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of Transportation
**Federal Aviation
Administration**

MARCH 2019



2017

**COMPARISON OF AIR TRAFFIC MANAGEMENT-RELATED
OPERATIONAL PERFORMANCE: U.S./EUROPE**

PRODUCED BY:
EUROCONTROL ON BEHALF OF THE EUROPEAN UNION
FAA AIR TRAFFIC ORGANIZATION SYSTEM OPERATIONS SERVICES

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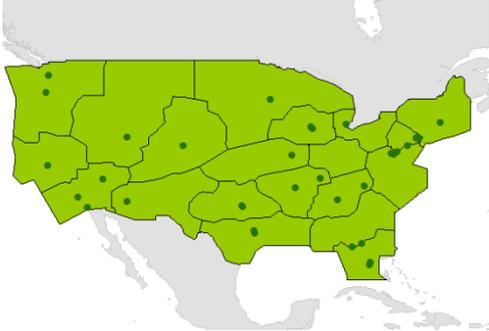
It is prepared in application of Appendix 2 to Annex 1 of the Memorandum of Cooperation NAT-I-9406A signed between the United States of America and the European Union on 13 December 2017 and managed by a joint European Commission-FAA Performance Analysis Review Committee (PARC). The report builds on the body of work developed since 2009 between the FAA and EUROCONTROL.

The objective is to make a factual high-level comparison of Air Traffic Management performance between the U.S. and Europe. It is based on a set of comparable performance indicators, developed jointly and reviewed year after year, creating a sound basis for factual comparisons between countries and world regions. The specific Key Performance Indicators (KPIs) are based on best practices from both the Air Traffic Organization System Operations Services and the performance scheme of the Single European Sky initiative.

Rolf Tuchhardt
PARC Co-Chair, European Commission

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FAA/ATO (CONUS) area



10.4 million km²

1 service provider

26 stand alone approach control facilities

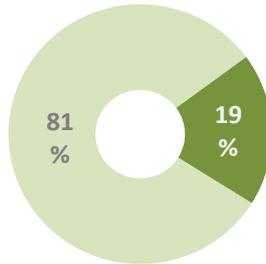
20 en-route facilities

517 airports with ATC services



AVERAGE DAILY FLIGHTS

41 874



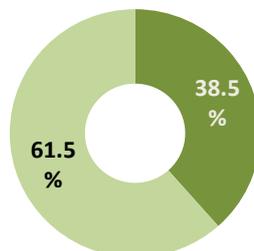
19%

share of general aviation (IFR)



TOTAL STAFF

31 647

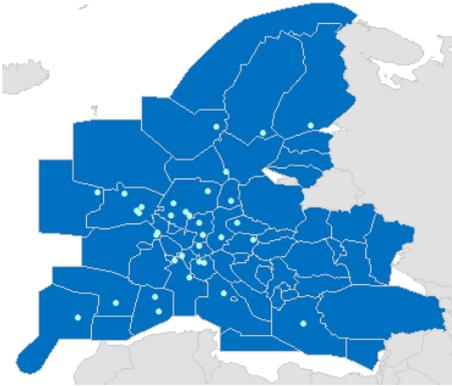


ATCOs in OPS

12 170

(38.5% of total staff)

EUROCONTROL area



11.5 million km²

37 service providers

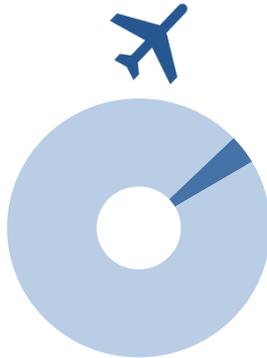
16 stand alone approach control facilities

62 en-route facilities

406 airports with ATC services

AVERAGE DAILY FLIGHTS

28 475

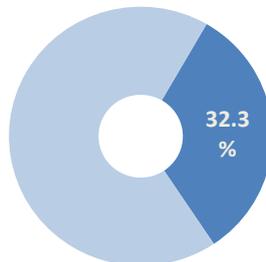


3.5%

share of general aviation (IFR)

TOTAL STAFF

55 130



ATCOs in OPS

17 794

(32.3% of total staff)

This report is available on the EUROCONTROL website at www.ansperformance.eu

2017 Comparison of ATM-related performance: U.S. – Europe

March 2019

ABSTRACT

This report is the sixth in a series of joint ATM operational performance comparisons between the U.S. and Europe. It represents the third edition under the Memorandum of Cooperation between the United States and the European Union. Building on established operational Key Performance Indicators, the goal of the joint study conducted by the Federal Aviation Administration (FAA) and EUROCONTROL on behalf of the European Union is to understand differences between the two ATM systems in order to further optimize ATM performance and to identify best practices for the benefit of the overall air transport system. The analysis is based on a comparable set of data and harmonized assessment techniques for developing reference conditions for assessing ATM performance.

Produced by EUROCONTROL on behalf of the European Union and the Federal Aviation Administration Air Traffic Organization System Operations Services

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EXECUTIVE SUMMARY

This report is the sixth in a series of joint ATM operational performance comparisons between the U.S. and Europe. It represents the third edition under the Memorandum of Cooperation between the United States and the European Union. The report provides a comparative operational performance assessment between Europe and the U.S. using Key Performance Indicators (KPIs) that have been harmonized by both groups. The report provides demonstrated examples of the KPIs listed in the ICAO Global Air Navigation Plan (GANP) which can be used to assess the benefits of the global implementation of Aviation System Block Upgrades (ASBUs).

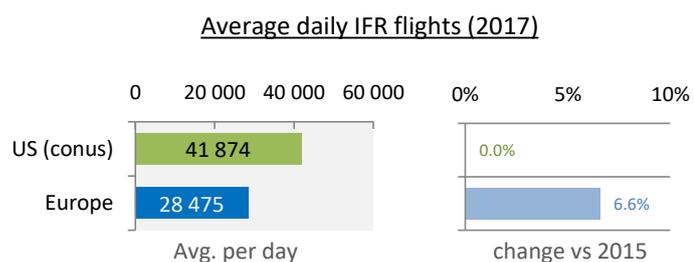
The indicators used are those proven to meet key Air Navigation Service Provider (ANSP) objectives of identifying system constraints through delay/capacity measures and improving flight efficiency by measuring actual trajectories against an ideal. The report also includes punctuality and block time indicators that relate performance more directly to the airline/passenger perspective.

The first part of this report examines commonalities and differences in terms of air traffic management and performance influencing factors, such as air traffic demand characteristics and weather, which can have a large influence on the observed performance.

Overall, air navigation service provision is clearly more fragmented in Europe with more ANSPs and physical facilities than in the U.S. The European area comprises 37 ANSPs with 62 en-route centers and 16 stand-alone Approach Control (APP) units (total: 78 facilities). The U.S. CONUS has 20 en-route centers supplemented by 26 stand-alone Terminal Radar Approach Control (TRACON) units (total: 46 facilities), operated by one ANSP.

Although the U.S. CONUS airspace is 10% smaller than the European airspace, the U.S. controlled approximately 47% more flights operating under Instrument Flight Rules (IFR) with 32% fewer full time Air Traffic Controllers (ATCOs) than in Europe in 2017. However, this percentage narrows to 22% more controllers in Europe when FAA developmental controllers and European on-the-job trainees are also considered. U.S. airspace density is, on average, higher and airports tend to be notably larger than in Europe.

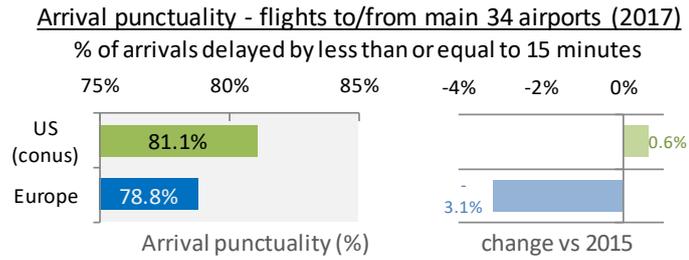
In terms of traffic evolution, there was a notable decoupling between the U.S. and Europe in 2004 when the traffic in Europe continued to grow while U.S. traffic started to decline to reach a plateau in 2011. Between 2000 and 2017, traffic in Europe grew by 23.1% but declined in the U.S. by -14.7% over the same time period. Between 2015 and 2017 U.S. CONUS traffic remained almost unchanged but traffic at the main 34 airports reported a growth of 2.1%. In Europe, traffic increased by 6.6% between 2015 and 2017 with a slightly lower increase of 5.2% at the main 34 airports.



The second part of this report analyses operational performance in both systems from an airline and from an ANSP point of view. The airline perspective evaluates efficiency and predictability compared to published schedules whereas the ANSP perspective provides a more in-depth analysis of ATM-related performance by phase of flight compared to an ideal benchmark distance or time. For the majority of indicators, trends are provided from 2008 to 2017 with a focus on the change in performance from 2015 to 2017.

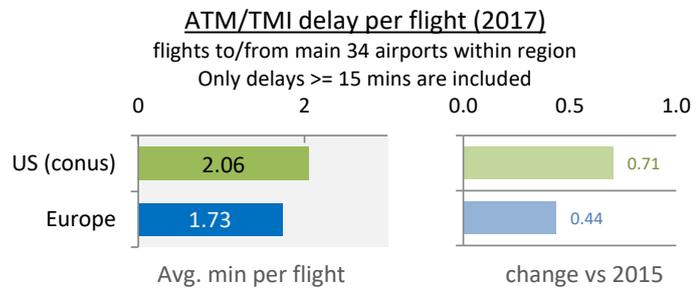
Punctuality is generally considered to be the industry standard indicator for air transport service quality.

The level of arrival punctuality was higher in the U.S. with 81.1% of flights arriving within 15 minutes of their scheduled arrival time in 2017 compared to 78.8% in Europe. Between 2015 and 2017, performance improved slightly in the U.S. whereas arrival punctuality in Europe degraded by 3.1% points versus 2015.



