; selection/grouping based on size and/or geography)
Utility of the KPI	The “variability” of operations determines the level of predictability for airspace users and hence has an impact on airline scheduling. It focuses on the variance (distribution widths) associated with the individual phases of flight as experienced by airspace users. The higher the variability, the wider the distribution of actual travel times and the more costly time buffer is required in airline schedules to maintain a satisfactory level of punctuality. In addition, reducing the variability of actual block times can potentially reduce the amount of excess fuel that needs to be carried for each flight in order to allow for uncertainties.
Parameters	Minimum monthly flight frequency filter: flights with a frequency less than 20 times per month are not included in the indicator. Outlier filter: Variant 1: Only 70% of the (remaining) flights are considered in the indicator, i.e. the 15^{th} percentile (percentile 1) is used to determine the shortest duration, the 85^{th} percentile (percentile 2) is used to determine the longest duration Variant 2: Only 60% of the (remaining) flights are considered in the indicator, i.e. the 20^{th} percentile (percentile 1) is used to determine the shortest duration, the 80^{th} percentile (percentile 2) is used to determine the longest duration
Data requirement	For each flight: OOOI data: gate “out” (AOBT), wheels “off,” wheels “on,” and gate “in” (AIBT) actual times
Data feed providers	Airlines
Formula / algorithm	At the level of flights with the same flight ID, at monthly or longer (e.g. annual) time aggregation level: 1. Exclude flight IDs not meeting the minimum monthly frequency requirement 2. Sort flights in ascending order of flight (phase) duration 3. Identify shortest (percentile 1) and longest (percentile 2) duration 4. Compute variability: (longest – shortest) / 2 At the more aggregated level: 5. Compute the KPI: weighted average of the individual flight ID variabilities
References & examples of use	Comparison of ATM-Related Operational Performance: U.S./Europe (June 2014) PRC Performance Review Report (EUROCONTROL 2015) CANSO Recommended KPIs for Measuring ANSP Operational Performance (2015)

KPI ID	**KPI16**
KPI Name	**Additional fuel burn**
Definition	Additional flight time/distance converted to estimated additional fuel burn attributable to ATM
Measurement Units	kg fuel/flight
Variants	None
Operations measured	Actual IFR flights
Object(s) characterized	This KPI is a conversion of the additional flight time/distance KPIs to a corresponding (estimated) additional fuel consumption; hence it describes a performance characteristic of the same objects as the additional flight time/distance KPIs: en-route airspace, terminal airspace and airports. Typically the KPI is published at the level of a State or (sub)region
Utility of the KPI	This KPI is designed to provide a simple method for estimating ATM-related fuel efficiency at aggregated level, without the need to model fuel burn at the level of individual flights. By adding the average additional fuel burn value of the individual flight phases, a gate-to-gate value is produced which is representative for an "average flight". The KPI is often further converted into additional CO_2 emission (for the environment KPA) and/or the monetary value of fuel savings (for the cost effectiveness KPA). The KPI is sometimes called the "benefit pool": it gives an indication of the ATM-induced flight inefficiency that is theoretically actionable by ATM. Two remarks need to be made here: 1. In practice the actionable "benefit pool" is smaller: real optimum performance is achieved at a residual non-zero value of the KPI. 2. Certain ATM-related inefficiencies are not covered by this KPI. For example ATM can deliver additional fuel burn benefits by removing vertical flight efficiency constraints.
Parameters	Average fuel flow (kg/min) during taxi Average fuel flow (kg/min) during arrival in terminal airspace Average fuel flow (kg/km) in en-route airspace
Data requirement	Indicator values to be converted to estimated additional fuel burn: KPI02 Taxi-Out Additional Time (min/flight) KPI13 Taxi-In Additional Time (min/flight) KPI05 Actual en-Route Extension (%) & average en-route distance flown (km/flight) KPI08 Additional time in terminal airspace (min/flight)
Data feed providers	Performance analysts
Formula / algorithm	At aggregated level: Compute the KPI: (Taxi-Out Additional Time x Average fuel flow during taxi) + (Taxi-In Additional Time x Average fuel flow during taxi) + (Actual en-Route Extension (%) x average en-route distance flown x Average fuel flow in en-route airspace) + (Additional time in terminal airspace x Average fuel flow during arrival in terminal airspace)
References & examples of use	Comparison of ATM-Related Operational Performance: U.S./Europe (June 2014)