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Recommended Key Performance Indicators for Measuring ANSP Operational Performance

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Recommended Key Performance Indicators for Measuring ANSP Operational Performance

Introduction

The objective of this report is to provide a set of recommended key performance indicators (KPIs) for measuring air traffic management (ATM) operational performance. This will enable air navigation service providers (ANSPs) to identify areas for improvement and take action to improve performance as well as communicate to stakeholders how actions can affect the performance of the system. The KPIs will also help ANSPs measure the actual benefits of implementing various Aviation System Block Upgrade (ASBU) modules.

A data-driven performance management process is essential for managing complex systems such as those in ATM. In principle, the performance of every facet of ATM can be measured. This document synthesises current practice of CANSO Members into a core set of recommended key performance indicators that most directly address the elements of ATM over which ANSPs have the most influence.

Maximising efficiency includes both the efficient use of capacity and providing the most efficient flight tracks to the airspace users. The indicators in this document focus on capacity, flight efficiency and predictability measures. Cost and safety performance indicators are covered by other CANSO reports.

These KPIs are developed to provide meaningful measures of progress to other stakeholders such as operators, airports and the flying public. This document provides guidance on the main external dependencies that affect ATM performance which include weather, demand and airport capacity as well as information on the databases and tools necessary to develop the measures. Demonstrated application of these KPIs may be found in the references listed at the end of the report.

This document is a publication of the Civil Air Navigation Services Organisation (CANSO), and was developed by the Operational Performance Workgroup (OPWG) of the CANSO Operational Standing Committee (OSC). The document was created based on a thorough review of current practices of CANSO Members as well as the various literature and documents related to ATM performance and measurement.

Acknowledgements

CANSO would like to thank ATNS and FAA for their leadership in producing the CANSO *Recommended Key Performance Indicators for Measuring ANSP Operational Performance*.

We also acknowledge the valuable input provided by Airways New Zealand, Airservices Australia, DECEA, Dubai Air Navigation Services, ENAV, NATS, ATAC and Boeing and the many other contributing CANSO Members.

Executive Summary

This report specifies 21 operational KPIs that allows ANSPs to track targeted areas of their systems.

CANSO recommends that ANSPs select those measures and KPIs that are most appropriate for their level of maturity and the resources they can devote to managing and tracking the selected KPIs. This means in practice that most ANSPs will not implement all the measures. But it is not necessary to track all KPIs to be effective. Therefore, this report recommends that ANSPs limit the use of KPIs to those that provide the best indication of what an ANSP can influence as well as the best indication of how flight efficiency can be improved for the operators.

In examining current practice, this report therefore recommends that ANSPs focus on assessing two primary goals: first, managing demand and capacity to maximise the use of available capacity; and second, providing the most efficient trajectories possible while meeting safety and capacity utilisation objectives.

The CANSO recommended KPIs for assessing these goals include measures for capacity and capacity utilisation, as well as flight efficiency. It is also recommended that the ANSP develop a KPI that identifies if ineffieincy is attributable to the ANSP. Recommended KPIs include:

Capacity utilisation KPI measures assess the core operational efficiency ANSP goal of ensuring that resources, such as available airport capacity, are optimised within the given conditions of the system (i.e. weather, airport maintenance etc.)

Flight trajectory efficiency KPI compares actual trajectories against a reference ideal trajectory.

ANSP attributable delay KPI records the causal reasons for a delay and allows the ANSP to assess its influence in mitigating the delay and improving efficiency.

This report is organised as follows:

Section 1

Provides background on the impetus and necessity to collect, measure, and monitor performance; highlights the objective to recommend KPIs that can be used across key performance areas of capacity, flight efficiency, and predictability; and to limit KPIs to those which an ANSP can exert influence.

Section 2

Provides an overview of current practice as given in relevant ICAO guidance documents on performance as well as actual practice among ANSPs. More details on ICAO guidance are provided in Appendix 2.

Section 3

Provides an overview of customer expectations for performance measures. These expectations often influence the priority managers and regulators place on key performance areas and key performance indicators.

Section 4

Addresses the role of system interdependencies. Interdependencies play a critical role in determining which indicators can effectively be calculated and used to drive management decisions. An understanding of these interdependencies is essential for an ANSP to communicate both its ability and its limitations in improving the overall ATM system performance.

Section 5

Provides a comprehensive description of KPIs that may be used by aviation stakeholders to assess performance for investment decisions. The section provides a summary of the tools and databases required to compute the KPIs.

Section 6

Provides a focused set of recommended KPIs that address the key performance issues for ATM. These include measuring the ANSP's ability to manage most effectively demand/capacity imbalances while providing the most efficient flight trajectories possible. International focus on these measures will meet the CANSO goal in promoting global harmonisation of KPIs.

1 Background

CANSO's objective is to transform air traffic management performance globally. The management process of setting goals and measuring improvement using a data-driven process is described in International Civil Aviation Organization's (ICAO) *Manual on Global Performance of the Air Navigation System* [1]. Furthermore, the technology acquisition process as well as any activity involving funding, is often built on a business case that identifies the performance improvements gained through the investment. Therefore, the ability to collect, measure, and monitor performance is a key requirement for this industry.

Current practice at the air navigation service provider (ANSP) level is mostly determined through local customers and stakeholders for the specific ANSP. The main objective of this CANSO report is to provide a set of recommended key performance indicators (KPIs) for measuring ATM operational performance which will improve the alignment of global ATM performance measurement. These KPIs were developed through a review of current CANSO Member practice, as well as by studying relevant available literature on ATM operational performance. These KPIs should also help an ANSP measure the actual benefits of implementing various Aviation System Block Upgrade (ASBU) modules.

The report recommends a full complement of KPIs that may be used across the spectrum of key performance areas (KPAs) of capacity, flight efficiency and predictability with environmental measures strongly linked to flight efficiency. These will be often referred to in this document as the operational performance measures. Other major KPAs such as cost and safety are covered by other CANSO reports.

Safety is rightly the number one priority of air navigation service providers. For this reason, a large share of the KPIs and activities that support this over-arching goal are related to safety. Many ANSPs are also required to track the cost of their service. CANSO reports productivity and cost-effectiveness measures as part of the annual *CANSO Global Air Navigation Services Performance Report* [2]. In addition to the primary safety measures and cost, ANSPs will regularly track a series of ATM operational performance measures that address capacity and flight efficiency while complementing the overall safety mission. These measures identify areas for prioritising improvements that enhance efficiency and reduce cost for both the ANSPs and other stakeholders, such as airlines.

From current practice it can be seen that many ANSPs collect data and measure performance in many similar areas. However, the specific KPI definitions will vary based on a number of factors including data availability. Also, the complexity of the airspace system and the number of stakeholders involved can lead to a proliferation of measures. Potentially, every phase of flight can be evaluated against a benchmark of ideal performance. The performance effects of every investment activity from training to system maintenance can in theory be measured.

An ANSP using a performance-based approach will prioritise and limit the number of KPIs to those that best improve management decisions. Although there are many stakeholders operating in the system, primary KPIs will tend to measure activities over which an ANSP can exert influence. For example, an ANSP cannot directly control weather, airport infrastructure and in many cases the demand schedules of the operators.

However, an ANSP can influence how effectively airport capacity is utilised given weather and demand.

Most ANSPs maintain a small set of indicators for overall management purposes that are practical and provide clear focus to their priorities and decision-making. These measures tend to fall under the capacity and efficiency KPAs as defined by ICAO and seek to limit effects outside the control of the ANSP. These effects are referred to as system interdependencies and are described in later sections of the report.

In addition to these primary indicators, there are many other measures that have been studied and in some cases used more formally by ANSPs. These fall under other ICAO KPAs such as predictability. There are also refinements to efficiency measures that focus on a particular phase of flight. These efficiency KPIs report improvements in time, track distance or fuel savings that can often be monetised. Measures that can be monetised play a critical role in the investment/technology acquisition process of an ANSP. In preparing this report, CANSO assessed three types of operational measures found among ANSPs today. These include:

1. **Measures regularly reported and tracked by an ANSP as part of the Performance-Based Approach (PBA):** These measures are currently found in service charters or are specified in national legislation. They include measures that are either in practice or in a trial mode to be formally implemented by a certain date. Measures in European legislation scheduled to take effect in Reference Period 2 fall into this category [3].

2. **Measures utilised as part of investment analysis:** These are measures that are not part of formal service charters but are found in existing analysis that supports investment decisions. These measures are often monetised and show efficiency improvements by phase of flight.

3. **ICAO KPIs not part of (1) or (2) above:** Literature on performance measures for aviation is extensive. However many measures have proven elusive to implement due to lack of data, or due to difficulty in separating the independencies so as to make a meaningful metric. Many of these measures fall into operational KPAs outside the more widely used efficiency or capacity KPAs. For these areas that are studied but not widely seen in practice, CANSO focused its review and recommendations on demonstrated indicators that have a proven implementation use to ANSPs.

2

Overview of ANSP Current Practice and ICAO Guidance

Current practice on key performance indicators can be found in guidance from the International Civil Aviation Organization (ICAO), ANSP service charters, national legislation affecting CANSO Members, and from cost-benefit studies used to support aviation investment. The latter cases reflect demonstrated application of measures by the ANSP and many are reflected in ICAO guidance.

2.1 ANSP Service Charters and Regulatory Governance

This CANSO best practice document will focus on the KPAs most relevant to ANSP influence. Safety and cost, although heavily influenced by ANSPs, are not directly addressed as they are covered by other CANSO guidance material [2][4]. Principal KPAs addressed include capacity and efficiency, with environment and predictability closely related to efficiency.

A review of current practice within ANSPs and national regulating authorities show that most organisations attempt to keep to the ICAO framework when monitoring performance. However, not all KPAs have useful KPIs that provide stakeholders with unique information distinct from other KPIs. The following sources provide some of the additional information on KPAs and KPIs, which are used by ANSPs globally:

- ICAO Document 9883 [1]
- Services Charter (Air Services Australia) 2011-12 [5]
- European Union Regulation (EU) No 390/2013 [3]
- EUR Region Performance Framework (EUR Doc 030) [6]
- UK NATS Fuel Efficiency Metric (3Di) [7]
- Performance Review Report: An Assessment of ATM in EUROPE during the Calendar Year 2012 [8]
- The PRC's European Performance measurement system 1999 (released June 2011) [9]
- U.S./EUROPE comparison of ATM Related Operational Performance 2013 [10]

ANSPs predominantly use indicators that monitor performance as dictated by the needs of their internal and/or external (regional) stakeholders' requirements. The KPIs used are those that measure KPAs within the influence of the ANSP, for example, maintaining adequate staffing that allows all operational sectors to be open as well as maintaining levels of equipment serviceability and availability. These are largely in control of the ANSP. It is important to note that some ANSPs are currently held responsible for capacity restrictions created by external factors to the ANSP, such as the impact of weather on delay and on-time performance. A more detailed discussion on these interdependencies is provided in Section 4 of this document. Current practice reveals many commonalities in the way ANSPs measure performance. This review also demonstrates the value in promoting alignment in order for CANSO to drive improvement in ATM performance globally.

2.2 ICAO Performance Indicators and Global Plan

ICAO has identified 11 key performance areas in the ATM system suitable for monitoring performance. These are described in ICAO's *Global Air Traffic Management Operational Concept Report* (Doc 9854) [11] and *Manual on Global Performance of the Air Navigation System* (Doc 9883) [1], which contains a high level description of the goals of the Performance-Based Approach (PBA) on management. Doc 9883 also describes the foundational requirements for measuring performance and a list of key performance indicators (KPIs) that may be considered for tracking operational performance. A summary of ICAO's KPAs and KPIs may be found in Table 3 of Appendix 2. They include measures that monitor implementation as well as track changes in system performance.

Following the 12th Air Navigation Conference (ANC/12), ICAO produced the *Global Air Navigation Plan 2013-2018, Fourth Edition (Doc 9750) (GANP)* [12]. This document specifies air navigation technology improvements as a series of 'Aviation System Block Upgrades' (ASBUs). ASBU is a programmatic and flexible global system engineering approach that allows all Member States to advance their air navigation capabilities based on their specific operational requirements. ICAO's goal is for all Member States to align their future aviation system developments against the GANP to achieve a seamless sky and global harmonisation.

The concept of improving capacity in absolute terms or improving the use of existing capacity (capacity utilisation) is discussed within the relevant modules. These 'capacity' indicators will be listed under capacity, efficiency or cost KPAs, as improved capacity efficiency leads to reduced costs. The other major operational performance KPA is efficiency, which likewise reduces cost, improves the environment, and may lead to increased throughput and capacity. Table 4 in Appendix 2 shows the KPAs identified for ASBU Block 0. The majority of the KPAs are related to cost, safety, capacity and efficiency. Many of the other KPAs such as environment, flexibility and predictability are related to capacity and efficiency as these measures move directly and as a consequence of capacity and efficiency improvements.

Although GANP does not provide specific performance indicator definitions for the KPAs, ICAO has developed a performance reporting framework, which does provide defined KPIs. Member States, through their Planning and Implementation Regional Groups (PIRGS), are expected to report implementation and performance information using the Air Navigation Report Form (ANRF). The ANRF also simplifies the reporting from the key performance areas shown in Table 4 of Appendix 2 to five priority KPAs: access and equity; capacity; efficiency; environment; and safety.

ICAO is focused on the implementation of ASBU Block 0 modules and created an ANRF for each module. There are 18 ASBU Block 0 modules and an example form using the Block Upgrade for Improved Flexibility and Efficiency in Descent Profiles or Continuous Decent Operation (CDO) can be found in Figure 11 of Appendix 2.

3

Stakeholder Expectations

A harmonised performance-based air navigation system as promoted by ICAO and CANSO has emanated from the requirement for sound and responsible industry performance (service delivery) aimed at supporting airline operational efficiency. In describing stakeholder expectations, most ANSP reports refer to the key performance areas that are provided in Doc 9883. The idea is that stakeholder expectations could be quantified in terms of performance measures. This document focuses on capacity, efficiency and predictability with environment strongly linked to efficiency.

Stakeholder expectations are interrelated. Often an improvement to a capacity expectation will have a corresponding improvement to the others. However, maximising available capacity by maximising achievable throughput may be in conflict with other stakeholder expectations such as predictability (which is sometimes called airline network reliability). Simply put, a system can be made more predictable by only allowing airline schedules that are compatible with the lower limits of what a facility can achieve. However, this comes at a cost of unused capacity during more favourable operating periods.

Periodic reviews and performance monitoring allow ANSPs to account for performance gaps within ATM service delivery and to identify areas of improvement in the total ATM system in a harmonised manner. Performance monitoring and continuous improvement require appropriate KPIs and data collection capabilities in all segments of the 'Efficient Flight'. Common KPIs and data collection should be similarly used throughout the industry. Figure 1 illustrates the five phases for a nominal flight. While each phase may be measured against an ideal benchmark, this ideal may represent a single flight that may not be feasible in the full network system. However, the total ATM system's operational performance may be measured against this ideal in order to identify areas of potential improvement and collaboration among stakeholders within the ATM system.