While the evaluation of air transport performance compared to airline schedules provides valuable first insights, the involvement of many different stakeholders and the inclusion of time buffers in airline schedules limit the analysis from an air traffic management point of view. Hence, the evaluation of ATM-related performance in this comparison aims to better understand and quantify constraints imposed on airspace users through the application of air traffic flow measures and therefore focuses more on the efficiency of operations by phase of flight compared to an unconstrained benchmark distance or time.

Both systems reported an increase in Air traffic flow management (ATFM)/Traffic Management Initiative (TMI) delays between 2015 and 2017. The ATM/TMI delay per flight summary corresponds to ATM-related departure restrictions explained in detail in section 5.3.1.

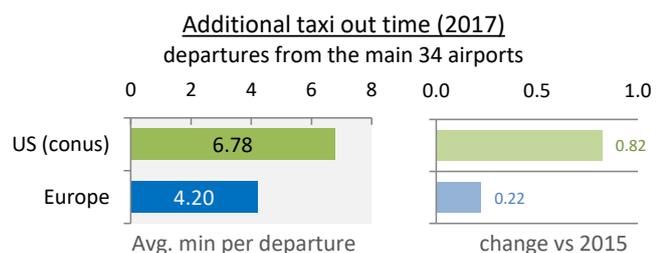


In 2017 in the U.S., the delay per flight (2.06 min per flight) was higher than in Europe (1.73 min) for flights to and from the main 34 airports within region, but the underlying drivers and the constraining locations are fundamentally different in the two systems.

Europe ascribes a greater percentage of delay to en-route facilities (51.6% of total delay in 2017) while in the U.S. the large majority is ascribed to constraints at the airport (82.8% of total delay in 2017). In the U.S., the seven most constraining airports (Newark, San Francisco, New York LaGuardia, New York JFK, Los Angeles, Boston, and Chicago O’Hare) accounted for 68.4% of total ATFM delay in 2017. In Europe on the other hand 40% of total ATFM delays was generated by seven en-route facilities (Karlsruhe, Maastricht, Marseille, Brest, Bordeaux, Nicosia and Barcelona).

Taxi-out efficiency in the U.S. improved notably between 2008 and 2012, which reduced the observed gap between the U.S. and Europe. In 2012, the additional time in the taxi-out phase started to increase in the U.S. while in Europe it continued to improve until 2014 when it also started to increase again.

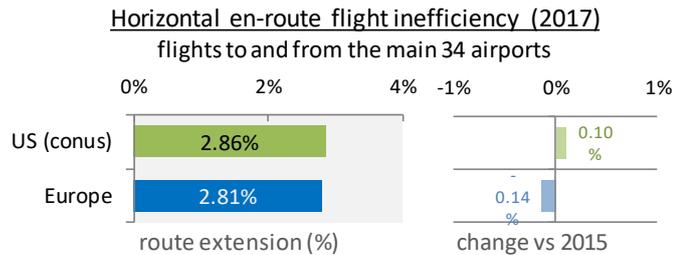
Between 2015 and 2017, additional taxi-out time increased in both systems but with a higher rate in the U.S. For the increase in additional taxi-out time in the U.S. from 2017 (+0.82 min per departure), almost half is driven by increases at San Francisco, Los Angeles, Newark, and Seattle. Runway/taxiway construction



projects at San Francisco and Los Angeles along with increase in departure operations at Seattle and Newark contributed to the overall increase in additional taxi-out time in the U.S.

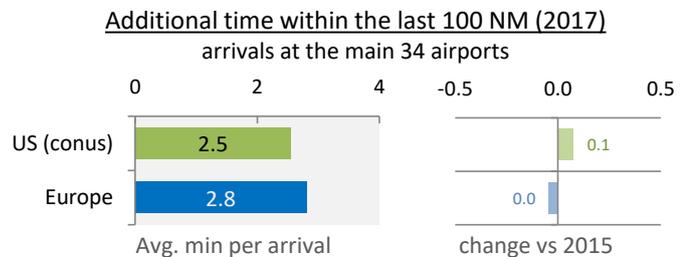
Overall, additional taxi-out time in 2017 was 2.5 minutes higher per departure than in Europe which is largely driven by different flow control policies and the absence of scheduling caps at most U.S. airports. While in Europe the inefficiencies are more evenly spread among airports, in the U.S. half of taxi-out inefficiency is driven at eight airports (Chicago ORD, New York LGA, Dallas DFW, New York JFK, Los Angeles, Atlanta, Charlotte, and Newark). These airports have high contributions to system totals based due to both high averages and the large number of operations at the facility.

Both systems show a comparable level of flight “inefficiency” in the en-route phase of the actual trajectories (between a 40 NM radius around the departure airport and a 100 NM radius around the arrival airport). Between 2015 and 2017 the inefficiency in the en-route phase



of the actual trajectories slightly decreased in Europe and increased in the U.S. The improvement in Europe is to some extent driven by the gradual implementation of Free Route Airspace which aims at removing the rigid route network in order to give airspace users more choices to file their flight plans. The increase in the U.S. is attributable to flights arriving at Seattle from West Coast airports (LAX & SFO) and flights arriving at New York JFK and Atlanta along with the presence of Special Use Airspace (SUA) at the coastal regions. The impact of SUA on flight efficiency indicators can be clearly seen but its unique impact is not quantified in this report.

Contrary to en-route flight efficiency, the U.S. showed a higher level of efficiency in the last 100 NM before landing. At system level, average additional ASMA time was 2.5 minutes per arrival in the U.S. in 2017 which was 0.3 minutes lower than in Europe.



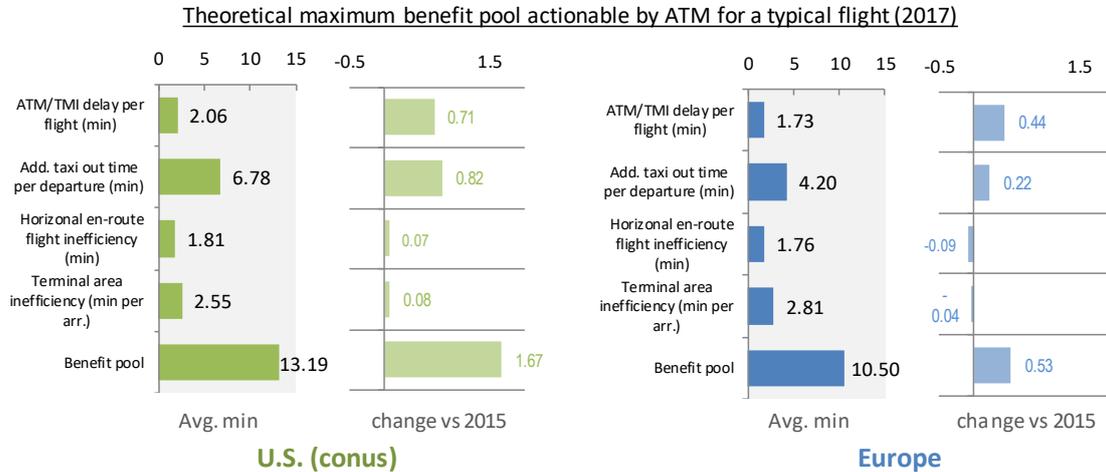
Although at different levels, performance in the U.S. and in Europe remained relatively stable between 2015 and 2017. In Europe the result is significantly affected by London Heathrow airport which had

an average additional time of 9.5 minutes per arrival which is almost twice as high as the second highest airport. In the U.S., efficiency levels in the terminal area are more homogenous.

Vertical flight efficiency in terms of average distance flown level per flight during the descent increased by 1.5 NM to 14.4NM per flight in Europe from 2015 to 2017 while it decreased by 2.5 NM to 28.0NM per flight in the U.S in the same time period. Still, the U.S. results are roughly double the European results, although the potential fuel saving per flight is roughly the same in both regions due to differences in aircraft mix and level segments at higher altitudes in the US (which have a lower environmental impact). The amount of level flight during the climb phase is significantly lower than during the descent phase. As a result, the total potential fuel savings for arriving flights is 10 times higher than the potential savings for departing flights.

As there are many trade-offs between flight phases, the aggregation of the observed results enables a high-level comparison of the theoretical maximum “benefit pool” actionable by ATM in both systems. For the interpretation of the observed results, it is important to stress that the

determined “benefit pool” is based on a theoretical optimum (averages compared to unimpeded times), which is, due to inherent necessary (safety) or desired (capacity) limitations, clearly not achievable at system level. For example, the authority for managing demand capacity imbalances through airport slot controls may involve more than the ANSP and delays due to severe weather are often beyond ANSP’s control.



Overall, the relative distribution of the ATM-related inefficiencies associated with the different phases of flight is consistent with the differences in flow management strategies described throughout the report. In Europe ATM-related departure delays (ATM/TMI) are much more frequently used for balancing demand with en-route and airport capacity than in the U.S., which leads to a notably higher share of traffic affected but with a lower average delay per delayed flight. Moreover the share of en-route-related TMIs in Europe is 51.6% while in the U.S. it is 17.2% as majority of the TMIs in the U.S. are airport-related (82.8%).

Consequently, in Europe flights are three times more likely to be held at the gate or on the ground for en-route constraints than in the U.S, however, the delay per delayed flight is higher in the U.S (28 vs 36 minutes). The percentage of flights delayed at the departure gate or on the surface for arrival airport-related constraints is higher in Europe than in the U.S., however, the delay per delayed flight in the U.S. is more than twice as high as in Europe (31 vs 71 minutes).

Although in a context of increasing traffic, system-wide ATM performance deteriorated in the U.S. and in Europe between 2015 and 2017.

The degradation in Europe between 2015 and 2017 was mainly driven by an increase in ATFM delay in a limited number of en-route facilities combined with an increase in additional taxi time. In the U.S., traffic increased at a more moderate rate than in Europe but the level of ATM-related inefficiencies increased at a higher rate compared to Europe between 2015 and 2017. The increase in the U.S. is mainly related to a limited number of key airports which experienced higher levels of weather-related ATFM delays. Newark also saw schedule peak increases after moving from IATA Level 3 to IATA Level 2 and ATFM Delay increased when reduced capacity could not support the increase in demand. Runway/taxiway construction at certain airports such as San Francisco and Los Angeles along with increase in departure operations at Newark and Seattle contributed to the increase of additional time in the taxi-out phase from 2015-2017.

1 INTRODUCTION

1.1 Background and objectives

The U.S. – Europe Comparison Report is jointly developed under Appendix 2 to Annex 1 of the Memorandum of Cooperation NAT-I-9406A signed between the United States of America and the European Union on 13 December 2017 and managed by a joint European Commission-FAA Performance Analysis Review Committee (PARC).

The EUROCONTROL Performance Review Unit (PRU) and the U.S. Air Traffic Organization¹ (FAA-ATO) have produced a series of joint performance studies using commonly agreed metrics and definitions to compare, understand, and improve air traffic management (ATM) performance.

The initial benchmark report comparing operational performance was completed in 2009 [Ref. [1]]. Subsequent benchmark reports comparing ATM performance in the U.S. and Europe have since been published in 2010, 2012, 2014, and 2016 [Ref. [2], [3]]. This report is the sixth in the series of joint ATM operational performance comparisons between the U.S. and Europe.

1.2 Report Scope

GEOGRAPHICAL SCOPE

Figure 1-1 shows the geographical scope of this report with the U.S. CONUS subdivided into 20 Air Route Traffic Control Centers (ARTCCs) and the European area subdivided into 62 en-route centers².

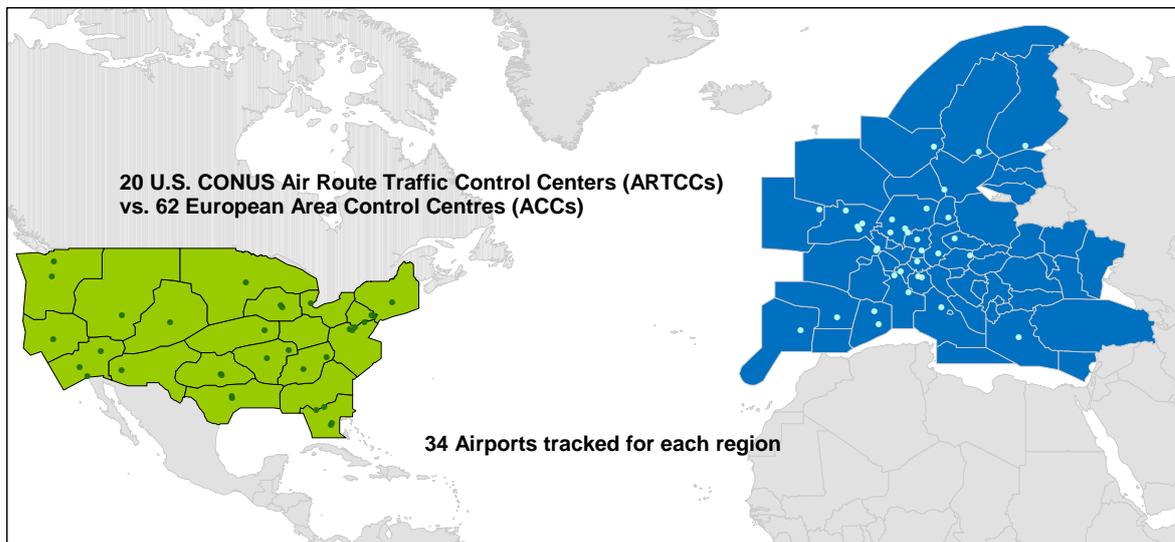


Figure 1-1: Geographical scope of the comparison in the report

Unless stated otherwise, for the purpose of this report, “Europe” is defined as the geographical area where the Air Navigation Services (ANS) are provided by the European Union Member

¹ The U.S. Air Traffic Organization (ATO) was created as the operations arm of the Federal Aviation Administration (FAA) in December 2000, to apply business-like practices to the delivery of air traffic services.

² The map shows European airspace at Flight Level 300. Therefore not all the en-route facilities are visible as some control lower airspace only.

States plus those States outside the EU that are members of EUROCONTROL³, excluding Oceanic areas, Georgia and the Canary Islands.

Unless otherwise indicated, “U.S.” refers to ANS provided by the United States of America in the 48 contiguous States located on the North American continent south of the border with Canada plus the District of Columbia, but excluding Alaska, Hawaii and Oceanic areas (U.S. CONUS).

In order to ensure the comparability of operational ATM performance, the analysis scope of this report was influenced by the need to identify a common set of data sources with a sufficient level of detail and coverage. The analysis in Section 5.2 covers all airports and all IFR traffic. In Section 5.3 the detailed analyses of ATM-related operational performance by phase of flight are limited to flights to or from the main 34 airports for IFR traffic in both the U.S. and in Europe. A detailed list of the airports included in this report can be found in Annex I.

Although they are within the top 34 airports in terms of traffic in Europe in 2017, Istanbul Ataturk (IST), Istanbul (SAW), Antalya (AYT), and Warsaw (WAW) airports were not included in the analysis due to data availability issues.

TEMPORAL SCOPE

The operational analyses in this report were carried out for the calendar year 2017 and, where applicable, comparisons to previous years were made to track changes over time. In particular, this report contrasts the performance of 2017 versus the performance observed (and reported) in the 2015 edition of this report.

1.3 Data Sources

Various data sources have been used for the analysis of operational ATM performance. These data sources include, inter alia, trajectory position data, ATFM imposed delay, key event times and scheduled data from airlines, and METAR information for weather.

DATA FROM AIR TRAFFIC MANAGEMENT SYSTEMS

Both the U.S. and Europe obtain key data from their respective air traffic flow management (ATFM) systems. There are two principal sources within ATM. These include trajectory/flight plan databases used for flight efficiency indicators, and delay databases that record ATFM delay and often include causal reasons for the delay.

For the U.S, flight data come from the Traffic Flow Management System (TFMS). In Europe, data are derived from the Enhanced Tactical Flow Management System (ETFMS) of the European Network Manager. These data sources provide the total IFR traffic picture and are used to determine the “main” airports in terms of IFR traffic and the flight hour counts used to determine traffic density.

Both ATFM systems have data repositories with detailed data on individual flight plans and surveillance track sample points from actual flight trajectories. They also have built-in capabilities for tracking ATM-related ground delays by departure airport and en-route reference location.

³ The list of EUROCONTROL States can be found in the Glossary.

The data sets also provide flight trajectories which are used for the calculation of flight efficiency in terms of planned routes and actual flown routing. The data sets which include data in the en-route transitional phase and in the terminal areas allow for performance comparison throughout various phases of flight. This report features an assessment of vertical flight efficiency for a subset of airports based on the aforementioned trajectory data.

DATA FROM AIRLINES

The U.S. and Europe receive operational and delay data from airlines for scheduled flights. This represents a more detailed subset of the traffic flow data described above and is used for punctuality or phase of flight indicators where more precise times are required.

These data include what is referred to as OOOI (Gate **Out**, Wheels **Off**, Wheels **On**, and Gate **In**) times. OOOI data along with airline schedules allow for the calculation of gate delay, taxi times, block times, and gate arrival time delay on a flight by flight basis. The data also contains cause codes for delays on a flight-by-flight basis.

In the U.S., most performance indicators are derived from the Aviation System Performance Metrics (ASPM) database which fuses detailed airline data with data from the Traffic Flow Management System (TFMS). Air carriers are required to report performance data if they have at least 1% of total scheduled-service domestic passenger revenues on a monthly basis. However, as of 2018, airlines with at 0.5% of the total scheduled-service domestic passenger revenues are required to report performance data on a monthly basis. In addition there are other carriers that report voluntarily. ASPM coverage in 2017 was approximately 95% of the IFR traffic at the main 34 airports (within region) with 86% of the total IFR traffic reported as scheduled operations. Airline-reported performance data, which includes airline reported delay cause, for traffic at the main 34 airports represent 62% of all IFR flights at these airports. This percentage (as well as the specific carriers that report) does not stay constant from reporting period to reporting period and this has some effect on the performance indicators based on OOOI data (On-Time percentage, Taxi-out, Taxi-in). However, from 2015-2017 (study period), OOOI data was available for nearly all commercial carriers with flights to and from the U.S. through OAG.

In Europe, the Central Office for Delay Analysis (CODA) collects data from airlines each month. The data collection started in 2002 and the reporting was voluntary until the end of 2010. As of January 2011, airlines which operate more than 35 000 flights per year⁴ within the European Union (EU) airspace are required to submit the data on a monthly basis according to EU Regulations [Ref. [4]]. In 2017, the CODA coverage was approximately 61% of total IFR flights and approximately 73% of flights at the 34 main airports.

A significant difference between the two airline data collections is that the delay causes in the U.S. relate to arrivals, whereas in Europe they relate to the delays experienced at departure.

ATM/TMI DELAY DATA

In the U.S., delay data is derived from the Operational Network (OPSNET) and is used to calculate ATM/TMI delay in this report. The data is only available for flights delayed by 15 minutes or more.

Individual flight level data is available for flights delayed due to the following Traffic Management Initiatives (TMIs): Ground Delay Programs (GDP), Ground Stops (GS), Airspace Flow

⁴ Calculated as the average over the previous three years.

Program (AFP), and Collaborative Trajectory Options Program (CTOP). These delays are reported using automation through the Air Traffic Control System Command Center (ATCSCC).

Flights delayed due to other TMIs, which include Severe Weather Avoidance Plan (SWAP), Miles-In-Trail (MIT), Departure Stop, Metering, and Departure/En-Route/Arrival Spacing Programs (DSP/ESP/ASP), are manually reported by facilities from where the aircraft departs (departure airport) [Ref. [5]]. A portion of these other TMI delays do not have a destination airport because they are recorded manually by the departure facility as a group of delayed flights. Because the destination airport is required to determine if a flight falls within the scope of this study, the U.S. CONUS area, the delays without a recorded destination airport are distributed proportionally to the share of international vs. U.S. CONUS operations at the departure airport.