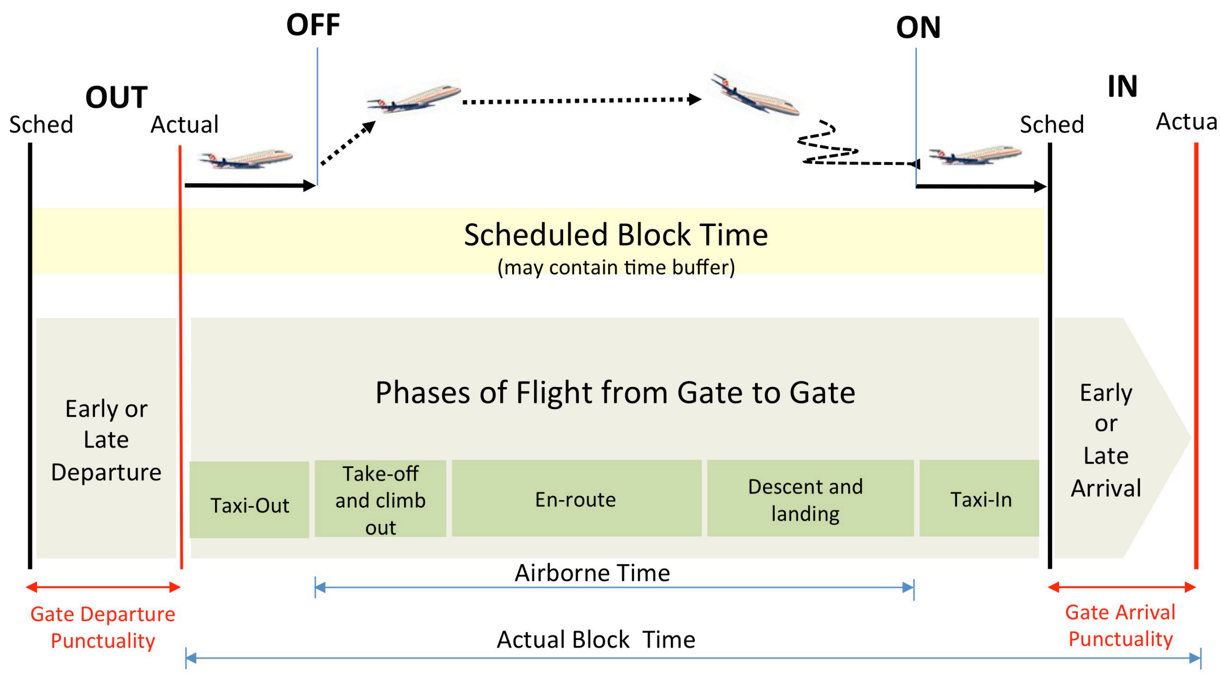


Figure 1 - Conceptual framework to measuring ATM related service quality

The quantitative differences between actual flight operations and ideal flight operations are often described as 'benefit pools' which describe a theoretical potential of what can be achieved. However, these theoretical pools do not consider the necessary structure required to maintain safety, avoid Special Use Airspace or respond to adverse weather. These interdependencies are described further in Section 4.

The difference between the actual flight and the efficient flight is an efficiency gap, which needs to be addressed within the scope of the total ATM system. The intent is not to assign cause to a particular component, as most solutions require a broader system level approach. Rather the purpose is to identify the component of the system that offers the potential to improve flight efficiency as well as the group responsible for implementing improvements, while acting within the overall collaborative decision-making (CDM) process. The CDM process allows stakeholders to prioritise flights based on all factors that address the system rather than the single flight perspective. This consideration of the overall process is essential as system interdependencies may limit single flight perspective efficiency gains or have adverse unintended consequences.

For airlines, an ideal flight would be the flight that minimises the cost of the overall operation. This may involve a trade-off (often called the cost index) in trajectories that minimise time or fuel [13]. ANSP performance databases will not typically have the data that can directly assess the degree a service minimises this cost. For this reason, other indicators such as flight time, flight distance, time in level flight during descent and overall block time are often tracked as surrogates for time and fuel elements of an airline's cost index. Several ANSPs are now tracking these values by key city pair.

There are various phases of flight, as indicated in Figure 1, that describe gate-to-gate total ATM efficiency. For these different phases of flight, there are various elements that impact efficiency. In separating phases of flights, ANSPs have used 'range rings' with radiuses such as 40 nautical miles and 100 nautical miles from the airport reference point to distinguish between terminal and en-route efficiency measures.

— Gate-out departure efficiency – mostly impacted by airport-based apron service capacity; as well as airline time and scheduling management; upstream flight delays; and traffic flow management initiatives.

— Taxi-out efficiency – impacted by airport-based apron service capacity; airline time and scheduling management; airport layout restrictions/limitations; gate pushback control policies; and air traffic control capacity.

— Take-off time efficiency – impacted mostly by airport layout restrictions/limitations; runway capacity; weather conditions; air traffic control and airline response to weather constraints; air traffic control capacity; as well as the interactive effects of arrival and departure traffic flow management initiatives.

— Departure terminal efficiency (from take-off to 40 NM ring around the airport) – impacted mostly by airspace design and restrictions that may be necessary for safe separation, weather conditions, and airspace capacity.

— En-route efficiency (from the departure airport 40 NM ring to 40 NM or 100 NM ring around the arrival airport) –

impacted mostly by weather conditions; airspace design and restrictions; airspace capacity; and air traffic control capacity.

- Arrival efficiency (from 100 NM ring to arrival runway) – impacted mostly by weather conditions; airport capacity; airspace design and restrictions; and air traffic flow control.

- Taxi-in efficiency – impacted by airport-based apron service capacity as well as airline time and scheduling management, airport layout restrictions/ limitations and air traffic control capacity.

The airborne phases of flight are all affected by the current airspace design as well as operating limitations due to factors such as special use airspace (SUA) or environmental noise restrictions.

Different phases of flight can impact other phases and it is possible that airborne inefficiencies can be traced back to gate or capacity limitations at the airport. Air traffic control influences most of the segments of the efficient flight. This is because air traffic control manages air traffic movements within the limitations provided by external factors/agencies. The influence of these external factors/agencies sometimes goes unnoticed, to a point that the only noticeable factor impacting ATM efficiency is the front line air navigation service provider.

In order to deliver an efficient flight, each aircraft has a predetermined timeline and schedule, according to which it must operate. Each flight schedule is part of an integrated system, both from an airline's perspective and air traffic management's point of view. As a result, delays will tend to propagate in and out of an airport and the system. Delay propagation is a process in which a delay at a flight stage causes a ripple effect in the subsequent stages of a flight [14] [15]. In general, delay propagation occurs when a flight arrives late at an airport causing a late departure in the subsequent stages, and a late arrival at the next destination.

4

ATM System Interdependencies

This section discusses the role of the components of an ATM system and its impact on ANSP operational performance. Causal reasons for inefficiency may often be assigned to the ANSP. However, there are certain operational performance areas that an ANSP can influence and others that are influenced by stakeholders external to the ANSP.

After establishing its high-level goals, the ANSP will need to address how to measure performance given the interdependencies in the system. Figure 2 below portrays several of the system interdependencies that exist when developing a key performance indicator for delay. With appropriate data, an ANSP can measure how well it utilised the capacity that was available or assess its ability to provide more flexible routings, which may be more direct. However, overall flight efficiency, as measured against an ideal flight will also be influenced by the airport infrastructure, weather conditions and airline schedules. In addition, there are other drivers such as special VIP events and interaction with Special Activity Airspace.

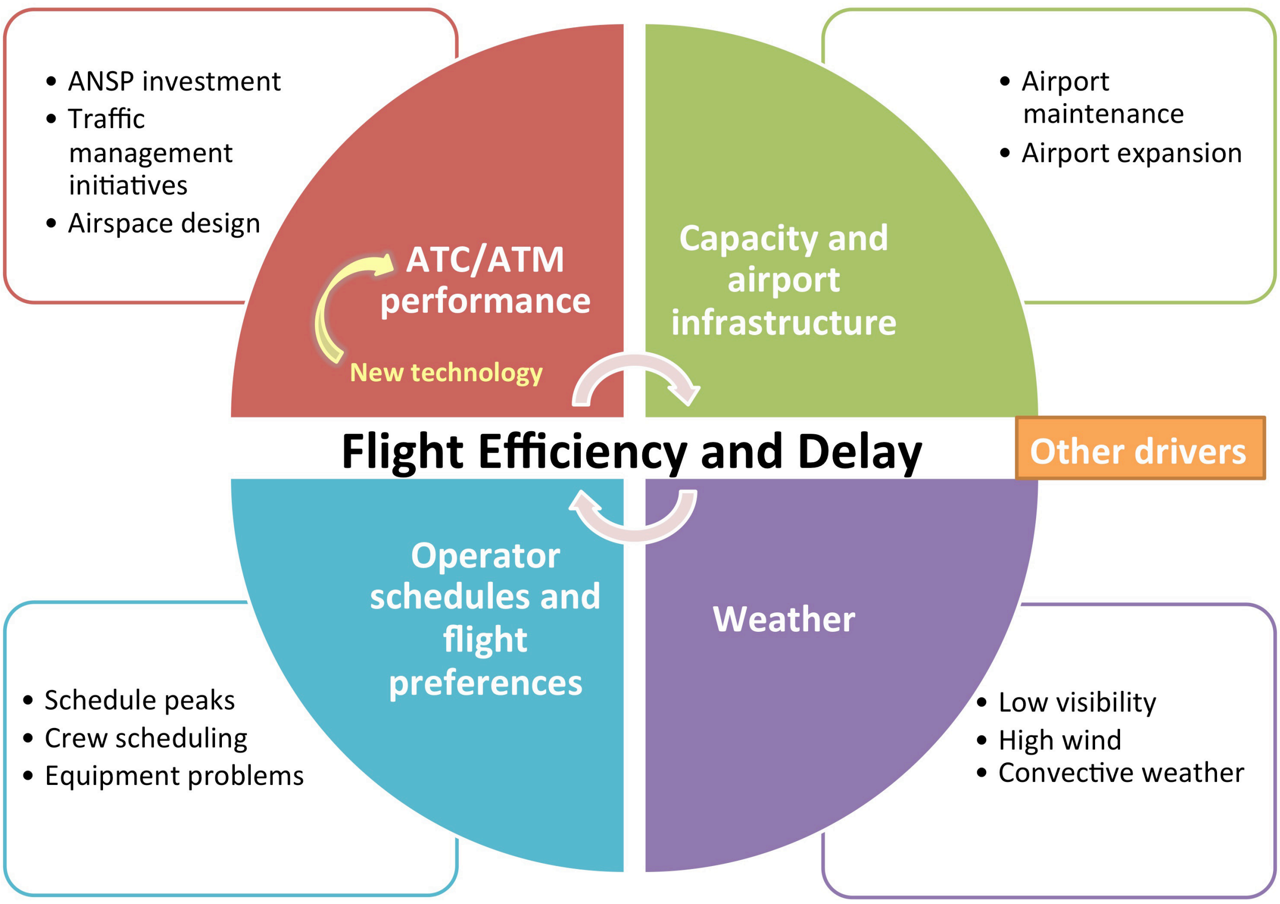


Figure 2 - System Interdependencies that Influence Flight Efficiency and Delay

There are several common procedures among ANSPs that address the interdependencies in the system. One strategy is to identify attributable causes of delay. It is important to understand the true reasons for delays to inform appropriate management actions. For example, if a delay occurs, is it due to the ANSP not making use of system resources, or due to severe weather conditions, airline-related causes, or some other event limiting capacity at the airport? In the latter cases, the delay would be classified as non-ANSP delay. These types of metrics are in use today. However, they require more sophisticated processing and often supplemental databases that track weather conditions or airline demand. One or more entities will have the responsibility of ascribing the delay to a particular cause. They may also require that capacities be developed for the airports to determine if demand is over capacity. Some ANSPs also utilise airline reported delay cause codes as required by their regulatory body [16][17]. International Air Transport Association (IATA), for example, provides a recommended set of delay cause codes [18]. Delay measures are discussed in more detail in Section 5.3 (a).

Another strategy is to develop non-delay like measures that are less influenced by complex interdependencies. Two such measures include capacity utilisation measures and metrics that track operational availability. Capacity utilisation measures the amount of accommodated demand given the available capacity of the system. For example, if a facility has a declared or rated capacity of 30 arrivals per hour, an ANSP would only be measured on its ability to deliver and land up to 30 arrivals in the hour, regardless of delay. Operational availability is a KPI of the ANSP's ability to keep all systems running and operational. Targets are developed which track the aircraft delayed due to equipment out of service or to limit the percentage of time equipment is non-operational except for cases of scheduled maintenance.

Although ANSPs will seek metrics such as an ANSP-attributable delay KPI or capacity utilisation and operational availability KPIs, it should be understood that passengers, operators and even regulatory bodies will react to the overall impact on aviation, e.g. the total system delay. Airline decisions on schedules and whether to incur cost through an increase in block time will be made on total delay and not total ANSP-attributable delay. As KPIs should foster communication among all stakeholders, it may be valuable for the ANSP to include KPIs that reflect the total customer experience, independent of cause code or whether capacity was available and delivered efficiently. This ensures that no potential efficiency gaps are masked by these ANSP-focused KPIs. The KPIs can be refined to distinguish where the ANSP has the most influence and separate the component that is ANSP-attributable.

5

Operational Performance KPAs and KPIs

This section presents the CANSO recommended operational key performance areas and associated indicators that support performance monitoring of ANSPs. These measures are based on a survey of current practice as described in Section 2 with specific references provided in Section 7. The performance measures are to an extent aligned to the ICAO key performance area framework discussed in Section 2. Whilst an ANSP will use KPIs to address the priorities of management, which in most cases are driven by local stakeholder requirements, the CANSO objective is to use these KPIs to promote global ATM transformation by harmonising the measures that help drive ATM efficiency improvements.

Understanding capacity and its drivers within an ATM context is fundamental to efficient air traffic control and traffic flow management. Furthermore, efficiency measures such as delay are the most publicly visible and are often tracked by stakeholders and regulators. Flight efficiency measures that track actual trajectories against an ideal are readily monetised with fuel burn benefits that have direct linkages to environmental KPAs. Predictability KPIs and the supporting measure of operational availability are also presented. These indicators allow management to assess how well the system meets the demands of the efficient gate-to-gate operation and its robustness to withstand unforeseen and natural factors. Lastly, ANSPs regularly employ a group of related and complementary measures that help quantify system interdependencies. These include measures such as runway occupancy time, non-ideal weather events, and airline scheduled demand relative to capacity.

Cause and Effect Relation of Key Performance Indicators

Although there are 11 distinct ICAO key performance indicators, it is rare that improvements in ANSP efficiency will affect one indicator independent of the others. For example, an improvement in capacity may allow for more flexibility in the system while making the system more predictable and operate at a reduced cost. In this case, capacity is the *causal* indicator while flexibility, predictability and cost are *affected* indicators. Furthermore, some of the affected indicators such as flexibility and predictability are difficult to quantify and monetise. It is also the case that when every effort is made to maximise utilisation of existing capacity, it may come at the expense of flight efficiency and predictability. Given limited resources, ANSPs should focus on the causal indicators that are feasible to quantify as priority indicators for implementation in a performance-based system.

Variant Forms of Key Performance Indicators

KPIs, such as excess minutes of flight time may be presented as total minutes of excess time or average minutes of excess time depending on the question asked. Alternatively, the ANSP may record the number of delayed flights as the percentage delayed above a threshold time. It is hard to find the perfect formula that fits all situations. Total minutes will provide the best indicator of the facility or scenario that is contributing most to system inefficiency. However, very large facilities or very popular operational scenarios may have a high contribution to total system excess time, but actually perform very well on average. Average values can relate how facilities or scenarios compare, but since average values do not contain frequency, they do not provide a good indicator of how much a facility or operating scenario contributes to overall system performance. This can furthermore be complicated by the relative frequency of a scenario or use of a facility changing over time. For this reason, performance teams will need to show KPIs with different variants or formulations to determine what actions will best improve system performance. In the description that follows, a basic KPI such as flight delay is presented, with the understanding that it may be calculated as total minutes, average minutes, percentage delayed, or some other 'form' in order to fully convey the impact of an operational scenario and the ability of an ANSP to improve performance. For the sections that follow, this variety in KPI formulation will be referred to as 'KPI forms'.