ANS PERFORMANCE DATA

This comparison study builds on the data describing the ANS operations within the aforementioned scope of the U.S. and European region. Within the field of air transport statistics a variety of sources report on air traffic. Care has to be taken when comparing the data from different sources, as data collection and reporting requirements entail different conventions concerning the breakdown of the data in terms of flight operations, type of flights, etc.

Across Europe, different sources also report on air traffic statistics for the purpose of market analysis. For example, Eurostat reports on air traffic observed at EU-28 level, while different States (typically the national civil aviation authorities or associated statistics agencies) report traffic at national level with varying granularity levels or breakdowns.

The data sets used in this study are derived from the aforementioned systems and ensure comparability of the data with respect to the provision of air navigation services and operational ANS performance.

ADDITIONAL DATA ON CONDITIONS

Post-operational analysis should identify the causes of delay and a better understanding of real constraints. In identifying causal factors, additional data is needed for airport capacities, runway configurations, sector capacities, winds, visibility, and convective weather. For this report, year over year trends for airport capacities and meteorological data have been used to help explain changes in the performance metrics (see Chapter 3).

1.4 European and FAA Performance Reporting

Both FAA and European ANSPs have their own reporting requirements. Some Key Performance Indicators (KPIs) such as ATM attributable delay are common to both groups using calculations and underlying databases that are very similar. There are other indicators that are common but have different priorities in terms of reporting status and/or regulation. For example, European indicators use horizontal trajectory efficiency and ATFM delay for official target setting whereas FAA management focuses on Capacity and NAS On-Time Arrival percentage for official targets [6]. FAA, under RTCA and the NextGen Advisory Committee (NAC) also report Block Time, Track Distance, Throughput, Taxi-out Time and Gate Departure Delay [Ref. [7]]. These metrics, using definitions that have been harmonized for joint EU—U.S. benchmarking are part of later chapters of this report.

The report examines several operational Key Performance Indicators derived from comparable databases for both EUROCONTROL and the Federal Aviation Administration (FAA).

KEY PERFORMANCE AREAS (KPAs) AND KEY PERFORMANCE INDICATORS (KPIs)

Comparisons and benchmarking require common definitions and understanding. Hence the work in this report draws from commonly accepted elements of previous work from ICAO, the FAA, EUROCONTROL and CANSO. An outcome of these performance evaluations is the development of harmonized Key Performance Indicators (KPIs) that can be used for international benchmarking. The KPIs used in this report are associated with ICAO’s Key Performance Areas (KPAs) and are developed using the best available data from both the FAA-ATO and the EUROCONTROL Performance Review Unit (PRU).

In its Manual on Global Performance of the Air Navigation System [Ref. [8]], ICAO identified eleven Key Performance Areas (KPAs) of interest in understanding overall ATM system performance: Access and Equity, Capacity, Cost Effectiveness, Efficiency, Environmental Sustainability, Flexibility, Global Interoperability, Predictability, Participation, Safety, and Security.

ICAO is in the process of updating the Global Air Navigation Plan (GANP, ICAO Doc 9750 [Ref. [9]). As part of this update, the ICAO assembly endorsed the recognition of ATM performance monitoring in 2016. Presently 19 KPIs are recommended for tracking performance improvements and identifying performance shortfalls [10].

The U.S.—Europe comparison reports provide demonstrated application for many of these indicators. The reports also show how common indicators can be used to benchmark performance across facilities and across ICAO regions.

This report addresses the Key Performance Areas that relate to the operational efficiency of the ATM system. These are the KPAs of Capacity, Efficiency, Predictability, and Environmental Sustainability as it is linked to Efficiency when evaluating additional fuel burn.

Table 1-1 provides an overview of the harmonized KPIs used in this report that are associated with the ICAO KPAs. Many of these indicators are linked. All flight efficiency indicators have a degree of variability which may be reported as a KPI for Predictability.

Table 1-1: U.S. —Europe Harmonized Key Performance Indicators

Key Performance Area	Key Performance Indicator	ICAO KPI
Capacity	Declared Airport Capacity	KPI 09
	Maximum Airport Throughput	KPI 10
Efficiency	Airline-Reported Delay Against Schedule	KPI 01/ 14
	En-route and Airport ATM-Reported Attributable Delay	KPI 07/12
	Taxi-Out Additional Time	KPI 02
	Horizontal En-Route Flight Efficiency (flight plan and actual)	KPI 04/05
	Additional Time in Terminal Airspace	KPI 08
	Vertical flight efficiency (CCO/CDO)	KPI 17/19
	Taxi-In Additional Time	KPI 13
Predictability	Airline-Reported Departure and Arrival Punctuality	KPI 01/ 14
	Capacity Variability	
	Phase of Flight Time Variability	KPI 15

In addition to the KPIs listed in Table 1-1, this report also provides a series of related indicators that help to explain why a KPI improved or became worse over time. These related indicators do not fit the standard ICAO KPA framework. However, they are typical indicators that would be monitored by an ANSP to help explain how external factors may influence the core KPIs. These Related Indicators principally address operator demand and weather. Table 1-2 below shows the main related indicators reported.

Table 1-2: U.S. —Europe - related indicators

Related Area	Related Indicator
Traffic/Schedules	System IFR Flight Counts
	System IFR Flight Distance
	Facility IFR Flight Counts
	Traffic Density
	Traffic Variability
	Schedule Block Time
Weather	Seat capacity on scheduled flights
	Operations by Met Condition
	Delay by Met Condition
System Characteristics	System size & structure

1.5 Organization of this report

The report is organized into six chapters:

- Chapter 1 contains the introduction and provides some background on report objectives, scope and data sources used for the analyses for ATM performance in this report. It also lists the Key Performance Indicators and related indicators that are studied in this report.
- Chapter 2 provides background information on the two ATM systems that may also be used to explain differences in the core KPIs. These include differences in air traffic flow management techniques as well as external factors such as weather and capacity restrictions which can be shown to have a large influence on performance.
- Chapter 3 provides a quantitative overview of the indicators that may externally influence the KPIs related to ATM performance. These are principally related to changes in traffic levels, traffic peaks, capacity at the aerodrome, and meteorological conditions.
- Chapter 4 provides a comparison of airline-related KPIs. These indicators assess delay and operational service quality as it relates to the airline schedule. It includes the causal reasons for delay as provided by the airlines.
- Chapter 5 provides a detailed comparison of the ATM-related KPIs focusing on Air Traffic Flow and Capacity Management (ATFCM) and associated efficiencies of actual operations by phase of flight. It includes causal reasons for delay as provided by the ANSP.
- Chapter 6 concludes with a summary of findings.

2 COMPARISON OF AIR TRAFFIC MANAGEMENT (ATM) IN THE U.S. AND EUROPE

This section provides background information on both the U.S. and European ATM systems that may be used to explain similarities and differences in the KPIs used throughout this report. This section starts with a comparison in terms of physical geographic airspace and organization of ATM.

2.1 Organization of ATM

While the U.S. and the European system are operated with similar technology and operational concepts, there is a key difference. The U.S. system is operated by one single service provider using the same tools and equipment, communication processes and a common set of rules and procedures. Although ATFM and ASM in Europe are provided/coordinated centrally by the Network Manager, at the ATC level the European system is much more fragmented and the provision of air navigation services is still largely organized by State boundaries.

In total, there are 37 different en-route ANSPs of various geographical areas in Europe. Historically, they have been operating different systems under slightly different sets of rules and procedures. Since 2004, the Single European Sky (SES) initiative of the European Union aims at reducing this fragmentation. It provides the framework for the creation of additional capacity and for improved efficiency and interoperability of the ATM system in Europe.

2.2 Airspace management (ASM) and design

In the U.S. the Federal Aviation Administration (FAA) is responsible for airspace management and route design, whereas in the amalgamated European ATM system, airspace management was traditionally the prerogative of the individual States.

In the current system, the design of airspace and related procedures is no longer carried out or implemented in isolation in Europe. Inefficiencies in the design and use of the air route network are considered to be a contributing factor towards flight inefficiencies in Europe, therefore the development of an integrated European Route Network Design is one of the tasks given to the Network Manager⁵. This is done through a Collaborative Decision Making (CDM) process involving all stakeholders.

A further challenge is the integration of military objectives and requirements which need to be fully coordinated within the respective ATM system. To meet their national security and training requirements while ensuring the safety of other airspace users, it is occasionally necessary to restrict or segregate airspace for exclusive use which may conflict with civilian objectives to improve flight efficiency as flights must then detour around these areas. To accommodate the increasing needs of both sets of stakeholders, in terms of volume and time, close civil/military cooperation and coordination across all ATM-related activities is a key requirement.

⁵ EU Regulation 677/2011 [29] defines the tasks of the Network Manager. The main ones are: the provision of ATFCM services, the development of an integrated European Route Network Design, providing the central function of radio frequency allocation, coordinating improvements to SSR code allocation, and providing support for network crisis management.

In terms of the organization of the civil/military cooperation, the U.S. and Europe both apply a similar model:

- In the U.S., the DoD Policy Board on Federal Aviation (PBFA) is the single voice of the military services in communicating the DoD position on airspace policy and air traffic management as both a global air navigation service provider and user; at the operational level the FAA headquarters is the final approval authority⁶ for all permanent and temporary Special Use Airspace (SUA)⁷, and operations are organized according to a common set of rules.
- In Europe, the European Defence Agency (EDA) represents the interests of military aviation in the development of the Single European Sky; at the operational level, through the implementation of the Flexible Use of Airspace (FUA) concept – which is included in EU legislation since 2005 [Ref. [11]] – the Network Manager coordinates civil and military requirements through a dynamic CDM process which culminates in the publication of the daily European Airspace Use Plan (AUP) on D-1 and Updated Airspace Use Plans (UUP) on the day of operations. The AUP and UUP activate Conditional Routes and allocate Temporary Segregated Areas and Cross-Border Areas for specific periods of time.