5.1 Capacity Key Performance Indicators

Many of the recommended performance indicators require that a capacity value be developed for the airport and associated airspace sectors as a means of balancing demand and capacity. Calculations of these capacity values should consider a wide variety of factors including:

- Airline schedules including fleet mix (i.e. percentage of heavy jets), and arrival/departure peaks
- An accepted delay tolerance which maximises the use of a facility
- Surface infrastructure including runways and rapid exit taxiways
- The availability of sectors open in the airborne phase (as affected by staffing)
- Airspace restrictions
- The presence of adverse weather and other short term limitations
- Equipment availability such as an operational Instrument Landing System (ILS)
- The number of aircraft parking bays and related services
- Number of passengers that can be processed through the terminal building (which in itself is impacted by security facilities, customs and immigration)

For many constrained facilities, it is understood that a certain level of delay is accepted in order to ensure a steady stream of demand at the facility. This balance of delay and maximum throughput is a key part of the capacity declaration process. Capacity is an important measure for assessing the ANSP role in system performance, as an ANSP must operate within the constraints of the system. Delay will occur when demand is above capacity and ANSPs can at best mitigate the consequence of this imbalance. For this reason, several ANSPs monitor aviation demand and system capacity together as part of a single metric to assess the operational efficiency of the system.

a) Capacity KPI (Declared Capacity)

Capacity is an indicator that measures an upper bound on the allowable throughput of a facility. This maximum value is often balanced against an accepted delay tolerance agreed to by stakeholders. This may be for an airport or a controlled region of airspace under normal conditions given the available resources. Capacity is influenced by factors outside and within the control of the ANSP. Factors external to the ANSP may include available runways and weather while those within the control of the ANSP may include staffing, training, and modernisation of technology. Other ANSP actions that affect capacity include those that ensure the equipment necessary to operate the ATM system is functioning. Indicators that assess the operational readiness of ATM are in use by several ANSPs today and are discussed separately below.

Declared fixed 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 fixed capacities, and only have these capacities declared daily based on known/current operational factors. Declaring fixed capacities provide an important reference for understanding the total system performance under normal operating conditions and provide a basis to work from when determining the impact of operational factors limiting capacity.

While each airport and airspace sector can have a declared fixed capacity, operational systemic factors may negatively impact service delivery and thereby reduce capacity of the airport and/or airspace sector. Declaring operational capacities objectively (through the use of analytical tools) can be an involved process for an ANSP especially due to the lack of sufficient common analytical tools for declaring capacity. Capacity of an airport and/or airspace sector will vary depending on operational factors, and ANSPs will be required to declare operational capacities considering these variables in real time.

b) Capacity Utilisation KPI

Capacity utilisation assesses how effectively capacity is managed by the ANSP. It is a measure of accommodated demand, compared to the available capacity of the facility. For example, if a facility is rated to have an arrival capacity of 30 operations per hour, and demand on the facility is 33 operations for a given hour, the ANSP is measured against its ability to accommodate 30 operations. The performance indictor is calculated by dividing the accommodated demand by the minimum of either the actual demand or the available capacity. Table 1 below demonstrates the capacity utilisation KPI.

This measure requires two key elements for its calculation. As noted above, the ANSP will need to have capacities developed for its facilities. These capacities should reflect the practical limits given weather or other airport conditions. Secondly, the ANSP will need a system that can calculate the demand being placed on a facility. Note that this metric does not reflect delay in the system or gauge how well air traffic control or traffic flow management is minimising delay. It is strictly a measure of the performance of the ANSP on accommodating demand, independent of the other factors such as total airline demand or weather.

c) Delay Attributed to Capacity KPI

Aircraft delay is often the product of demand exceeding capacity. Delays related to capacity constraints (i.e., excess demand) may be tracked through delay codes (reasons for the delay) separate from an efficiency measure. For delay measures, it is still important to track excess demand delays throughout all phases of flight, as this is a primary indicator of a capacity shortfall. However, delay indicators may be more easily calculated than a capacity utilisation measure that requires capacity values, demand and accommodated demand.

Demand (D)	Capacity (C)	Accommodated Demand (AD)	Capacity Efficiency	
33	30	30	100%	(AD/C)
33	30	27	90%	(AD/C)
27	30	27	100%	(AD/D)
27	30	25	92.6%	(AD/D)

Table 1 - Capacity Utilisation Example

5.2 Efficiency Key Performance Indicators by Phase of Flight

The following KPIs can be used to measure flight efficiencies by phase of flight. There are five phases of flight identified in Figure 3 below. Within these categories there are 11 components. This section describes each component and provides a set of KPIs that may be used to assess the corresponding flight efficiency.

Many of the KPIs that may be implemented for the different phases of flight compare an actual time against a scheduled time for the purpose of determining a delay. However, there are often two additional conditions that are met before an event is determined to be inefficient. These include meeting a minimum threshold for delay as well as information on causal factors. Typical minimum thresholds include 5, 10 or 15 minutes. For example with a 10 minute threshold, a flight is not considered late or inefficient until its actual time is greater than the target time by 10 minutes. For causal information, an ANSP or regulatory authority will assign a reason for a delay. Typical reasons include airline, airport, weather, or ANSP imposed delay. Section 5.3 (a) provides a more detailed description of cause codes. IATA has developed a recommended set of cause codes to be used in the reporting of delays [18].

Sections 5.2.2 to 5.2.4 address the airborne phase of flight. Airborne phase of flight may be separated by terminal/en-route phase or by facility (e.g., aerodrome or Flight Information Region (FIR)). One simple method for creating performance benchmarks by phase of airborne flight is to separate the phases by using circles that form a consistent boundary at 40 nautical miles (NM) from the origin aerodrome and 40 NM or 100 NM from the destination aerodrome. These circles will approximate exiting terminal airspace to the top of descent (100 NM) as points from which to begin measuring the effectiveness of continuous climb or continuous descent operations or direct flight between airports. This guidance illustrates the measures using the departure 40 NM and arrival 100 NM rings to separate out phases of flight. However, many ANSPs use the 40 NM circle to demarcate the en-route and arrival phase.

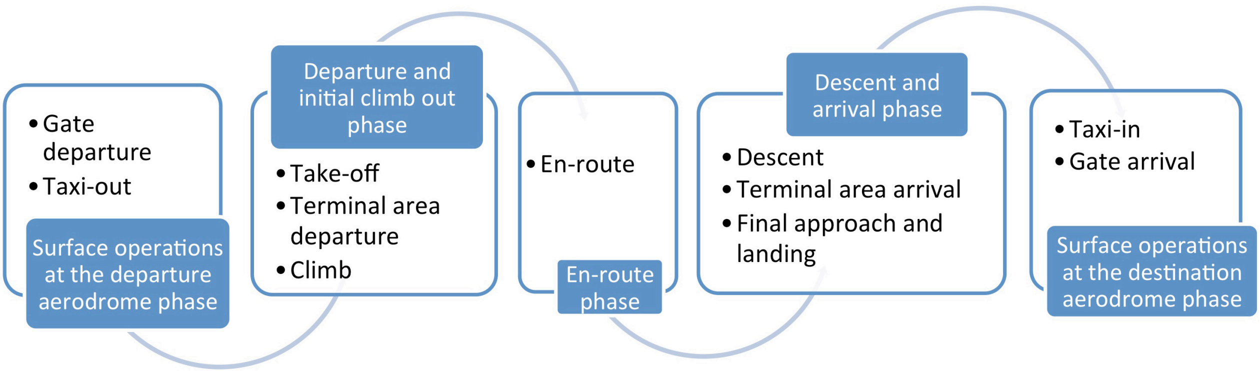


Figure 3 - Performance Segments for Five Phases of Flight

5.2.1 Surface Operations at the Departure Aerodrome Phase

Gate departure

Once the crew has concluded the pre-departure formalities, the aircraft is ready for start or pushback from the gate. This phase is mainly impacted by apron control services. Prior to pushback and leading up to gate departure, there are various interactions in and around the aircraft that affect adherence to a scheduled time, and thereby impact the efficiency of the flight as well as the ATM system. Factors that impact the gate-out phase include flight crew sign on time, aircraft turnaround time, pre-flight departure preparations such as flight inspections, fuelling, loading of cargo and baggage including catering, passenger boarding, availability of tugs and related service personnel as well as air traffic control clearances. Provision of clearance to leave the gate/pushback is also dependent on the local procedures and complexity of the ground operation, that is, volume of aircraft movements around the area and the design and control scheme of the apron facility.

De-icing events will extend surface times as aircraft taxi to and from de-icing locations and apply de-icing fluid. This time will usually be captured in the taxi-out phase. However, counting this time as "inefficiency" may be misleading as it is required for the safe operation of the aircraft. Ideally, the performance system could account for these events separately.

Most ANSPs are not responsible for providing air traffic service to aircraft before entering the manoeuvring area. It must be noted that aircraft can still be delayed/held at the gate due to restrictions in the surrounding airspace (weather or congestion), limitations at the destination aerodrome, or equipment outages, or air traffic control (ATC) staff shortages. Improved collaborative decision-making and updated live information to allow efficient gate operations is required to maintain efficiencies. Because each ANSP is different and each airport is unique in terms of operational challenges, performance targets and resource requirements will always differ. Therefore, the choice of using a particular operational KPI will vary based on its value for each ANSP and possibly each airport.

The value of the KPI	The KPI allows stakeholders to assess performance for a targeted phase of flight that will include all actions prior to push back. It is understood that drivers of this measure include both the ANSP and operator. Furthermore, surface CDM may promote pushing delay back to this phase in order to improve overall efficiency.
Data requirement	Actual off-block time and airline scheduled (strategic) or airline filed estimated off-block time
Formula	Actual off-block time minus scheduled or filed estimated off-block time
KPI Forms	Number of gate departure delayed aircraft; average gate departure delay per flight; average gate departure delay per delayed flight
Tips/warning	For many ANSPs, this KPI measures performance outside a direct area of responsibility. Actual off block time does not necessarily mean that an aircraft has begun taxiing for departure and may not be a useful measure of punctuality. Actual off-block time is difficult for airport surveillance systems to capture and is typically provided by requiring airlines to report OOOI (i.e., gate Out, wheels Off, wheels On, and gate In) times. Not all flights have scheduled off-block times or report such OOOI times.
System Requirements	Requires reliable source of scheduled or airline filed estimated off-block times and actual off-block times.

Gate Departure Delay KPI

This performance indicator measures the time difference between scheduled off-block time to leave the gate against the actual time the aircraft left the gate/parking bay (i.e., actual off-block time). The excess time is referred to as a delay. For the purpose of performance management, most ANSPs and governments define this delay against a minimum threshold time (i.e. all delays greater than 10 or 15 minutes) in order to allow for contingencies.

Taxi-out

The efficiency of this segment is impacted by task completion by the flight crew, the complexity of the aerodrome layout, unavailability of taxiways, the distance between the taxiing aircraft to the take-off runway, the number of aircraft in the queue, as well as ATC and ATM.

Taxi-out delay is defined as the actual taxi-out time minus an ideal or nominal taxi-out time. For ideal or nominal times, ANSPs have developed approximations for these using the data available in existing performance databases [19]. The system used for data collection and/or analysis should be able to capture the key surface times as shown in Figure 4 below for departure operations.

Variations in this measure often relate to the domain of control exercised by the ANSP. Often, the area of responsibility on the surface is separated into the movement area or taxiway system, where the ANSP exercises control, and the non-movement area or apron area, which is controlled by another entity such as the airline operator or the airport authority. Figure 4 below illustrates this division for the taxi-out phase.

Key performance indicators track total time or delay on the surface. In the case of delay, total time is compared against an ideal un-impeded time. Calculation of travel time or delay depends on the ability to obtain key event times such as the start and end of taxi. Start taxi and end taxi times may be difficult to obtain. For this reason, the OOOI times collected by airlines are used as surrogates for the key event times necessary for surface measures. OOOI data is also used for

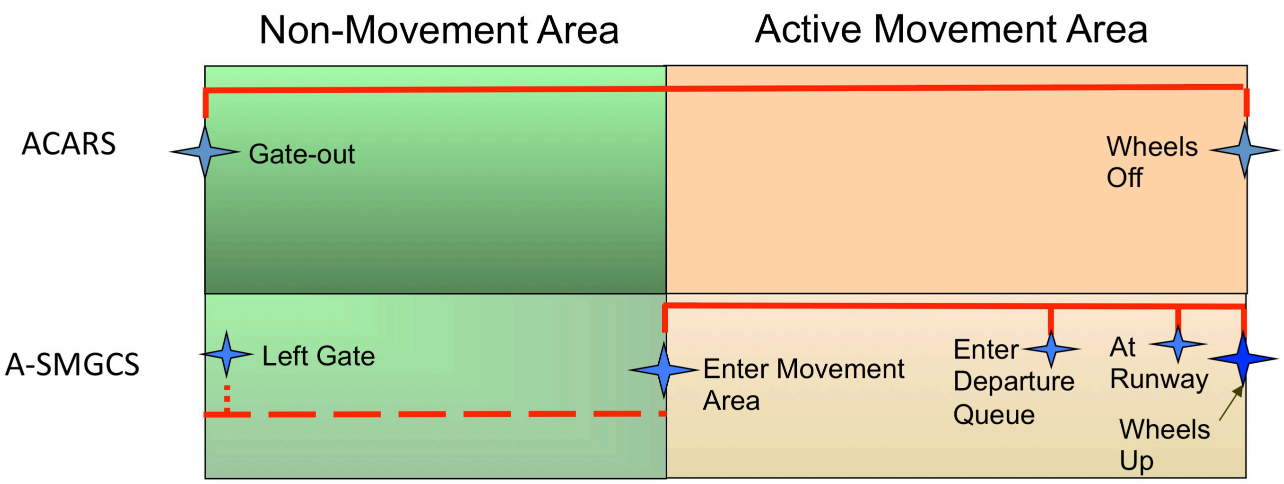


Figure 4 - Key Event Times in Taxi-Out Calculation

punctuality measures that compare actual gate times with scheduled gate times or actual landing times with estimated airborne times. OOOI data, however, may be quite limited for turboprop aircraft types and an independent surveillance system such as Advanced Surface Movement Guidance and Control Systems (A-SMGCS), may provide a more consistent source of high fidelity movement data.

Taxi-out Delay KPI

This performance indicator measures the time difference between the taxi time (start taxi to end taxi at the holding point) and the nominal taxi time. The excess time is referred to as a taxi-out delay.

This delay measure requires the ANSP to determine an ideal un-impeded taxi-out time for each flight. One procedure to determine these times is to calculate travel distances and assume a nominal taxi speed. Ground surveillance data may also calculate for each flight the amount of time spent in a non-taxi state after the aircraft has left the gate. This 'zero-velocity' time may be used as an indicator of delay.

Determining nominal times can be complex as ideal times change with gate/runway configuration as well as tactical conditions such as crossing active runways. As a simplification to measuring taxi-out delay, the ANSP may choose to track total taxi-out time. This removes the added complication of having to determine an ideal benchmark time but allows stakeholders to track if overall surface times are increasing or decreasing.

5.2.2 Departure and Initial Climb out Phase

Take-off Segment

It is important in air traffic management to make the most efficient use of runway resources. Runway efficiency is impacted by air traffic control's capacity and pilot responsiveness while on the runway. Reduced and streamlined use of radio telephony (RT) phraseology may also improve efficiency.

The value of the KPI	This KPI assists stakeholders to identify surface inefficiencies during taxi-out.
Data requirement	Start taxi time, end taxi time and nominal taxi time
Formula	Actual taxi-out time – nominal taxi-out time
KPI Forms	Number of taxi-out delayed aircraft; average taxi-out delay per flight; average taxi-out delay per delayed flight
Tips/warning	This KPI measure may be partially outside the area of responsibility of the ANSP. The start of taxi phase can be defined differently by different sources (e.g., defined as gate out vs. defined as entry of the movement area). Measurement of this time can be constrained by airport surveillance system coverage. For example, A-SMGCS systems can typically measure one second accuracy while Aircraft Communications Addressing and Reporting System (ACARS) can measure accuracy rounded to the nearest minute.
System Requirements	Manual data management or automated air traffic management tools such as A-SMGCS or ACARS.

Calculated Take Off Time (CTOT) Compliance KPI

This indicator measures the compliance with the CTOT.

The value of the KPI	This KPI shows the actual flight compliance to traffic flow management (TFM) initiatives and the performance of ANSP TFM actions. It assists ATM in managing traffic flow and enhancing total ATM capacity.
Data requirement	CTOT for the flight, the actual time of departure.
Formula	Actual departure time considered against the aircraft CTOT and applying the before and after threshold.
KPI Forms	CTOT compliance, number of early departures, and number of late departures
Tips/warning	
System Requirements	Requires sophisticated air traffic flow management (ATFM) tools, to generate the CTOTs and surveillance systems to determine actual take off times;

Terminal Area Departure and Climb Segments

Flight efficiency has both horizontal (distance) and vertical (altitude) components in which inefficiencies will adversely impact fuel burn. The ideal profile includes continuous climb operations (CCO) and direct routing to the exit point. The terminal boundary area for these measures may vary and depend on how an ANSP will segregate the other airborne phases of flight discussed below. If using a simplified circle radius, recommended distances include 40 NM or 100 NM where 100 NM is used as a proxy for the top of climb.

Horizontal efficiency is essentially a measure of direct flight. This may be measured using actual trajectories compared to a great circle distance or actual trajectories compared to an ideal yet achievable path. Vertical efficiency assumes departures fly a CCO from take-off to top of ascent, which will vary by aircraft type, payload and even take-off noise abatement procedures. It may be determined using the aircraft's filed altitude or through a process which assigns a theoretical optimum altitude to the flight. Aircraft operators consider 'optimal' to be function of both fuel costs and time costs combined in a 'cost index'. Since an optimal altitude can vary by aircraft weight and other factors (such as jet streams) which influence the time of flight, it is recommended that vertical performance be assessed against actual values that are accessible to the ANSP, such as the filed altitude.

There are limitations to the pure time-based methods as winds can drive times independent of ATM. The combined excess distance and level segment method is partially independent of winds; however, it cannot discern the effects of aircraft speed on flight efficiency. By using both methods, ANSPs and stakeholders can provide a bound on this "improvement opportunity pool". It should be noted that the "excess" time spent in the departure ascent phase may be required during busy periods when capacity constraints stipulate excess time be absorbed. From an ANSP standpoint, the challenge is to manage delay in a manner that maximises safety and minimises cost to stakeholders.

Terminal Departure Flight Distance/Time Efficiency KPI

This performance indicator measures the excess time an aircraft takes to traverse the terminal airspace during departure from take-off until the time the flight crosses the 40 NM ring. The baseline measure should be a modelled trajectory time for the specific aircraft type in the prevailing conditions, but an average time may be substituted. In general, it is very difficult to get a baseline "ideal" value for this phase of flight. Departure climb, even for a similar aircraft type will vary greatly by take-off weight and atmospheric (temperature) conditions.

The value of the KPI	This KPI helps identify terminal airspace inefficiencies and can aid in the identification of sources of such inefficiencies.
Data requirement	The minimum trajectory time for the aircraft type in the prevailing conditions, the time of take-off, the time the aircraft crosses the 40 NM ring.
Formula	Time the aircraft crosses the 40 NM ring – the time of take-off – compared to the ideal travel time trajectory from take-off to 40 NM ring. Alternatively, actual distance may be compared to ideal distance.
KPI Forms	Total excess miles or time, number of departing aircraft delayed in the terminal airspace, average departure delay per flight, average departure delay per delayed flight; average excess horizontal distance per flight.
Tips/warning	The baseline 'ideal' flight will be difficult to obtain as it is influenced by aircraft weight and atmospheric conditions. The fidelity will be dependent on the accuracy of the calculations for the ideal time/distance of the trajectory and the actual trajectories collected by ANSPs. Extended flight and excess distance may be imposed on ATM due to noise restrictions.
System Requirements	Automated air traffic management tools that determine ideal and actual trajectories of the departure segment, data reporting systems that capture take-off and (40NM) ring crossing times.

Terminal Departure Level Flight Efficiency KPI

This measure tracks the time or distance spent in level flight from departure until top of ascent. Phase of flight simplifications may use 40 NM or 100 NM circles as an approximation for the departure exit point or top of ascent. This is the primary measure for assessing the progress of continuous climb operations.

ANSPs have developed specialised algorithms for detecting level flight from the source trajectory position databases. These procedures address sparse or spurious data and the granularity of the altitude provided.

5.2.3 En-Route Phase

En route flight efficiency is defined as the difference between the length of the actual flight's trajectory (A) from a terminal exit point to a terminal arrival point and the great circle distance (G) or the flight plan distance or direct distance (D) between departure points. En route flight efficiency measures consist of *Direct Route Extension and Flight Plan Route Extension* and are explained in the following sections.

En-Route Direct Route Extension KPI

En route extension is defined as the difference between the length of the actual trajectory (A) and the great circle distance (G) between the departure and arrival terminal areas.

The terminal environments are approximated by a 40 NM circle around the departing airport and a 40 NM or 100 NM circle around the arrival airport. Two great circle distances between the entry and exit points (D) and the two reference circles (G) provide upper and lower benchmark trajectories for the en route environment. The differences between the actual

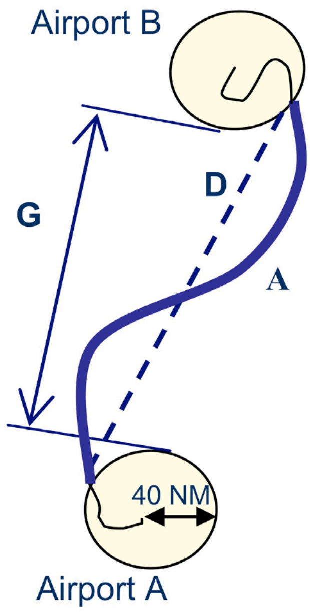
The value of the KPI	In the absence of often proprietary data, this measure is the primary means of detecting continuous climb operations and allows ANSPs to track benefits from new procedures.
Data requirement	Key events associated with airborne flight trajectory including the time and distance in level flight from take-off to crossing the 40 NM or 100 NM circle from an airport.
Formula	Actual level flight time/distance from take-off to 40 NM or 100 NM radius from airport or top of ascent.
KPI Forms	Total or average minutes or miles in level flight. If useful, this can be provided by approach fix and runway configuration.
Tips/warning	Metric is sensitive to fidelity of RADAR data (1-minute vs. 30 second sampling). A threshold for level flight is required as short level flight detected by RADAR is not indicative of inefficiency.
System Requirements	RADAR or position data with sufficient accuracy for performing airborne trajectory measures as well as a procedure for level flight.

trajectory (A) and the two benchmark distances (D&G) are indicators of en route inefficiency.

A-G provides a consistent lower bound for tracking changes over time for a particular city pair. The value of G as a pure great circle distance is that it does not change over time. However, the value of G is in most cases not feasible. The benchmark distance D is more indicative of what can actually be flown as the beginning and end of the benchmark represent flight locations that actually exist in the current network. Excess distance as determined by A-D, is principally caused by events that occur en route. Excess distance as determined by A-G is strongly affected by the interface between TMA and the en-route environment. It may include entry/exit points that are not feasible given runway orientation or the need to safely separate arriving and departing traffic.

In converting the excess distance to an excess time, it is assumed that the aircraft would fly the same speed on the theoretical G and D segment as that observed on the actual segment.

Figure 5 – Illustration of en route reference distances



This is referred to below as the modelled trajectory time for D and G. For example, modelled time on the direct distance D is simply direct distance (D) divided by actual velocity on (A), where actual velocity on A is actual distance (A) / actual time on (A).

The value of the KPI	This KPI helps stakeholders target the en-route flight phase for inefficiencies that could be improved though allowing direct flight between airports. It will show the trade-off on traffic management initiatives (TMI) that extend flight to allow more capacity.
Data requirement	Time the aircraft crossed the 40 NM ring on departure, the time the aircraft crossed the 100 NM ring of the destination airport, the modelled trajectory time for segment G or D, the associated distances for G, D and A for the selected city pair.
Formula	Actual time the aircraft spent en-route from crossing the 40 NM ring on departure to crossing the 100 NM ring of the destination airport minus the modelled trajectory time for segment D; the actual distance flown (A) minus the reference distances of G or D.
KPI Forms	Total excess time or distance, average en route excess time or distance per flight; average en route excess time or distance per delayed flight.
Tips/warning	This KPI is often affected by special use airspace and the need to keep traffic flows separate for safety reasons. For long travel distances, it is also impacted by winds, as operators prefer a wind-optimal flight rather than a direct distance flight.
System Requirements	RADAR or position data with sufficient accuracy for performing airborne trajectory measures.

The measure allows the ANSP to make an initial determination of the areas in the ATM system most likely to benefit from investment. However, there are some caveats. There is a high likelihood that the measure will identify flight trajectories that are affected by special use airspace and the true performance efficiency will need to be adjusted accordingly. Secondly, ideal trajectories for flight lengths greater than 1,000 NM should consider a wind-optimal trajectory. Lastly, the fidelity of the benchmark time and distances will be dependent on the accuracy of the modelled trajectory time and actual time and distance data collected by ANSPs.

Filed Flight Plan En Route Extension KPI

This measure assesses inefficiency from the point of view of filed routings available to end-users. Similar to the en route extension KPI defined above, this measure compares filed distance to a reference great circle route. The last pre-departure flight plan would be used to obtain the filed distance. This measure identifies if available routes are becoming more direct or less direct over time. It can also identify areas where available routings are the least direct in the airspace system. ATM improvements, such as improved airspace design and/or improved coordination with special use airspace will lead to improvements in this measure. This measure should highly correlate with the actual versus great circle described above. The advantage of this measure is that the effect of winds, thunderstorms, and other operational constraints such as special use airspace, will be contained in the flight plan. Whereas this measure focuses on the flight plan system and process, trajectory measures based on the real trajectories focus on what was actually achieved.

The value of the KPI	This KPI identifies if filed flight distances are becoming more or less direct.
Data requirement	Filed time/distance from where the aircraft crossed the 40 NM ring on departure to the point where the aircraft crossed the 100 NM ring of the destination airport. The modelled trajectory time/distance for segment G or D, for the selected city pair.
Formula	Filed time the aircraft spent en-route from crossing the 40 NM ring on departure to crossing the 100 NM ring of the destination airport minus the modelled trajectory time for segment D; the actual distance flown (A) minus the reference distances of G or D.
KPI Forms	Total filed time or distance, average time or distance per flight above the great circle benchmark.
Tips/warning	Causal reasons for filing longer distances may be to weather, airline equipage for over water, or increase use of special use airspace.
System Requirements	RADAR or position data with sufficient accuracy for performing airborne trajectory measures. Identification of appropriate flight plan data for determining intent.

Figure 6 below shows an example of a city pair's actual trajectories compared to flight plan operating in proximity to special use airspace (blue regions). At certain times, direct flights are available (red flights); however, there are other times when flights must be routed around the SUA (green flights). The flight plans (shown in orange) provide an indication of when aircraft can file a direct route. Comparing actual trajectories to the flight plan will generally show less inefficiency than comparing actuals to the great circle (which is not always feasible).

There are other types of flight efficiency measures that utilise the flight plan. These metrics assess 'variability' or 'predictability' and are described in more detail in section 5.4 below. Examples include measures that compare actual trajectories against a flight plan trajectory and are commonly known as 'filed versus flown'. A filed versus flown measure does not consider inefficiencies in the current flight plan structure that could be improved if there were improvements to ATM. These are more directly captured using the direct route and filed en route extension measures described below.

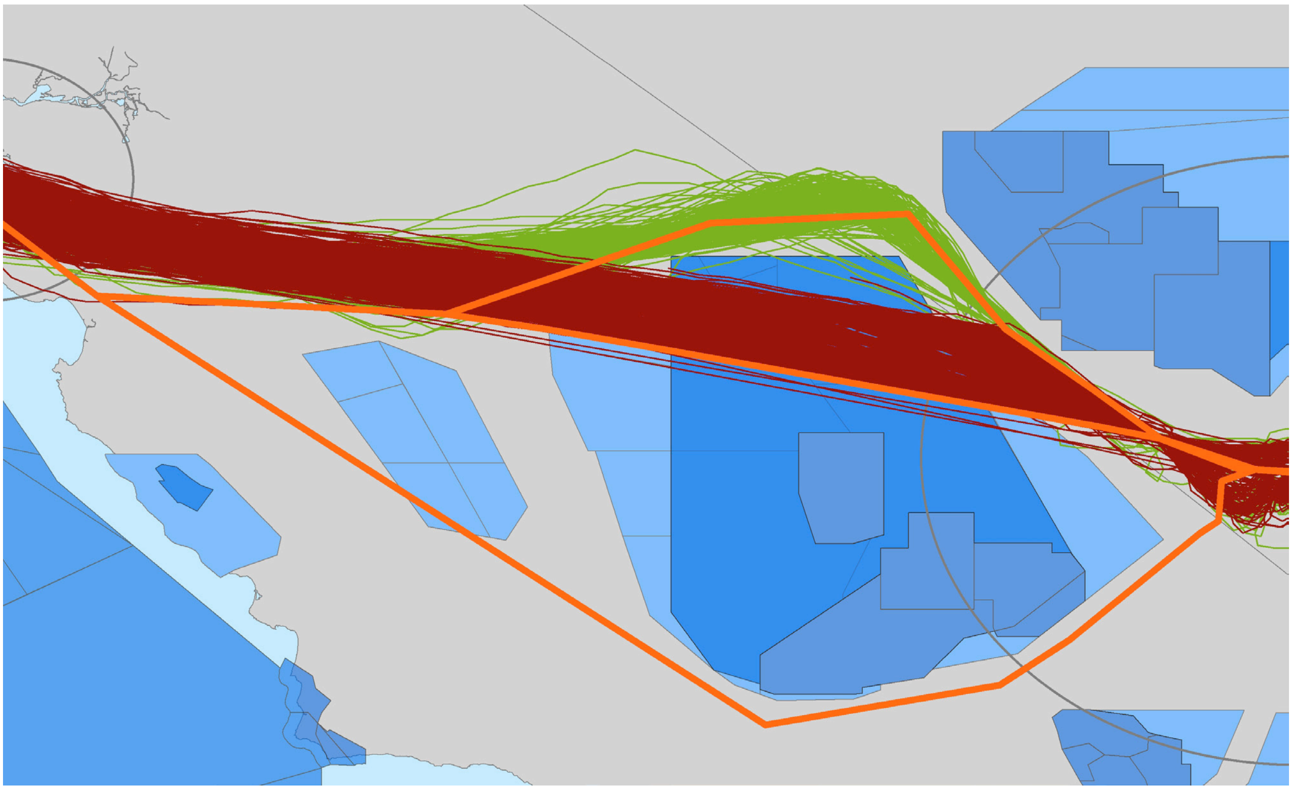


Figure 6 - Actual Trajectory Compared to Flight Plan

5.2.4 Descent and Arrival Phases

Descent and Terminal Area Arrival

Flight efficiency in the arrival phase compares the actual flight trajectories against an ideal or nominal benchmark trajectory. CANSO has developed guidelines for calculating an ideal trajectory in the descent phase in its publication *Methodologies for Calculating Delays/ Improvement Opportunity Pools by Phase of Flight* report [19]. In the CANSO methodology, flights are grouped by common aircraft type, approach fix and runway configuration. The benchmark is then taken from the top percentile of best performing observed flights.