Looking at the map, the comparison of SUA between the U.S. and Europe (in Europe generally referred to as segregated airspace) in Figure 2-1 illustrates a significant difference in the number and location of the special use airspace within the respective ATM systems⁸. It is to be emphasized that these airspace volumes are not all active at the same time, because they are managed flexibly.

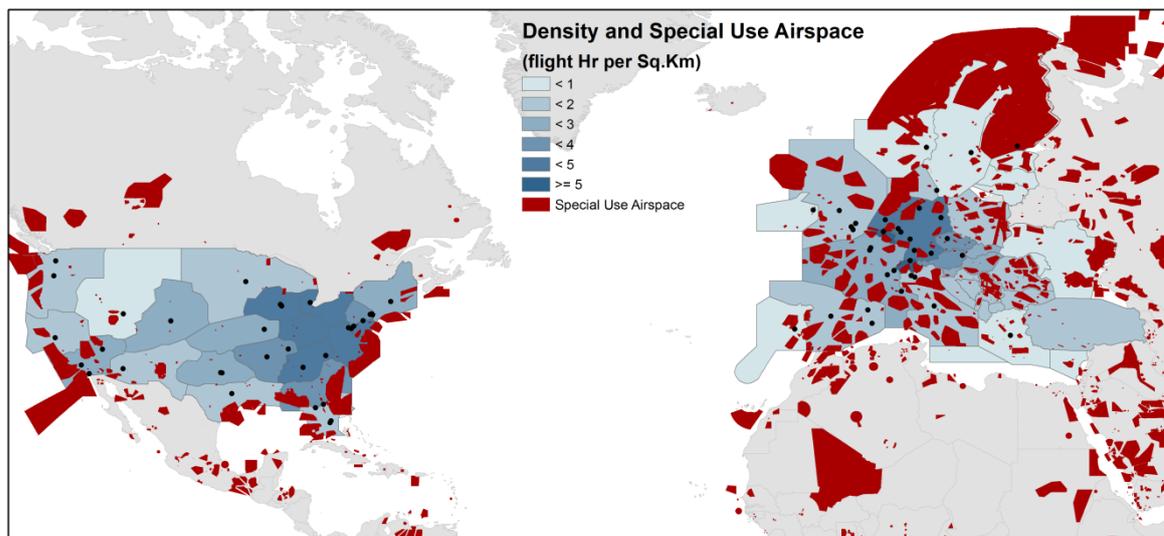


Figure 2-1: Comparison of Special Use Airspace (SUA)

Europe clearly shows a larger number of SUA than the U.S. with quite a number being located directly in the core area of Europe and potentially affecting the flow of civil air traffic. In the U.S., SUA tends to be located along the coastlines allowing for less constrained transcontinental connections.

⁶ [FAA Order JO 7400.2J – Part 5 Chapter 21](#)

⁷ Airspace of defined dimensions identified by an area on the surface of the earth wherein activities must be confined because of their nature and/or wherein limitations may be imposed upon aircraft operations that are not a part of those activities. Often these operations are of a military nature.

⁸ Based on Aeronautical Information Publication (AIP) data available from the European AIS Database (EAD).

2.3 Air traffic flow management (ATFM) and air traffic control (ATC)

ATFM is a function of air traffic management (ATM) established with the objective of contributing to a safe, orderly, and expeditious flow of traffic while minimizing delays. The purpose of ATFM is to avoid safety risks associated with overloaded ATC sectors by regulating traffic demand according to available capacity. When ATFM also includes a capacity management function, it is called ATFCM. At the tactical level, ATC also plays a role in flow management.

This section compares the similarities and differences between the U.S. and Europe in terms of facility organization and the strategies for balancing demand and capacity.

2.3.1 ATFM AND ATC FACILITY ORGANIZATION

Both the U.S. and Europe have established system-wide, centralized traffic management facilities to ensure that traffic flows do not exceed what can be safely handled by ATC units, while trying to optimize the use of available capacity. Table 2-1 provides an overview of the key players involved and the most common ATFM techniques applied [Ref. [12]].

Table 2-1: Organization of ATFM (Overview)

	FLIGHT PHASE	LOCAL ATC UNITS		ATFM MEASURES	NETWORK (ATFM)	
		US (CONUS)	EUROPE		US	EUROPE
<i>STRATEGIC</i>	ORIGIN AIRPORT			AIRPORT SCHEDULING (DEPARTURE SLOT)		
	TAXI-OUT	Ground control	Airports with ATC services: 517	DEP. RESTRICTIONS (GROUND HOLDING)	Air traffic Control System Command Center (ATCSCC)	Eurocontrol Network Operations Centre (NMOC),
	TAKE-OFF	Tower control	Airports with ATC services: 406			
	EN ROUTE	En route Area control	Air Route Traffic Control Center (ARTCC): 20	ROUTING, SEQUENCING, SPEED CONTROL, HOLDING		
	APPROACH	Terminal control	Terminal Radar Approach Control (TRACONS): Stand-alone: 26	AIRBORNE HOLDING (CIRCULAR, LINEAR), VECTORING	located in Warrenton, Virginia.	located in Brussels, Belgium (formerly - CFMU).
	LANDING	Tower	Collocated: 134			
	TAXI-IN	Ground	Collocated: 263			
<i>STRATEGIC</i>	DESTINATION AIRPORT			AIRPORT SCHEDULING (ARRIVAL SLOT)		

The key difference is that the European ATM system is an amalgamation of a large number of individual ANSPs whereas the U.S. system is operated by a single ANSP.

There are 20 Air Route Traffic Control Centers (ARTCC) in the U.S. CONUS compared to 62 ACCs in Europe⁹. Figure 2-2 depicts the size of the 20 U.S. ARTCCs compared to the 20 largest ACCs in Europe, in terms of average daily IFR flights.

⁹ For Europe, a 63rd en-route centre is located in the Canaries, outside of the geographical scope of the study. In the U.S., 3 additional en-route centres are operated by the FAA, outside of the U.S. CONUS.

**Avg. daily IFR flights and controlled area
top 20 en-route area control centres (2017)**

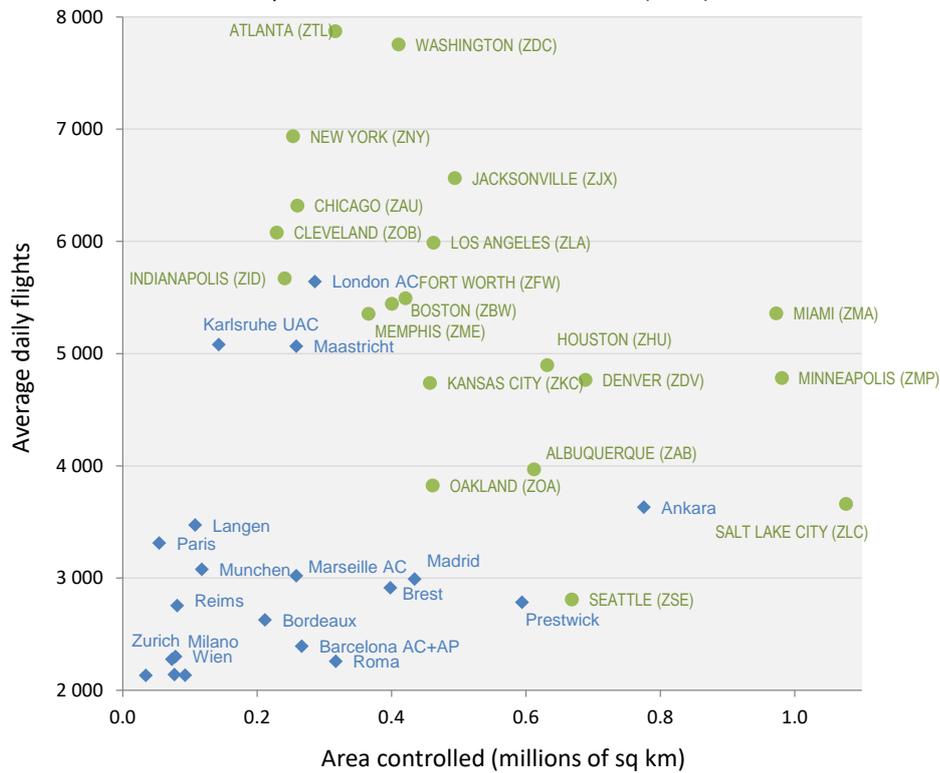


Figure 2-2: Comparison of en-route area control centers (2017)

Hence, in Europe many issues revolve around the level of fragmentation and its impact on ATM performance in terms of operations and costs.

Although there are a number of initiatives aimed at reducing the level of fragmentation (development of Functional Airspace Blocks (FABs) under the Single European Sky initiative), ATM is still largely organized according to national boundaries which is reflected by the considerably higher number of en route centers than in the U.S. and a diversity of flight data processing systems.

Figure 2-3 shows the relatively high number of different Flight Data Processing (FDP) systems in use in Europe [Ref. [13]].

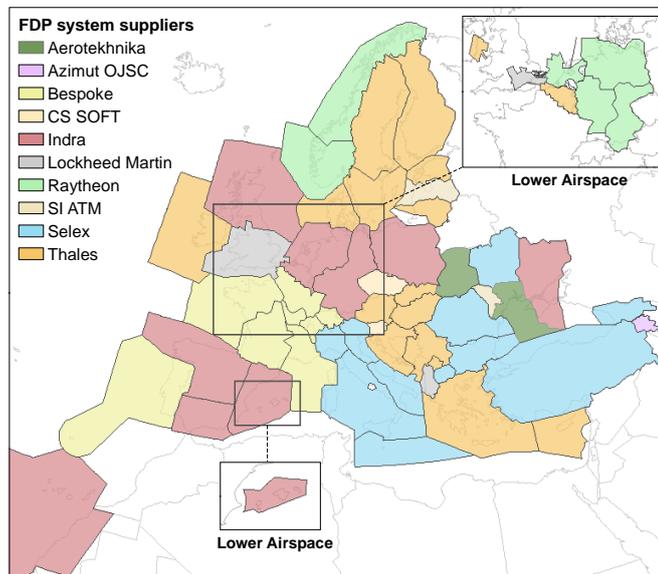


Figure 2-3: Flight data processing (FDP) systems in Europe (2016)

Although on the one hand the competition between suppliers can reduce the price, the considerable number of different systems can impact on operational performance in terms of interoperability issues with adjacent service providers and higher customization and maintenance costs.