Flight trajectory efficiency is heavily influenced by all the interdependencies described in Section 4. Flights will fly excess distances due to weather or situations can occur in which excess distance is required to keep aircraft separated.

In Figure 7, the flight tracks shown in red represent an idealised trajectory which is specific for a given aircraft class, arrival fix and landing runway combination. The other trajectories in green and light blue are compared to the ideal to obtain measures of excess distance or excess time. Progress towards the ideal trajectory is reflected as time and distance savings that can be monetised. These measures are often used in cost-benefits analyses, which demonstrate time and fuel savings to airspace users such as airlines. However, it is understood that the ideal trajectory is not attainable 100 percent of the time due to system uncertainty and requirements for safety that cannot be compromised.

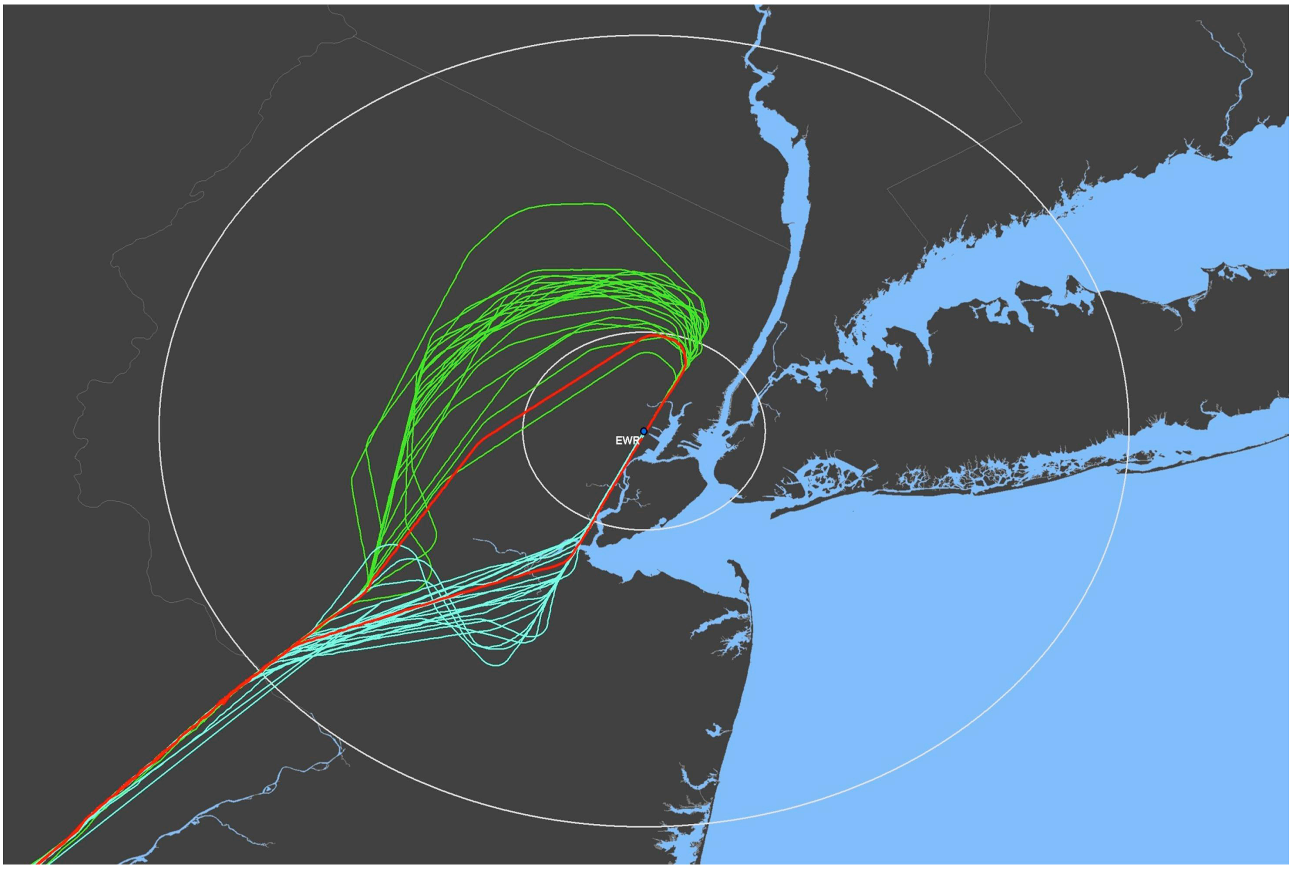


Figure 7 – Flight track actual and benchmark trajectories

This flight efficiency measure is closely related to a delay measure but looks at excess distance and time as opposed to just excess time. In fact, a flight may not be delayed due to schedule padding or flying faster than the optimal speed. However, the flight may still show an excess distance using this measure. A non-delayed flight may also have level segments instead of more fuel optimal continuous descent operations. There also may be excess distance due to vectoring or extended flight tracks leading to final approach that are required to keep aircraft separated.

In addition to excess distance and time, ANSPs have been monitoring the time and distance spent in level flight during the approach phase as an indicator of progress towards continuous descent operations. The CANSO publication *Methodologies for Calculating Delays / Improvement Opportunity Pools By Phase of Flight* [19] provides procedures for both excess distance and level flight, either as stand-alone measures or as one integrated measure. The following two KPIs separate out extended flight tracks and level flight as two distinct measures.

Arrival Flight Distance/Time Efficiency KPI (from 40/100 NM ring around the airport)

This performance indicator measures the excess time and distance an aircraft takes in the arrival phase of flight. ATM that effectively utilises capacity along with efficient use of traffic flow management will have minimal excess distance/time in the terminal environment.

The value of the KPI	This measure allows ANSPs to track benefits from new procedures such as those achieved through performance-based navigation (PBN).
Data requirement	Key events including the time and location crossing the 100/40 NM circle from an airport, time of touchdown and distance travelled from 100/40 NM to touchdown. The KPI requires a procedure for determining the ideal trajectory for an aircraft group.
Formula	Actual time/distance from 100/40 NM to touchdown minus ideal time/distance from 100/40 NM to touchdown.
KPI Forms	Total or average excess minutes or miles by aircraft group, operating configuration of arrival airport.
Tips/warning	Care should be taken that benchmark trajectories do not change significantly over time. It also may be difficult to obtain an accurate value for the landing time and location.
System Requirements	RADAR or position data with sufficient accuracy for performing airborne trajectory measures.

Arrival Level Flight Efficiency KPI (from 100NM ring around the airport)

This performance indicator measures the time and distance an aircraft spends in level flight on approach.

The value of the KPI	In the absence of often proprietary data, this measure is the primary means of detecting continuous descent operations and allows ANSPs to track benefits from new procedures such as those achieved through PBN.
Data requirement	Key events associated with airborne flight trajectory including the time and distance in level flight from crossing the 100 NM circle from an airport to touchdown.
Formula	Actual level flight time/distance from 100 NM to touchdown.
KPI Forms	Total or average minutes or miles in level flight. If useful, this can be provided by approach fix and runway configuration.
Tips/warning	Metric is sensitive to fidelity of RADAR data (1-minute vs. 30 second sampling). A threshold for level flight is required as short level flight detected by RADAR is not indicative of inefficiency.
System Requirements	RADAR or position data with sufficient accuracy for performing airborne trajectory measures as well as a procedure for level flight.

Final Approach and Landing

Similar to the KPI measuring take off time compliance at the departure runway, it is important also to measure the time spent using arrival runway resources. Arrival capacity at an airport is dependent on the aircraft arrival fleet mix, their respective separation requirements and external environmental factors, as well as the expected runway occupancy time. An arriving aircraft must be clear of the runway safety protected area before another arrival can land. Arrival throughput can therefore be maximised when runway occupancy time is minimised.

Arrival Runway Occupancy Time KPI

This indicator measures the time each aircraft spends on the runway

The value of the KPI	This KPI assists stakeholders in identifying excess runway occupancy times as part of runway throughput capacity enhancements.
Data requirement	Wheels-on time and actual time of vacating the runway clear of the runway safety protected area (holding point line).
Formula	Actual time of vacating the runway clear minus wheels on time
KPI Forms	Total and average runway occupancy time per aircraft category
Tips/warning	Runway occupancy times are affected by the availability and configuration of taxiways to assist aircraft to get on and off the runway.
System Requirements	Runway surveillance data from systems such as A-SMGCS.

5.2.5 Surface Operations at the Destination Aerodrome Phase

Taxi-In

The efficiency of the taxi-in segment is for the most part, less impacted by ATM than the taxi out segment. Taxi-in efficiency tends to be more dependent on several factors including the complexity of the aerodrome layout, the availability of rapid exit taxiways, downstream effects such as availability of gates at the apron facility and airport/airline staffing.

Taxi-in delay KPI

This performance indicator measures the time difference between the taxi time (start taxi leaving the runway to end taxi leaving the manoeuvring area) and the nominal taxi-in time.

Similar to taxi-out delay, this measure requires the calculation of a nominal taxi-in time from which to benchmark an efficiency measure. One procedure to determine these times is to calculate travel distances and assume a nominal taxi speed. Ground surveillance data may also calculate for each flight the amount of time spent in a non-taxi state after the aircraft has exited the runway. This ‘zero-velocity’ time may be used as an indicator of delay.

Determining nominal times can be complex as ideal times change with gate/runway configuration as well as tactical conditions such as crossing active runways. As a simplification to measuring taxi-in delay, the ANSP may choose to track total taxi-in time. This removes the added complication of having to determine an ideal benchmark time but allows stakeholders to track if overall surface times are increasing or decreasing.

The value of the KPI	This KPI targets the surface taxi-in phase and can aid in the identification of surface inefficiencies.
Data requirement	This KPI requires start taxi-in time (time exiting runway), end taxi-in time (time leaving manoeuvring area). The KPI also requires a procedure for determining a nominal taxi-in time.
Formula	Actual taxi-in time minus nominal taxi-in time
KPI Forms	Number of taxi-in aircraft delayed, average taxi-in delay per flight, average taxi-in delay per delayed flight.
Tips/warning	This KPI measure may be outside the area of responsibility of the ANSP and may in influenced by staffing by the airport or airline. The fidelity of the measure will be dependent on the breadth and accuracy of the data collected by the ANSP. Taxi end definitions may be different (e.g., end of movement area vs. gate in) and may be constrained by available surveillance systems.
System Requirements	Manual data management or automated air traffic management tools such as A-SMGCS or ACARS.

Gate Arrival

Gate arrival is the last performance segment in the five phases of flight. As such, gate arrival delay is dependent on the performance of all the previous flight phases. Gate arrival delay may also mask some inefficiency in previous flight phases as the schedule arrival time may include an overall buffer time to achieve a higher level of on-time performance.

Gate Arrival Delay KPI

This performance indicator measures the time difference between the actual on-block time and the scheduled on-block time.

The value of the KPI	This KPI allows stakeholders to assess the combined effects of all previous phases of flight. It provides a measure for managing gate arrival punctuality.
Data requirement	Actual on-block time and airline scheduled (strategic) or airline filed estimated on-block time
Formula	Actual on-block time minus scheduled on-block time
KPI Forms	Number of gate arrival delayed aircraft, total and average gate arrival delay per flight, average gate arrival delay per delayed flight.
Tips/warning	This KPI measures performance outside many ANSP's direct area of responsibility. Actual in-block time is difficult for airport surveillance systems to capture and is typically provided by airlines requiring OOOI times. Not all flights have scheduled in-block times or report such OOOI times.
System Requirements	Requires reliable source of scheduled or airline filed estimated in-block time and actual in-block times.

5.3 Other Efficiency Key Performance Indicators

In addition to the capacity and efficiency KPAs by phase of flight, CANSO Members have utilised other operational KPIs to gauge system efficiency. These measures complement capacity and efficiency measures by addressing interdependencies, or looking at combined phases of flight, or monitoring the readiness and operability of ATC systems. Three of these measures are described below.

a) ANSP-Attributable Delay KPI

Delay is one of the most visible measures available to the public on aviation performance. Airline on-time statistics are often monitored by regulatory authorities, quoted in the press or reported by airlines to highlight their performance. Delay however, especially delay against a scheduled time, has two key issues that can mask ANSP performance.

First, airlines may pad their schedules to account for uncertainty in their schedule times. This reduces delay compared to the schedule and increases on-time performance. However, the increase in block time will mask other inefficiencies such as the phase-of-flight based efficiency measures described above.

Second, delay may occur due to conditions such as weather or demand exceeding capacity of the departing or arriving airport facility.

Flight efficiency measures are one strategy for addressing issues with schedule padding and delay as measured against a schedule time. Another is to measure delay against a filed time rather than the scheduled time. Filed times may be more accurate in terms of assessing performance. However, the degree to which filed times also account for planned congestion or uncertainty should be understood.

Another strategy that is employed by ANSPs and regulatory authorities is to attribute the delay experienced by a flight to casual reasons [20]. For this performance indicator, the ANSP will have procedures in place for assigning a delay cause code to a delayed flight. Table 2 shows common categories for delay cause codes in use by ANSPs. The delay causal reasons listed in Table 2 below also identify interdependencies that exist in the system that together drive total system performance and overall flight efficiency (Figure 2). IATA has also developed formal cause codes for attributing delay, which can be mapped to the categories shown in Table 2 [18].

In the table below, delays attributable to ATC are related to staffing, training and keeping the equipment operational. Delays attributed to capacity are due in part to demand exceeding capacity, where capacity is not limited due to ATC reasons (e.g., staffing, equipment failure). Managers of performance would need to assess if modernised ATM could increase capacity or better manage the imbalance of demand to capacity through improved traffic flow management. In the case of weather, most delays may be unavoidable due to necessary safety considerations. However, there may be some ATC modernisation actions that could improve delay during lower visibility conditions.

ANSP-attributable punctuality is very similar to ANSP-attributable delay. The main difference is that the delay measure is expressed in terms of an on-time percentage. For punctuality measures, a flight is considered late if its actual arrival or departure time is after a certain threshold of its planned arrival or departure time and the delay can be attributed to the ANSP. ANSPs report different thresholds for punctuality such as more than 15 or 30 minutes past the target time. Target times may include:

— The scheduled time (for both departure and arrival)
— The filed time en route (arrivals)
— A Target Off-Block Time (departures)

b) Average Flight Time Between City Pairs KPI

This indicator provides a simple but useful measure for appraising the ability of the overall aviation system to maintain flight efficiency as the number of flights increase.