A further key difference between the two systems is the role of the network ATFM function. The fact that the ATM system in the U.S. is operated by a single provider puts the Air Traffic Control System Command Center (ATCSCC) in a much stronger position with more active involvement of tactically managing traffic on the day of operations than is the case in Europe.

As far as traffic management issues are concerned, there is a clear hierarchy in the U.S. Terminal Radar Approach Control (TRACON) units' work through the overlying ARTCC which coordinate directly with the ATCSCC in Virginia. The ATCSCC has final approval authority for all national Traffic Management Initiatives in the U.S. and is also responsible for resolving inter-facility issues.

In Europe, the Network Manager Operations Centre (NMOC) in EUROCONTROL monitors the traffic situation and proposes flow measures which are coordinated through a CDM process with the local authority. Usually the local Flow Management Positions (FMP), embedded in ACCs to coordinate the air traffic flow management in the area of its responsibility, requests the NMOC to implement flow measures.

In 2009, the role of the network function in Europe was strengthened by the second package of Single European Sky (SES) legislation¹⁰. This evolution foresees a more proactive role in Air Traffic Flow Management, ATC capacity enhancement, airspace structure development and the support to the deployment of technological improvements across the ATM network for the European Network Manager.

2.3.2 DEMAND CAPACITY BALANCING (DCB)

In order to minimize the effects of ATM system constraints, the U.S. and Europe use a comparable methodology to balance demand and capacity¹¹. This is accomplished through the application of an "ATFM planning and management" process, which is a collaborative, interactive capacity and airspace planning process, where airport operators, ANSPs, Airspace Users (AUs), military authorities, and other stakeholders work together to improve the performance of the ATM system.

This CDM process allows AUs to optimize their participation in the ATM system while mitigating the impact of constraints on airspace and airport capacity. It also allows for the full realization of the benefits of improved integration of airspace design, ASM and ATFM. The process contains a number of equally important phases:

- ATM planning
- ATFM execution
 - Strategic ATFM
 - Pre-tactical ATFM
 - Tactical ATFM
 - Fine-tuning of traffic flows by ATC
 - Traffic Management Initiatives (TMIs) that have an impact on traffic prior to take-off
 - TMIs acting on airborne traffic
- Post-operations analysis.

A detailed description and comparison of the different phases – including an overview of the Traffic Management Initiatives used on both sides of the Atlantic – can be found in Annex II.

¹⁰ The SES I legislation adopted in 2004 was revised and extended by the SES II package in 2009 aimed at increasing the overall performance of the air traffic management system in Europe, shifting the focus from capacity to performance in general. SES II also introduced the performance scheme with target-setting at EU-level.

3 EXTERNAL FACTORS AFFECTING KEY PERFORMANCE INDICATORS

This chapter describes and quantifies the effects of some of the main external factors that impact the primary Key Performance Indicators. These related indicators focus on changing traffic levels, airport capacity, and weather in the U.S. and Europe. In addition to external factors, the way the ATM system is managed (i.e. the U.S. having a single provider and the European system having multiple ANSPs) can also influence the resulting KPIs. These differences in the ATM systems are addressed in more detail in Chapter 2.

3.1 Traffic characteristics in the U.S. and in Europe

This section provides some key air traffic characteristics of the ATM system in the U.S. and in Europe to provide some background information and to ensure comparability of traffic samples.

Table 3-1: U.S. –Europe ATM key system figures at a glance (2017)

Year 2016/17	U.S. ¹²	Europe ¹³	U.S. vs. Europe
Geographic Area (million km ²)	10.4	11.5	≈ -10%
Nr. of civil en-route Air Navigation Service Providers	1	37	
Number of Air Traffic Controllers (ATCOs in Ops.)	12 170 ¹⁴	17 794	≈ -32%
Number of OJT/developmental ATCOs	2 260	696	≈ +225%
Total ATCOs in OPS plus OJT/developmental	14 430	18 490	≈ -22%
Total staff	31 647	55 130	≈ -43%
Controlled flights (IFR) (million)	15.3	10.4	≈ +47%
Flight hours controlled (million)	23.8	16.0	≈ +48%
Relative density (flight hours per km ²)	2.3	1.4	≈ x1.6
Share of flights to or from top 34 airports	66%	64%	
Share of General Aviation (IFR flights)	19%	3.5%	
Average length of flight (within respective airspace)	554 NM	591 NM	≈ -6.3%
Number of en-route facilities	23 ¹⁵	62	-42
Number of stand-alone APP/TRACON units	27 ¹⁶	16	+11
Number of APP units collocated with en-route or TWR fac.	134	263	-129
Number of airports with ATC services	517 ¹⁷	406	+111
Of which are slot controlled	3 ¹⁸	> 100 ¹⁹	
Number of FMPs (Europe) / TMUs (U.S.) ²⁰	≈65	51	≈ +14
Source	FAA/ATO	EUROCONTROL	

¹¹ In line with the guidance in ICAO Doc 9971 (Manual on Collaborative Air Traffic Flow Management).

¹² Area and flight hours refer to CONUS only. Centre count and staff numbers refer to the NAS excluding Oceanic.

¹³ Area and flight hours refer EUROCONTROL States, excluding Oceanic areas, Georgia and Canary Islands. European staff and facility numbers refer to EUROCONTROL States excluding Oceanic and Georgia and represent 2016 which is the latest year available.

¹⁴ This value reflects the CANSO reporting definition of a fully trained ATCO in OPS and includes supervisors. It is different than the total controller count from the 2018 FAA Controller Workforce Plan which does not include supervisors. The number of ATCOs in OPS does not include 1 297 controllers reported for contract towers. The number of ATCOs in OPS including Oceanic is 12 347.

¹⁵ 20 en-route centers (ARTCCs) are in the U.S. CONUS, 3 are outside.

¹⁶ 26 stand-alone TRACONs are in the U.S. CONUS, 1 is outside (Alaska).

¹⁷ Total of 517 facilities of which 264 are FAA staffed and 253 federal contract towers.

¹⁸ IATA Level 3: JFK. In addition restrictions exist at DCA and LGA based on Federal and local rules. IATA Level 2: ORD, LAX, EWR, MCO, SFO, SEA.

¹⁹ IATA Level 2: ±70. IATA Level 3: ±100.

²⁰ FMPs and TMUs are the local ATFCM partners for the collaborative process with the NMOC and ATCSCC respectively.

As shown in Table 3-1, the total surface of continental airspace analyzed in the report is similar for Europe and the U.S. However, the U.S. controls approximately 47% more flights operating under Instrument Flight Rules (IFR)²¹ with fewer Air Traffic Controllers (ATCOs)²² and fewer en-route and terminal facilities.

Using the definition employed by the ACE and CANSO benchmarking reports which excludes those designated as “on-the-job training” in Europe or as a “developmental” at the FAA, the U.S. operated with some 32% less full-time ATCOs than Europe in 2016/2017. However, this percentage narrows to 22% more controllers in Europe when FAA developmental controllers and European on-the-job trainees are also considered.

The ATM system in Europe is more fragmented and operates with more physical facilities than the U.S. The European region comprises 37 ANSPs (and a similar number of different regulators), 62 Area Control Centers (ACC) and 16 stand-alone Approach Control (APP) units (total: 78 facilities). The U.S. has one ANSP and the U.S. CONUS is served by 20 Air Route Traffic Control Centers (ARTCC) supplemented by 27 stand-alone TRACONs providing services to multiple airports (total: 47 facilities). In addition, the U.S. has 134 Approach Control Facilities combined with Tower services; Europe has 263 collocated APP units.

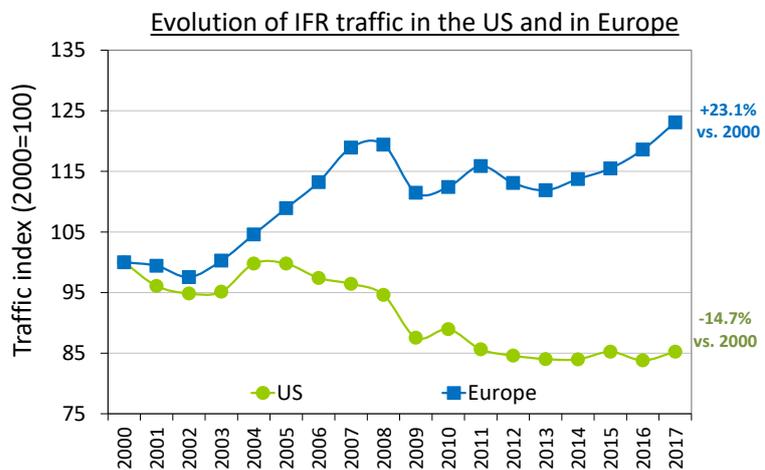
A notable difference illustrated in Table 3-1 is the low number of airports with schedule or slot limitations in the U.S. compared to Europe, where most of the airports are slot-coordinated.

Notwithstanding the large number of airports in the U.S. and Europe, only a relatively small number of airports account for the main share of traffic. The main 34 airports account for approximately 64% and 66% of the controlled flights in Europe and the U.S., respectively.

3.1.1 AIR TRAFFIC GROWTH

Figure 3-1 depicts the evolution of IFR traffic in the U.S. and in Europe between 2000 and 2017. The effect of the economic crisis starting in 2008 is clearly visible on both sides of the Atlantic.