The average flight time is calculated as the summation of the time used by a given quantity of flights of a select aircraft type (or category of aircraft with similar speed performance) to travel from one airport to another divided by the number of flights. The time of each individual flight is the duration from wheels-off at the departure airport to wheels-on at the arrival airport. Summation should be performed for time periods sufficiently long (e.g. yearly) so as to reduce the influence of hourly, daily or seasonal variations of flight distance and time associated to weather conditions. Tailoring the indicator to measure the average flight time between specific runway pairs may improve the accuracy and validity of the KPI.

ATC	Capacity	Weather	Airline	Other
Insufficient staffing	Demand exceeds airspace capacity	Low visibility, high winds	Aircraft maintenance	Environmental restrictions
Equipment failures	Demand exceeds aerodrome capacity	Wet pavement, freezing conditions de-icing	Late arriving crew	Security events
Phasing in new procedures		Convective weather	Aircraft fuelling, loading, late weight/balance documentation	Military activity

Table 2 - Common Delay Causal Reasons for Assessing Performance

The main advantages of this indicator include its simplicity (i.e., only wheels-off and wheels-on times, dates, aircraft types, and city pair information are necessary), data accessibility and availability (i.e., wheels-off and wheels-on times are used by all stakeholders and are therefore reported with great accuracy and reliability). However, it is recognised that flight times are also dependent on factors external to the ANSP, e.g. airline operating strategy (cost index settings), weather trends, and airport congestion due to capacity restrictions related to government policy.

Figure 8 below illustrates four evolution scenarios of the average flight time between airport pairs in the presence of progressively increasing quantity of flights. Scenario #1 shows a possible no-action scenario, where additional flights are absorbed at the expense of additional time per flight. Scenario #2 shows the case where actions are taken to improve the ATM system to limit or cap the increase in average flight time and resulting efficiency loss to a certain amount. Scenario #3 shows the result of actions taken to increase ATM efficiency that not only limit the progression of the average flight time, but also reduces it to levels before air traffic growth. Scenario #4 shows an even more effective set of operational improvements, resulting in a reduced average flight time as compared to the baseline (2015) performance, even in the presence of an increased number of flights.

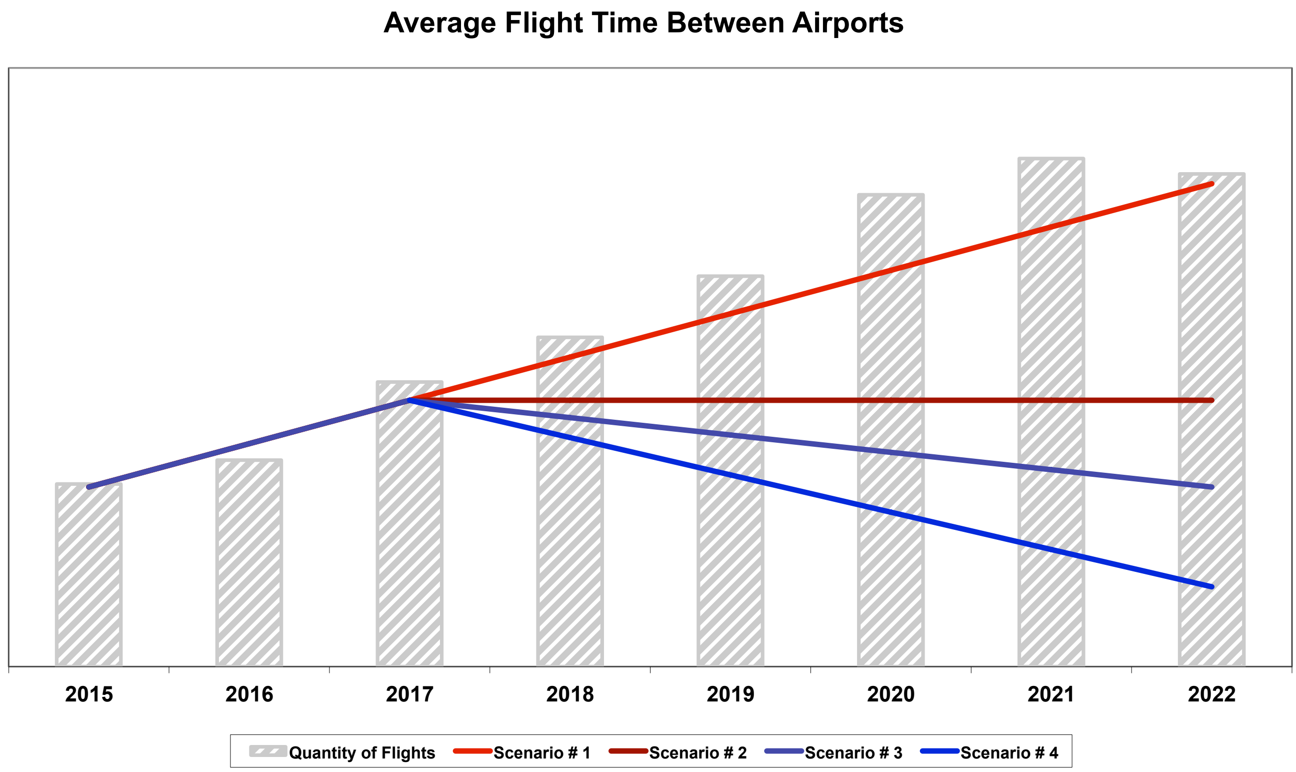


Figure 8 - Average Flight Time between Airport Pairs KPI Example

Even though the indicator does not take into account possible gains in efficiency resulting from ATM improvements (e.g., adoption of continuous climb and/or descent profiles) that may increase the average flight distance (and consequently, the average flight time) as a beneficial trade-off, it serves as a first-order approach for pinpointing airport pairs that may require more detailed performance monitoring.

c) Operational Availability KPI

This indicator measures the availability of the equipment necessary to provide ATM service. Loss of RADAR or communications equipment will affect the speed and number of aircraft that can be handled. Operational availability affects safety, capacity and flight efficiency measures. It is often used as an ANSP performance measure because many of the variables that affect the KPI are under the control of the ANSP. There are few, if any, interdependencies. An ANSP can ensure operational availability through adequate funding to support maintenance, training and staffing, as well as investing in equipment with high reliability and low expenses in terms of repair costs.

The KPI may be calculated as the maximum facility service hours minus outage time divided by the maximum facility service hours. This will provide a percentage of the operational availability of the facility. Outage time may be adjusted to account for planned or scheduled service, which is necessary and designed to minimise the impact on the system.

5.4 Predictability Key Performance Indicators

Predictability is defined in ICAO document 9854, *Global Air Traffic Management Operational Concept* as the "ability of airspace users and ANSPs to provide consistent and dependable levels of performance". For example, publicly available measures such as on-time performance give some indication of how dependable a scheduled arrival or departure time is based on historical performance. However, this measure only focuses on times greater than the target time (i.e., the schedule) and does not provide a complete picture of how consistent travel time may be. In fact, airlines may add time buffers into a schedule time to mask the effects of inconsistency in travel time.

Consistent and efficient use of capacity is a stakeholder expectation and it is recommended that ANSPs track and report capacity as a measure. However, predictable capacity would measure the variability of capacity and how often higher ideal rates are achieved. In many cases, capacity variation or capacity resiliency is a better indicator of where performance can be improved.

Measures of variability can be used to quantify the consistency of service in the system and can be in the form of standard deviations or as differences in percentiles. The use of standard deviation as a measure for variability typically assumes travel times, distances or other measures such as capacity or throughput are normally distributed and not skewed. Percentile methods do not rely on this type of assumption and can provide an easy to understand procedure that is consistent. As noted earlier, on-time performance is a very public measure that is used as an indicator of dependable service. However, measures of variability may also be used by ANSPs and other stakeholders to indicate areas with opportunity for improvement.

Three measures for variability are described below that may be used as KPIs for predictability. For these KPIs, CANSO provides default guidance using a non-parametric percentile method for measuring the consistency of capacity, travel time and flight plan distance. The percentiles chosen are 15^{th} and 85^{th}. This measures the variability among 70 percent of the events and corresponds to the population covered by approximately one standard deviation from the mean if in fact, events were normally distributed.

a) Capacity Variation KPI

Given that an ANSP has a measure of the capacity or facility 'declared called rate', this measure tracks the variability in called rate that occurs. This variability will often track with changes in weather condition. Absent strategic schedule limitations that plan for a worse case (i.e., lower 15th percentile rate), facilities with high capacity variation will provide clear indications of areas that have high delay, extended trajectories or lower on-time performance. This effect is magnified as demand comes close to the upper limits of the capacity (i.e., 85th percentile).

b) Travel Time Variation KPI

Travel time variation is first defined by the time perspective that separates the measure into strategic predictability and tactical or day-of-operation predictability. A strategic predictability KPIs evaluates times based on the schedule, which airlines plan months in advance. A tactical predictability KPI would assess planned travel times such as the filed times, which are established close to the actual operation. Increases in schedule block time in the strategic phase may reflect uncertainty due to all the factors described in Section 4. Strategic values may be calculated on a city pair or flight ID basis. It may measure the variability of the entire gate-out to gate-in travel time or may be sub-divided by phase of flight. Figure 9 below shows an example of a strategic measure with travel time variation between a scheduled gate-out time and the actual gate-in time as recorded by a system such as ACARS or a ground based surveillance system.

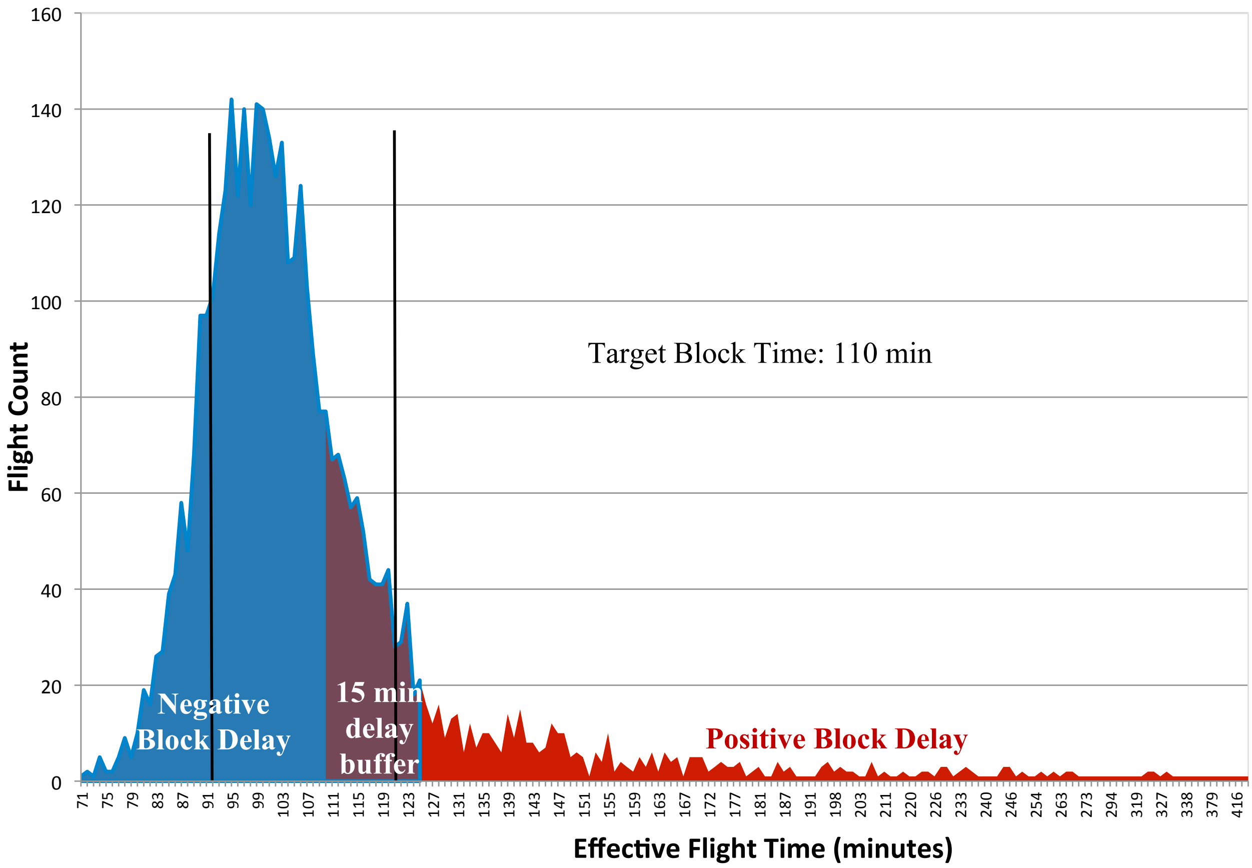


Figure 9 - Travel Time Punctuality and Variability

The example on the previous page is for a city pair with a target travel block time of 110 minutes from gate-out to gate-in. This is based on the time provided in the schedules. Approximately 29 percent of the flights have actual times greater than 110 minutes; this is represented by the purple and red portions of the chart. If the regulator or ANSP allows for a 15-minute buffer, only the flights represented by the red region (12 percent) are considered delayed. On-time punctuality is therefore 88 percent, which is high for many large activity airports [10]. However, this high measure is also accompanied by significant variability in the travel time.

Alternatively, the ANSP may consider the variability in flight time, which in this example is 29 minutes relative to a median time of 102 minutes, which may be considered high. At this time, there are no known examples where an ANSP or regulator has set performance targets based on this measure of predictability. The KPI is in fact very much an aviation industry measure that depends not only on the ANSP, but also on other interdependencies such as the business model of the operators. The value of this measure is that it can be used to identify the phases of flight or city pairs with the most variability (i.e. least predictability) and identify possible areas that may improve the reliability of the system for all stakeholders.

Strategic variability measures may complement delay or on-time measures that use schedule times as the reference. It is often the case that groups of flights may have high on-time arrival percentages or low schedule delay, but high variation in travel times. This is an indicator that schedule times have been padded to mask inefficiency in the system.

c) Flight Plan Variation KPI

Flight plan variation measures the consistency of the last pre-departure flight plan for a given population of flights. In assessing variability, stakeholders may begin with flight plans for a specific city pair across all conditions. A more targeted assessment of variability may account for seasonal or time-of-day variations, or specific runway configurations at origin/destination airports. Variability across the last pre-departure flight plan may use the 15th to 85th percentile method to rank city pairs that have the most variability within the ATM system.

Another more tactical measure of flight plan variation is to compare actual trajectories with the pre-departure flight plan. These are often called filed versus flown measures. In this case, the average mean difference provides an indication of the city-pairs with the most variability. A similar measure which correlates with filed versus flown compares the pre-departure flight plan with the last amended flight plan. This shows variability but also flexibility in accommodating improved routing as the system evolves over the course of the flight.

5.5 Summary of KPI Data Requirements and Tools

The performance indicators described in this document require that certain data sources and performance tools are available to the ANSP. In surveying ICAO guidance and current practices from ANSPs, CANSO finds the following five precursors (data and tools) are required.

1. An analytical capability of establishing capacity values. This will most likely involve simulation tools but may include a combination of tools and best judgment based on knowledge of the facility. Declared capacity values would be developed for airports and airspace regions such as sectors.

2. The ability to calculate the demand placed on a facility or region of

airspace. This may be based on the filed time en route (FTE) or an updated demand projection as the flight gets closer to the facility, such as within 100 NM. This is necessary for performance indicators that assess how well demand is being accommodated given the capacity calculated in (1) above.

3. The ability to process trajectory data. This is necessary for all flight efficiency measures that assess actual trajectories against an idealised unimpeded trajectory. The higher fidelity the position information, the more accurate the indicator. ANSP performance groups benefit from entities that can provide a "clean" trajectory source for performance analysis.