In terms of traffic evolution, there was a notable decoupling between the U.S. and Europe in 2004 when the traffic in Europe continued to grow while U.S. traffic started to decline to reach a plateau in 2011.



Source: EUROCONTROL-PRU / FAA-ATO

Figure 3-1: Evolution of IFR traffic in the U.S. and in Europe

²¹ Although not included in this study, the U.S. also handles significantly more Visual Flight Rules (VFR) traffic.

²² ATCO’s refer to civil ATCOs – military ATCOs with a civil license were not considered in the report.

Between 2000 and 2017, traffic in Europe grew by 23.1% but declined in the U.S. by -14.7% during the same time. Over the past two years (2015-2017), U.S. CONUS traffic remained almost unchanged but traffic at the main 34 airports reported a growth of 2.6%. In Europe, traffic increased by 6.6% between 2015 and 2017 with a slightly lower increase of 5.2% at the main 34 airports.

The system level averages mask contrasted growth rates within the U.S. and Europe as illustrated in the map in Figure 3-2. Traffic growth in Europe shows a contrasted picture between the more mature markets in Western Europe and the emerging markets in Central & Eastern Europe which shows a substantial growth. Also the notable shift of traffic following the tragic events in Ukraine in 2014 and the resulting airspace closure contributed to some of the observed high growth rates in States affected by changed traffic flows.

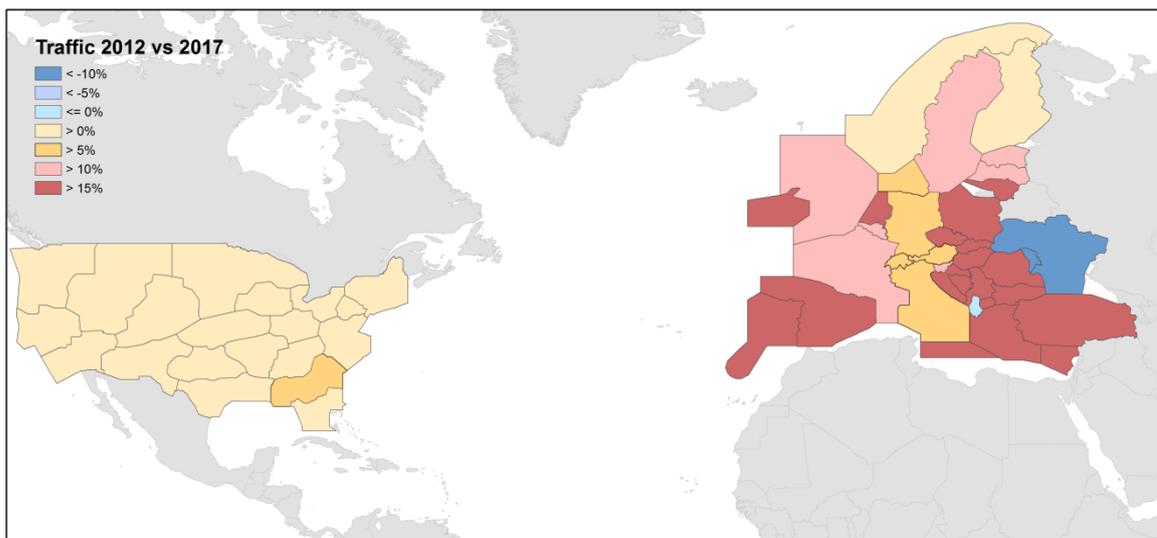


Figure 3-2: Evolution of IFR traffic in the U.S. and in Europe (2017 vs. 2012)

The U.S. is a more homogenous and mature market which shows a different behavior. Compared to 2012, traffic levels stayed relatively constant, aside from the Florida Jacksonville center, which experienced a stronger growth. The traffic growth at the main airports in the U.S. and Europe is shown in Figure 3-8 on page 26.

3.1.2 AIR TRAFFIC DENSITY

Figure 3-3 shows the traffic density in U.S. and European en-route centers measured in annual flight hours per square kilometer for all altitudes in 2017. For Europe, the map is shown at the State level because the display by en-route center would hide the centers in lower airspace.

In Europe, the “core area” comprising the Benelux States, Northeast France, Germany, and Switzerland is the densest and most complex airspace.

Similarly in the U.S., the centrally located centers of Cleveland (ZOB), Chicago (ZAU), Indianapolis (ZID), and Atlanta (ZTL) have flight hour densities of more than twice the CONUS-wide average. The New York Centre (ZNY) appears less dense due to the inclusion of a portion of coastal/oceanic airspace. If this portion was excluded, ZNY would be the center with the highest density in the U.S.

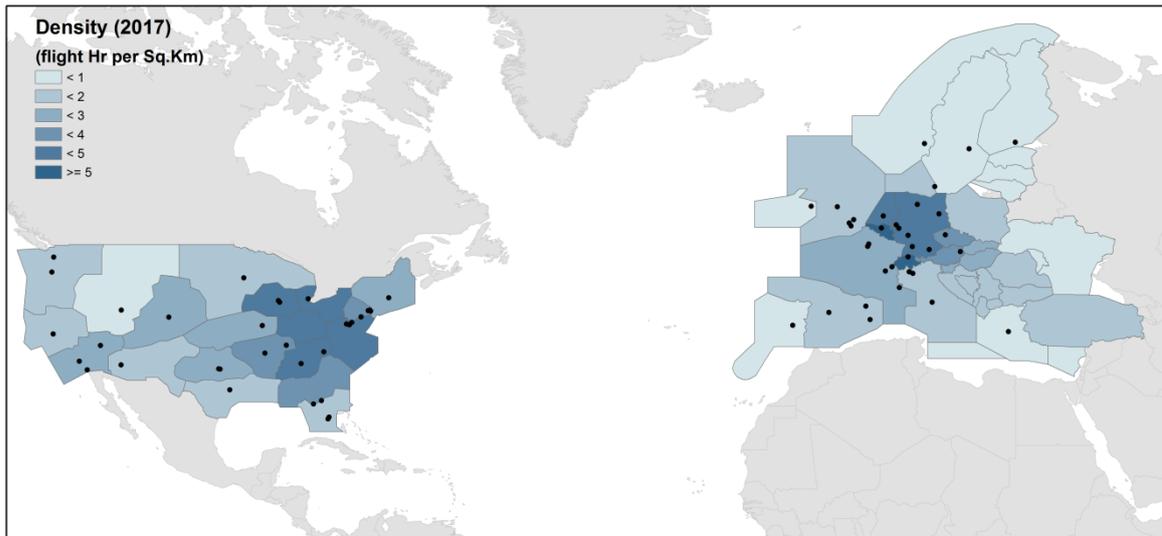


Figure 3-3: Traffic density in the U.S. and in Europe (2017)

In contrast to Europe where high volume airports are concentrated in the center of the region, many of the high volume airports in the U.S. are located on the coasts or edges of the study region creating a greater percentage of longer haul flights, especially when only flights within the CONUS area are considered. The airborne trajectory on these transcontinental flights may be more affected by the influences of wind and convective weather.

3.1.3 AVERAGE FLIGHT LENGTH

Table 3-2 provides a more detailed breakdown of IFR traffic for the U.S. and Europe in 2017. The average great circle distances shown in Table 3-2 refer only to the distances flown within the respective airspace and not the length of the entire flight.

The table is broken into two parts which both show similar trends. The top portion shows all flights while the lower focuses on traffic to or from the main 34 airports. The population of flights in the lower part of the table (traffic to or from the main 34 airports) is the basis for many of the metrics in this report.

ALL IFR TRAFFIC	EUROPE (2017)			US CONUS (2017)		
	N	% of total	Avg. dist. (NM)	N	% of total	Avg. dist. (NM)
Within region	8.2 M	78.5%	517 NM	12.6 M	82.8%	559 NM
To/from outside region	2.1 M	20.0%	869 NM	2.2 M	14.6%	542 NM
Overflights	0.2 M	1.5%	809 NM	0.4 M	2.6%	476 NM
Total IFR traffic	10.4 M	100%	591 NM	15.3 M	100%	554 NM

Traffic to/from main 34 airports	EUROPE (2017)			US CONUS (2017)		
	N	% of total	Avg. dist. (NM)	N	% of total	Avg. dist. (NM)
Within region	5.3 M	80.3%	542 NM	8.4 M	82.5%	660 NM
To/from outside region	1.3 M	19.7%	960 NM	1.8 M	17.5%	567 NM
Total	6.6 M	100%	624 NM	10.1 M	100%	643 NM

Table 3-2: Breakdown of IFR traffic (2017)

By far the largest share of total IFR traffic in both systems is due to traffic within the respective region. In the U.S. this share is 82.8% compared to 78.5% in Europe. When all IFR flights including overflights are taken into account, the average flight length in Europe is 591 NM compared to 554 NM in the U.S. For the U.S., this represents a 5.7% increase in flight distance over 2015. For Europe this corresponds to a 2.6% increase compared to 2015.

However, this changes when only “domestic” flights within the respective regions are considered. For example, en-route efficiency indicators shown later in Section 5.3.3 use “Within Region” traffic to or from the main 34 airports (lower part of). For this population, the average flight length in the U.S. is 643 NM compared to 624 NM in Europe. This is due mainly to the large amount of transcontinental traffic in the U.S. system.

For the U.S., a significant amount of “Outside Region” traffic has a coastal airport as a final destination or traverse a significant distance through Canada before entering U.S. airspace. For Europe, the “Outside Region” traffic is less concentrated at coastal entry airports but more scattered with direct long haul flights to worldwide destinations from almost every capital city airport. For instance, a flight from London Heathrow (LHR) to the Middle East would traverse almost the entire European airspace before exiting the airspace. As a consequence, the average distance of those flights is considerably higher in Europe than in the U.S.

3.1.4 SEASONALITY

Seasonality and variability of air traffic demand can be a factor affecting ATM performance. If traffic is highly variable, resources may be underutilized during off-peak times but scarce at peak times. Figure 3-4 compares the seasonal variability (relative difference in traffic levels with respect to the yearly averages) and the “within week” variability.