4. The ability to determine an ideal unimpeded trajectory. This is important for calculating all flight efficiency measures that assess actual trajectories against an idealised unimpeded trajectory. The benchmark standard used for the ideal unimpeded trajectory can vary based on the assumptions made (e.g., through trajectory modelling or use of statistical methods such a choosing the 5th percentile trajectory travel time as one matching the ideal).

5. The flight plan and flight trajectory efficiency indicators are influenced by several interdependencies such as weather, airport infrastructure and airline demand. For this reason, ANSPs will often develop tools to determine if inefficiency is ANSP-attributable or attributable to other sources.

Therefore, the fifth precursor is the ability to attribute delay or inefficiency to a cause code. Some ANSPs record delay cause codes as provided by the airlines. In Europe, this airline provided information follows the IATA recommended reporting for delay cause codes.

An ANSP may also have procedures or automation tools for assigning delay to the constraining facility or attributing delay to other sources such as extreme weather, security or airline causal reasons.

6

Conclusion and Recommendations

This CANSO report specifies 21 operational KPIs that allow the ANSP to track targeted areas of their systems. Each of these KPIs can have different formulations depending on if facilities are compared to each other (average values) or to their contribution to total system performance (total values). Furthermore, many of these measures can be expressed in either excess distance or excess time. Care should be taken in the use of time, as the same population of flights will show more variability in terms of time than distance. This is largely attributable to wind and aircraft performance.

The KPIs can be used to determine and prioritise areas of improvement as well as communicate to stakeholders how actions can affect the performance of the system. However, most groups will not implement all measures and not all measures are suitable for all purposes. Resources must be prioritised and it is not necessary to track all KPIs to be effective. Therefore, this report recommends that ANSPs limit the use of KPIs to those that provide the best indication of what an ANSP can influence as well as the best indication of how flight efficiency can be improved for the operators.

In assessing the value of investing in the data, tools and personnel to track a particular KPI, the ANSP should consider the following criteria:

1. What is the specific purpose and audience of the KPI?
2. Does the KPI lead to informed decision-making?
3. Does the KPI add value distinct from other KPIs? Can it be shown that management and stakeholders will find inefficiencies from this KPI that would not have been found from existing KPIs?
4. Can the KPI be monetised? Monetisation can be used in the cost/benefit process for program acquisition and to communicate priorities to stakeholders.

In examining current practice, this CANSO report recommends that ANSP operational performance measurement focus on assessing two primary goals:

First, managing demand and capacity to maximise the use of available capacity.

Second, providing the most efficient trajectories possible while meeting safety and capacity utilisation objectives.

The ability of an ANSP to meet these objectives will be strongly influenced by the degree to which the ANSP has control or can influence the flight from gate-out to gate-in. ANSPs in which there is a network manager will have a greater ability to manage demand/capacity as well as provide efficient trajectories for all phases of flight.

However, despite these differences in the scope and influence of ANSPs, there are common metrics that can be employed which address capacity utilisation and flight efficiency. In fact, the measures will provide insight as to when a region would benefit from improvements in traffic flow management and when it will be beneficial to invest in network manager capabilities for a region.

6.1 CANSO Recommended Core KPIs

To assist ANSPs, oversight bodies and other stakeholders in managing and improving system performance, CANSO recommends the following KPIs for capacity and capacity utilisation, as well as flight efficiency. This performance framework does not require that the ANSP control all flight phases, such as the en-route phase of flight, and implementation of these measures in fact can focus on the arrival phase of flight for both capacity utilisation and flight efficiency.

In addition, it is recommended that the ANSP develop procedures for determining efficiency shortfalls that are attributable to the ANSP.

6.1.1 Capacity and Capacity Utilisation

Capacity utilisation measures assess the core operational efficiency ANSP goal of ensuring that resources, such as available airport capacity, are optimised within the given conditions of the system (i.e. weather, airport maintenance etc.) Suggested measures in this category include the capacity utilisation measure described in 5.1 (b) which is a KPI currently in use by several ANSPs. Its advantage is that capacities can be developed to match operating conditions and therefore minimise the effects of external dependencies such as runway maintenance or weather. Furthermore, the KPI does not penalise the ANSP for when demand exceeds the capacity of the facility.

This KPI, however, requires that the ANSP develop rated capacities for the facilities that are being evaluated. These rated capacities may be simplified to one representative value for the facility to a complex set of values that span many conditions such as weather, runway orientation and even fleet mix that would account for different sizes of heavy aircraft that can occur throughout the operating day. The degree of sophistication will depend on the value management and oversight bodies see in the measure in order to justify the investment. In general, the more constrained the facility, the more time the ANSP will spend on defining the declared or rated capacity and even develop different capacities for specific operating conditions. This level of detail may be necessary to determine the source of inefficiency in the system.

6.1.2 Flight Trajectory Efficiency

It is difficult to develop a single ideal flight efficiency indicator that represents the necessary ATM constraints in the system as well as show progress in improving flight efficiency for stakeholders. To form a complete picture, the ANSP will most likely need a set of complementary measures. Furthermore, there may be a KPI for the total flight with specific KPIs calculated for each phase of flight.

Not all ANSPs will control all phases of flight. Many of the ANSPs surveyed for this report controlled the arrival phase of flight and many have either developed or are in the process of developing an arrival flight efficiency measure. These measures are described in 5.2.4.

For other ANSPs that control the en-route phase of flight, one recommended KPI is to compare actual trajectories against a reference great circle trajectory. An example of this for the en-route phase of flight is described in 5.2.3. This KPI will track if actual flight distances are increasing or decreasing over time.

Other KPIs for the airborne phase include system and city pair assessments of whether filed flight plan distances are increasing or decreasing over time. This KPI is described in 5.2.3. The advantage of using the flight plan is that it addresses all the constraints in the systems that are necessary for safe separation of aircraft.

Airborne flight efficiency measures make direct attempts to track improvements for stakeholders by focusing on the actual trajectories compared to a benchmark ideal trajectory. The challenge for the ANSP is then to assess the feasibility of the benchmarks and determine if the benefit identified by improving the KPI can be realised without degrading performance elsewhere.

6.1.3 ANSP Attributable Delay

As described in Chapter 4, ANSP operational performance is complicated by the degree to which the measure is influenced by factors outside the control of the ANSP. If resources allow, KPIs should be supported by other measures or software that allow the ANSP to determine causal reasons for how performance improves or degrades. Using delay or punctuality as an example, the KPI becomes ANSP-attributable delay or ANSP-attributable punctuality.

For the core CANSO recommended measures in this chapter, capacities may be developed that reflect the specific interdependencies of weather, fleet mix as well as runway conditions. Flight efficiencies may also be linked to weather conditions in order to separate out ideal versus non-ideal conditions. However, it is recommended that the ANSP have the ability to report on all conditions to management and stakeholders. Tactical use of the measures may show ANSPs utilising the system as efficiently as possible while strategic use of the measures may show opportunities for investment in technology or procedure re-design. The latter is only possible if all conditions, ANSP-attributable or not, are reported.

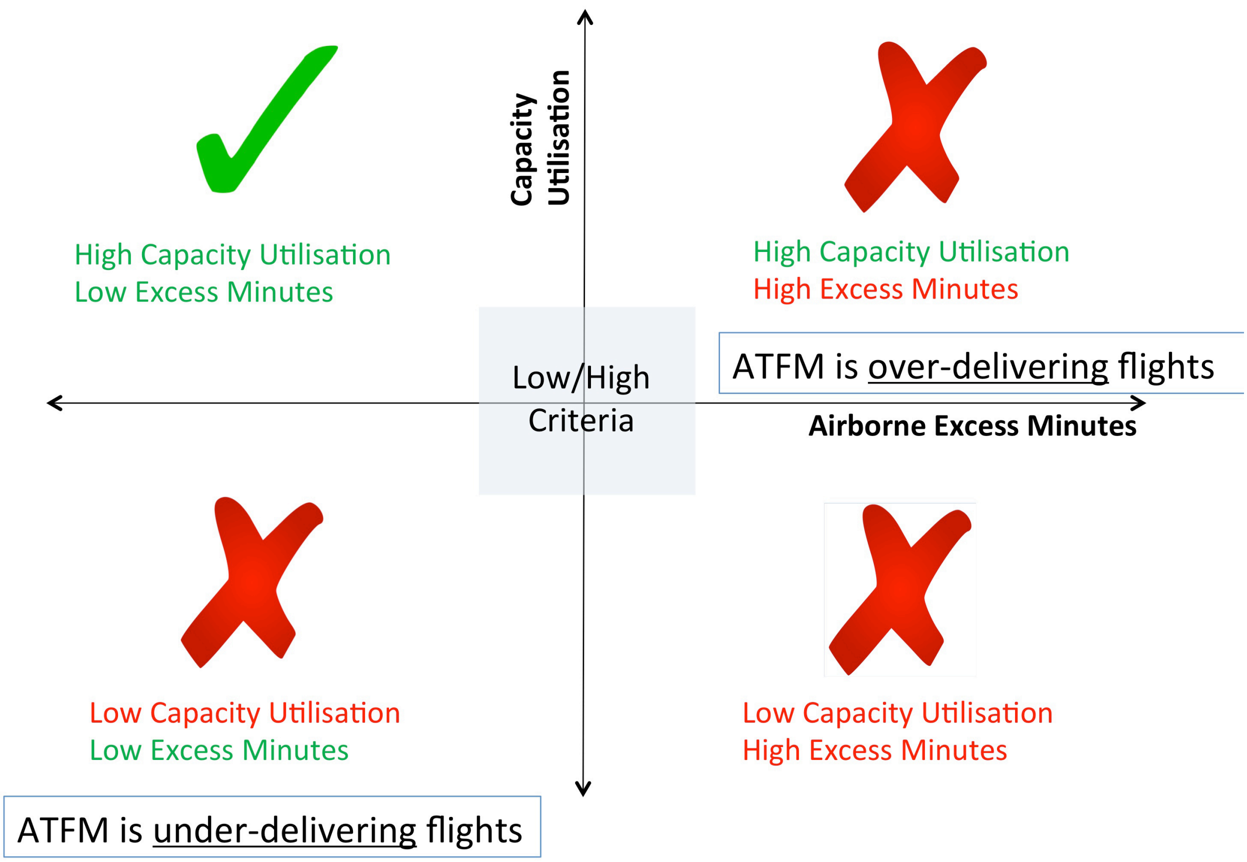


Figure 10 – Framework for Capacity Utilisation/Arrival Flight Phase Efficiency

ANSPs with network, arrival or departure managers should have the ability to record ANSP imposed delay as well as the causal reason (weather, staffing, equipment etc.) for delaying the flight. These systems would capture delay cause codes (such as the IATA codes) or provide linkage to weather events that could assist in correlating the effects of weather on performance. This KPI is described in Section 5.3 (a) and has demonstrated use by ANSPs.

6.2 Application of Core Recommended KPIs

The core recommended KPIs of capacity utilisation and flight efficiency might involve trade-offs that reflect the value of capacity. In these cases, capacity is developed with an assumed target level of delay for the aircraft. ANSPs, oversight bodies and other stakeholders will need a common understanding of what constitutes low/high capacity utilisation as well as low/high flight efficiency. Figure 10 on the previous page shows a specific application framework using flight efficiency in the arrival phase of flight.

In the example framework in Figure 10, the ANSP has developed low/high criteria for capacity utilisation and flight efficiency in the arrival phase. As an example, the ANSP and stakeholders may have agreed on a target level of delay, which averages five minutes per flight. All scenarios with more than five minutes average delay are considered high and all scenarios with an average of less than five minutes are considered low or acceptable. Similarly, the ANSP may have set 95 percent as the target level of capacity utilisation. In these cases, all scenarios with less than 95 percent capacity utilisation are considered low and all scenarios with greater than or equal to 95 percent utilisation are considered high.

This framework divides ATC operational scenarios into four possible outcomes. The upper left quadrant of Figure 10 shows the ideal outcome for the ANSP with both capacity utilisation and flight efficiency reaching their target levels. The lower right quadrant shows the other extreme with both capacity utilisation and flight efficiency below their target levels.

The upper right and lower left quadrants demonstrate operational scenarios where only one KPI meets the target level of service. For the upper right, capacity utilisation meets the target but at a cost of flight efficiency that has high excess minutes. This is usually observed by holding patterns or long downwind flight paths in the vicinity of the airports. It may be evidence that aircraft are being over-delivered to the ANSP or facility. For the lower left quadrant, flight efficiency meets the target criteria. However, the KPI for capacity utilisation indicates the facility is under-utilised. In both of these latter cases, the solution most likely requires improvements in air traffic flow management and improvements in the network manager role for the region.

7

References

1. **International Civil Aviation Organization**, "ICAO Manual on Global Performance of the Air Navigation System," Doc 9883, ICAO, 2009.

2. **Civil Air Navigation Services Organisation**, "CANSO Air Navigation Services Performance Report 2012," http://www.canso.org/cms/streambin.aspx?requestid=92AF6FDB-1EDB-4A96-931D-4C48AF1B8C82

3. **European Union**, "Commission Regulation (EU) 390/2013," Official Journal of the European Union, 2010, May 2013.

4. **Civil Air Navigation Services Organisation**, "CANSO Safety Performance Benchmarking Report" Access restricted to CANSO Members only. http://www.canso.org/safety/committees

5. **Airservices Australia**, "Services Charter 2011-2012," 2011. http://www.airservicesaustralia.com/wp-content/uploads/11-114BKT_Services_Charter-WEB.pdf

6. **International Civil Aviation Organization**, "EUR Regional Performance Framework Document," Doc 030, April 2013. http://www.paris.icao.int/documents_open/download.php?maincategory=48&subcategory=170&file=EUR%20Doc%20030_%20EUR%20Performance%20Framework.pdf

7. **NATS**, "NATS Fuel Efficiency Metric" OA 1161, Version 1.3, January 2012. http://www.nats.aero/wp-content/uploads/2012/03/fuelEfficiencyMetric.pdf

8. **EUROCONTROL**, Performance Review Commission, "Performance Review Report: An Assessment of Air Traffic Management in Europe during the Calendar Year 2012," May 2013. http://www.eurocontrol.int/sites/default/files/prr-2012.pdf

9. **EUROCONTROL**, Performance Review Unit, "The PRC's European ATM Performance Measurement System," January 1999. https://www.eurocontrol.int/sites/default/files/content/documents/single-sky/pru/publications/other/prc-eu-atm-perf-measurement-system.pdf

10. **Federal Aviation Administration**, EUROCONTROL, "2013 Comparison of Air Traffic Management-Related Operational Performance: U.S./Europe," June 2014. http://www.faa.gov/air_traffic/publications/media/us_eu_comparison_2013.pdf

11. **International Civil Aviation Organization**, "Global Air Traffic Management Operational Concept," Doc 9854, ICAO, 2005.

12. **International Civil Aviation Organization**, "2013-2028 Global Air Navigation Plan, 4th Edition", ICAO 2013

13. **Airbus**, "Getting to Grips with the Cost Index," Airbus, 1998.

14. **Federal Aviation Administration**, "Delay Propagation," April 2009. http://aspmhelp.faa.gov/index.php/Delay_Propagation

15. **Beatty, R., Hsu, R., Berry, L. and Rome, J**. "Preliminary evaluation of flight delay propagation through an airline schedule," 2nd USA/Europe Air Traffic Management R&D Seminar, Orlando, 1998

16. **NATS Holdings Limited**, "Annual Report and Accounts 2013," June 2013. http://www.nats.aero/news/annual-report-accounts-2013/

17. **Federal Aviation Administration**, "Operational Data Reporting Requirements," OPSNET Order JO 7210.55F. March 2011. http://www.faa.gov/documentLibrary/media/Order/7210.55F.pdf

18. **International Air Transport Association**, "Airport Handling Manual: Standard IATA Delay Codes," (730 &731).

19. **Civil Air Navigation Services Organisation**, "Methodologies for Calculating Delays/Improvement Opportunity Pools By Phase of Flight," May 2013. http://www.canso.org/cms/streambin.aspx?requestid=CB940A7D-4BA1-4D15-A21D-619911E23D93

20. **United States Department of Transportation, Bureau of Transportation Statistics**, "Understanding the Reporting of Causes of Flight Delays and Cancellations." http://www.rita.dot.gov/bts/help/aviation/html/understanding.html#q7

Appendix 1

CANSO Operational Performance KPIs

KPAs	Key Performance Indicators (KPIs)	Example KPI Form Definitions
Capacity	Declared Capacity	Target acceptance rate for a facility or sector
	Capacity Efficiency	Percentage of Demand Accommodated by Facility's Capacity and Actual Demand
	Delay Attributed to Capacity Limits	Total or Average Delay by Airport
		Total or Average Facility Attributable Delay
Efficiency	Gate Departure Delay	Number of Gate Departure Delayed Aircraft
		Average Gate Departure Delay per Flight
		Average Gate Departure Delay per Delayed Flight
	Taxi Out Delay	Number of Taxi-Out Delayed Aircraft
		Average Taxi-Out Delay per Flight
		Average Taxi-Out Delay per Delayed Flight
	Calculated Take-Off Time Compliance	Calculated Take-Off Time Compliance
		Number of Early Departures
		Number of Late Departures
	Terminal Departure Flight Distance/ Time Efficiency	Number of Departing Aircraft Delayed in the Terminal Airspace
		Average Departure Delay per Flight
		Average Departure Delay per Delayed Flight
	Terminal Departure Level Flight Efficiency	Actual level flight time/distance from take-off to 40/100 NM circle.
	En Route Direct Route Extension	Average or Total Actual Flight Distance/Time above that obtained from a great circle benchmark.
	Filed Flight Plan En Route Extension	Average of Total Filed Distance/Time above that obtained from a great circle benchmark
	Arrival Flight Distance/Time Efficiency	Total or Average Excess Minutes or Miles by Aircraft Group, Operating Configuration, or Arrival Airport
	Arrival Level Flight Efficiency	Actual level flight time/distance from 100/40 NM circle landing.
	Arrival Runway Occupancy Time	Average Runway Occupancy Time per Aircraft Category
	Taxi In Delay	Number of Taxi-In Aircraft Delayed
		Average Taxi-In Delay per Flight
		Average Taxi-In Delay per Delayed Flight
	Gate Arrival Delay	Number of Gate Arrival Delayed Aircraft
		Average Gate Arrival Delay per Flight
		Average Gate Arrival Delay per Delayed Flight
	ATM Attributable Delay	Delay against a schedule or a filed time that can be attributed to ATM.
	Average Flight Time Between City Pairs	Average Travel Time Between City Pairs.
Capacity and Efficiency	Operational Availability	(Maximum facility service hours minus outage time) divided by maximum facility service hours.
Predictability	Capacity Variation	Difference between the 85th and 15th percentile declared capacity for a facility.
	Travel Time Variation	Difference between the 85th and 15th percentile travel time for a phase of flight for a city pair.
	Flight Plan Variation	Difference between the 85th and 15th percentile flight plan distance or time for a city pair.

Appendix 2

ICAO Performance Indicators

Table 3 - ICAO Doc 9883 - Key Performance Areas and Key Performance Indicators

Key Performance Area	ICAO Key Performance Indicators
Access and Equity	Unsatisfied demand versus overall demand
Capacity	Number of flights or flight hours that may be accommodated. *Separate measures for airspace and airport either through models or though actual values.* *Values may be specific for a weather condition.*
Cost Effectiveness	Average cost per flight Total operating cost plus cost of capital divided by IFR flights Total labour obligations to deliver one forecast IFR flight. *All of the above using flight hour instead of flight to normalise for flight duration*
Efficiency	Percentage of flights departing on-time. Percentage of flights with on-time arrival. Average departure delay per delayed flight Percentage of flights with normal flight duration. Average flight duration extension of flights with extended flight duration. Total number of minutes to actual gate arrival time exceeding planned arrival time. *For all of the above consider 1) ATM caused delay, 2) target time for delay (filed or schedule) and 3) delay threshold value (i.e. 15 minutes)*
Environment	Amount of emissions attributable to ATM inefficiency Number of people exposed to significant noise Fuel efficiency per revenue plane-mile
Flexibility	Number of rejected changes to the number of proposed changes to the number of flight plans initially filed each year Proportion of rejected changes for which an alternative was offered and taken.
Global Interoperability	Number of filed differences with ICAO Standards and Recommended Practices. Level of compliance of ATM operations with ICAO CNS/ATM plans and global interoperability requirements.
Participation by ATM Community	Number of yearly meetings covering planning, implementation and operations.
Predictability	Closely related to delay measures under efficiency *Possible refinement to delay measures by phase of flight.*
Safety	Number of accidents normalised to either number of operations or number of flight hours
Security	Number of acts of unlawful interference to ATC Number of incidents involving direct unlawful interference to aircraft that require air traffic service provider response Number of incidents due to unintentional factors such as human error, natural disasters, etc., that have led to unacceptable reduction in air navigation system capacity

There are eighteen ASBU Block 0 modules defined in the Global Air Navigation Plan (GANP, ICAO Doc 9750). They are:

Airport Operations
— APTA: Optimisation of Approach Procedures including Vertical Guidance
— WAKE: Increased Runway Throughput through Optimised Wake Turbulence Separation
— SURF: Safety and Efficiency of Surface Operations
— ADCM: Improved airport Operations through Airport Collaborative Decision Making
— RSEQ: Improved Traffic Flow through Sequencing

Globally Interoperable Systems & Data
— FICE: Increased Interoperability, Efficiency and Capacity through Ground –Ground integration
— DATM: Service Improvement through Digital Aeronautical Information Management (Note: DATM integrates all digital ATM information in Block 1.)
— AMET: Meteorological Information Supporting Enhanced Operational Efficiency and Safety

Optimum Capacity & Flexible Flights
— FRTO: Improved Operations through Enhanced En0route Trajectories
— NOPS: Improved Flow Performance through Planning based on a Network-wide View
— ASUR: Initial Capacity for Ground Surveillance
— ASEP: Air Traffic Situational Awareness (ATSA)
— OPFL: Improved Access to Optimum Flight Levels through Climb/Decent Procedures using ADS-B
— ACAS: Airborne Collision Avoidance Systems (ACAS) Improvements
— SNET: Increased Effectiveness of Ground-Based Safety Nets

Efficient Flight Paths
— CDO: Improved Flexibility and Efficiency in Descent Profiles using Continuous Descent Operations (CDOs)
— TBO: Improved Safety and Efficiency through the Initial Application of Data Link En-route
— CCO: Improved Flexibility and Efficiency Departure Profiles using Continues Climb Operations (CCOs)

The Global Air Navigation Plan indicates the relationship between ASBU Modules and KPAs. The Table 4 shows ASBU Block 0 modules and their supporting KPAs. The Air Navigation Report Form has selected five (5) KPAs namely, access and equity, capacity, cost effectiveness, efficiency and safety to be reported. These 5 KPAs are highlighted in bold letters in Table 4 on the next page.

	Airport Operations					Globally Interoperable Systems and Data			Optimum Capacity and Flexible Flights							Efficient Flight Paths		
Key Performance Area	APTA	WAKE	SURF	ACDM	RSEQ	FICE	DATM	AMET	FRTO	NOPS	ASUR	ASEP	OPFL	ACAS	SNET	CDO	TBO	CCO
Access & Equity	X	X	X						X	X								
Capacity	X	X	X	X	X	X		X	X	X	X		X				X	
Cost	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X
Efficiency	X		X	X	X	X		X	X	X	X	X	X	X		X	X	X
Environment	X		X	X			X	X	X	X			X					X
Flexibility		X			X	X		X	X								X	
Interoperability						X	X	X										
Participation								X		X								
Predictability					X			X	X	X						X		
Safety	X		X				X	X		X	X	X	X	X	X	X	X	X

Table 4 - ICAO Key Performance Areas for ASBU Block 0

There are eight sections in the Air Navigation Report Form (ANRF) with an example provided in Figure 11 on the next page.

- Section 1: Describe the ICAO Region or Member State.
- Section 2: Describe the ASBU module selected to be implemented.
- Section 3: Identify which KPAs are impacted by this module.
- Sections 4, 5, and 6: Describe planned implementation elements and its implementation date/year.
- Section 7: Describe the implementation challenges
- Section 8: Describe performance monitoring and measurement. This section is further sub-divided into two sections, section 8A and section 8B describing implementation monitoring and performance monitoring, respectively.
- Section 8A: Describe implementation monitoring elements and its performance indicators/supporting metrics.
- Section 8B: Describe performance monitoring elements and its metrics.

ICAO has filled in the majority of sections with samples tailored for each module. Regions and Member States are expected to select which modules to implement based on their operational needs and modify the contents of the sample ANRF as appropriate. Note that the information regarding ANRF is gathered from ICAO headquarters and multiple ICAO Regions in different times. Regions and Member States have some liberty to interpret these indicators and supporting metrics when reporting. Further coordination between ICAO, CANSO and Member States is needed to use ANRF.

<table>
<tr><th colspan="6">1. AIR NAVIGATION REPORT FORM (ANRF)
MY STATE Planning for ASBU Modules
2. REGIONAL/NATIONAL PERFORMANCE OBJECTIVE – B0-05/CD0:
Improved Flexibility and Efficiency in Descent Profiles (CDO)
Performance Improvement Area 4: Efficient Flight Path</th></tr>
<tr><td colspan="6">3. ASBU B0-05/CDO: Impact on Main Key Performance Areas (KPA)</td></tr>
<tr><td></td><td>Access & Equity</td><td>Capacity</td><td>Efficiency</td><td>Environment</td><td>Safety</td></tr>
<tr><td>Applicable</td><td>N</td><td>N</td><td>Y</td><td>N</td><td>Y</td></tr>
<tr><td colspan="6">4. ASBU B0-05/CDO: Planning Targets and Implementation Progress</td></tr>
<tr><td colspan="3">5. Elements</td><td colspan="3">6. Targets and implementation progress (Ground and Air)</td></tr>
<tr><td colspan="3">1. CDO implementation</td><td colspan="3">2015</td></tr>
<tr><td colspan="3">2. PBN STARs</td><td colspan="3">2015</td></tr>
<tr><td colspan="6">7. ASBU B0-05/CDO: Implementation Challenges</td></tr>
<tr><td colspan="2" rowspan="2">Elements</td><td colspan="4">Implementation Area</td></tr>
<tr><td>Ground System Implementation</td><td>Avionics Implementation</td><td>Procedures Availability</td><td>Operational Approvals</td></tr>
<tr><td colspan="2">1. CDO implementation</td><td>The ground trajectory calculation function will need to be upgraded.</td><td>CDO Function</td><td>Letters of Agreement and Training</td><td rowspan="2">In accordance with application requirements</td></tr>
<tr><td colspan="2">2. PBN STARs</td><td>Airspace Design</td><td></td><td>LOAs and Training</td></tr>
<tr><td colspan="6">8. ASBU B0-05/CDO: Performance Monitoring and Measurement
8A. ASBU B0-05/CDO: Implementation Monitoring</td></tr>
<tr><td colspan="3">Elements</td><td colspan="3">Performance Indicators/Supporting Metrics</td></tr>
<tr><td colspan="3">1. CDO implementation</td><td colspan="3">Indicator: percentage of international aerodromes/TMA with CDO implemented
Supporting metric: number of international aerodromes/ TMAs with CDO implemented</td></tr>
<tr><td colspan="3">2. PBN STARs</td><td colspan="3">Indicator: percentage of international aerodromes/TMA with PBN STAR implemented
Supporting metric: number of international aerodromes/ TMAs with PBN STAR implemented</td></tr>
<tr><td colspan="6">8. ASBU B0-05/CDO: Performance Monitoring and Measurement
8 B. ASBU B0-05/CDO: Performance Monitoring</td></tr>
<tr><td colspan="3">Key Performance Areas</td><td colspan="3">Metrics (if not indicate qualitative Benefits)</td></tr>
<tr><td colspan="3">Access & Equity</td><td colspan="3">NA</td></tr>
<tr><td colspan="3">Capacity</td><td colspan="3">NA</td></tr>
<tr><td colspan="3">Efficiency</td><td colspan="3">Cost savings through reduced fuel burn. Reduction in the number of required radio transmissions</td></tr>
<tr><td colspan="3">Environment</td><td colspan="3">Reduced emissions as a result of reduced fuel burn ICAO Fuel Savings Estimation Tool (IFSET)</td></tr>
<tr><td colspan="3">Safety</td><td colspan="3">More consistent flight paths and stabilised approach paths. Reduction in the incidence of controlled flight into terrain (CFIT)</td></tr>
</table>

Figure 11 - Sample ANRF using ASBU Block 0 Module - Continuous Decent Operation

Appendix 3

Abbreviations

ACARS: Aircraft Communications Addressing and Reporting System	IATA: International Air Transport Association
ANRF: Air Navigation Report Form	ICAO: International Civil Aviation Organization
ANSP: Air navigation service provider	IFSET: ICAO Fuel Savings Estimation Tool
ASBU: Aviation System Block Upgrade	ILS: Instrument landing system
A-SMGCS: Advance Surface Movement Guidance and Control Systems	KPA: Key performance area
ATC: Air traffic control	KPI: Key performance indicator
ATFM: Air traffic flow management	NM: Nautical mile
ATM: Air traffic management	OOOI: Gate Out, Wheels Off, Wheels On, Gate In
CCO: Continuous climb operations	PBA: Performance based approach
CDM: Collaborative decision-making	PBN: Performance-based navigation
CDO: Continuous descent operations	PIRGS: Planning and Implementation Regional Groups
CFIT: Controlled flight into terrain	RADAR: Radio Detection And Ranging
CTOT: Calculated take off time	RT: Radio telephony
FIR: Flight Information Region	SUA: Special use airspace
FTE: Filed time en route	TFM: Traffic flow management
GANP: Global Air Navigation Plan	TMI: Traffic management initiative

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— DCA Myanmar
— Department of Airspace Control (DECEA)
— Department of Civil Aviation, Republic of Cyprus
— DFS Deutsche Flugsicherung GmbH (DFS)
— Dirección General de Control de Tránsito Aéreo (DGCTA)
— DSNA France
— Dutch Caribbean Air Navigation Service Provider (DC-ANSP)
— ENANA-EP ANGOLA
— ENAV S.p.A: Società Nazionale per l'Assistenza al Volo
— ENAIRe
— Estonian Air Navigation Services (EANS)
— Federal Aviation Administration (FAA)
— Finavia Corporation
— General Authority of Civil Aviation (GACA)
— Ghana Civil Aviation Authority (GCAA)
— Hellenic Civil Aviation Authority (HCAA)
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— Israel Airports Authority (IAA)
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— Serco
— skyguide
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— Micro Nav Ltd
— The MITRE Corporation – CAASD
— MLS International College
— MovingDot
— NEC Corporation
— NLR
— Northrop Grumman
— NTT Data Corporation
— Núcleo de Comunicaciones y Control, S.L.U.
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