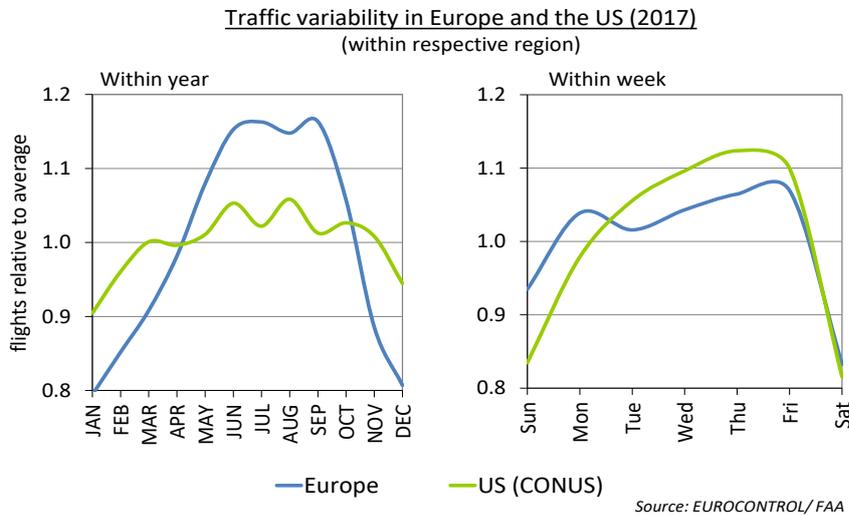


Figure 3-4: Seasonal traffic variability in the U.S. and Europe (system level)

Weekly traffic profiles in Europe and the U.S. are similar with the lowest level of traffic during weekends. In the U.S., traffic increases throughout the week and peaks on Thursdays whereas in Europe the data shows a dip in traffic on Tuesdays making it closer to the average. The seasonal variation is higher in Europe where traffic shows a clear peak during the summer months. Compared to average, traffic in Europe is in summer about 15% higher whereas in the U.S. the seasonal variation is more moderate.

Figure 3-5 shows the seasonal traffic variability in the U.S. and in Europe for 2017. In Europe, a very high level of seasonal variation is observed for the holiday destinations in Southeastern

Europe where a comparatively low number of flights in winter contrast sharply with high demand in summer.

In the U.S., the overall seasonality is skewed by the high summer traffic in northern en-route centers (Boston, Chicago, and Minneapolis) offsetting the high winter/spring traffic of southern centers (Miami and Jacksonville) (see Figure 3-5).

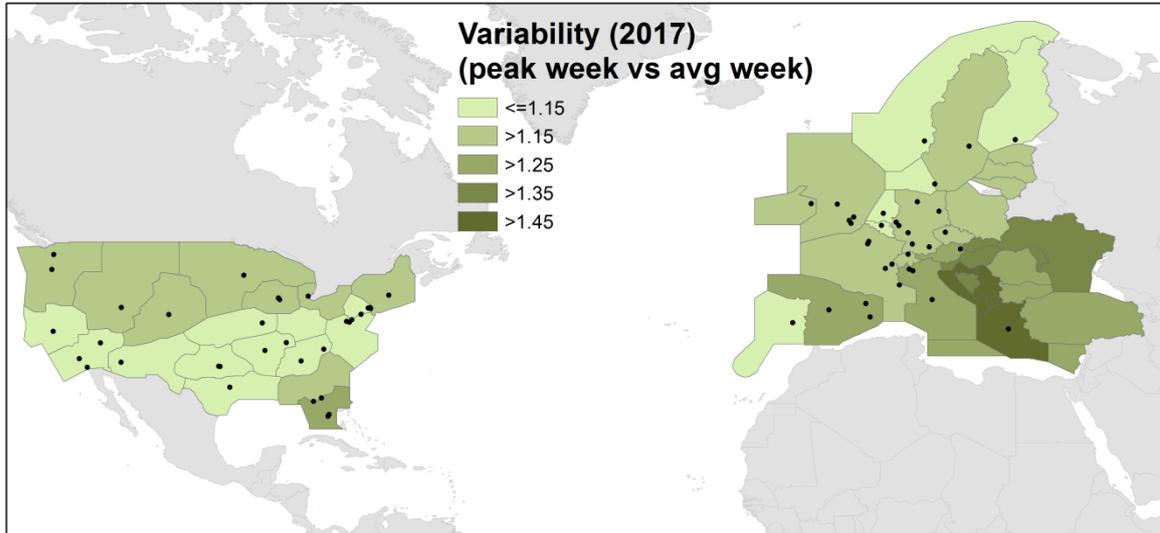


Figure 3-5: Seasonal traffic variability in the U.S. and in Europe (2017)

3.1.5 TRAFFIC MIX

A notable difference between the U.S. and Europe is the share of general aviation which accounts for 19% and 3.5% of total traffic in 2017, respectively (see Table 3-1 on page 17). For the US, the 19% is reduction from the 22% reported in 2015. This is confirmed by the distribution of physical aircraft classes in Figure 3-6 which shows a large share of smaller aircraft in the U.S. for all IFR traffic (left side of Figure 3-6).

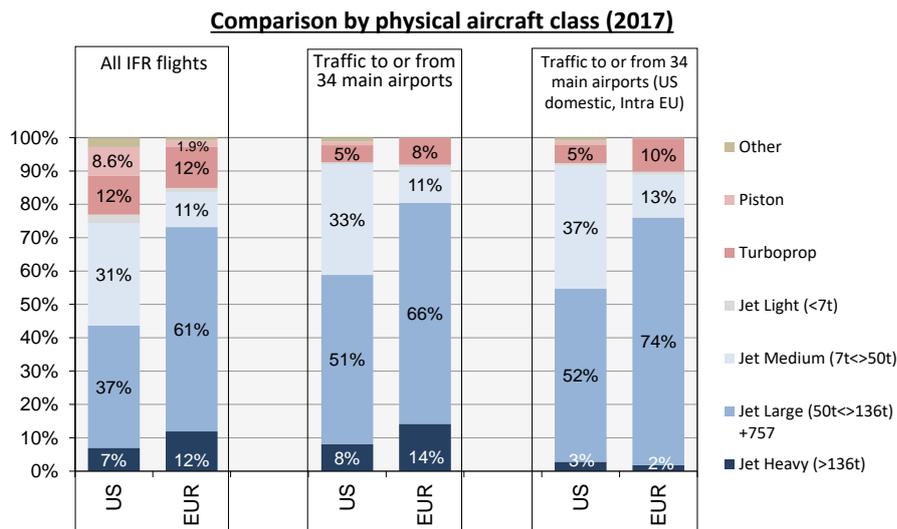


Figure 3-6: Comparison by physical aircraft class (2017)

In order to improve comparability of data sets, the more detailed analyses in Chapters 4 and 5 are limited to controlled IFR flights either originating from or arriving to the main 34 U.S. and European airports (see Annex I). The samples are more comparable when only flights to and

from the 34 main airports are analyzed as this removes a large share of the smaller piston and turboprop aircraft (general aviation traffic), particularly in the U.S. The main 34 airports account for approximately 64% and 66% of the controlled flights in Europe and the U.S., respectively.

Figure 3-7 shows the evolution of the average number of seats per scheduled flight in the U.S. and in Europe, based on data for passenger aircraft. For 2017, the average number of seats per scheduled flight is 32% (+ 36 seats) higher in Europe for traffic to or from the main 34 airports. This is consistent with the observation in Figure 3-6 showing a higher share of larger aircraft in Europe.

Whereas in Europe the average number of seats per flight increased continuously between 2008 and 2017, the number of seats per aircraft declined in the U.S. between 2008 and 2010. However, since 2010 there has been an increasing trend in aircraft gauge in the U.S. Figure 3-7 indicates the potential for growing the number of U.S. passengers with relatively flat or modest growth in operations.

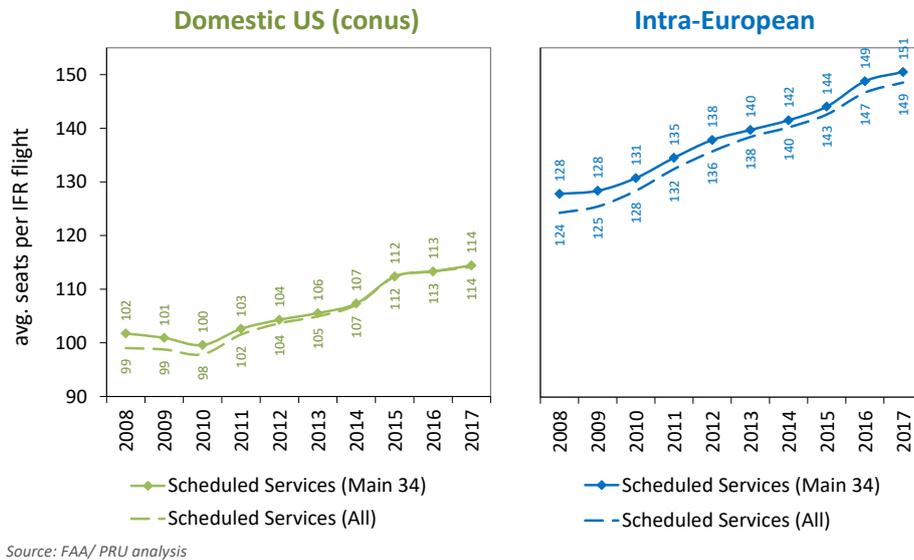


Figure 3-7: Average seats per scheduled flight (2008-2017)

The notable difference observed in aircraft gauge in the two regions is tied to the different practices of airlines, which are linked to demand, market competition, and other factors [Ref. [14]]. An increasing number of European low cost carriers are utilizing a high density one-class seat layout compared to a standard two-class configuration preferred by U.S. carriers. Additionally, since only a few U.S. airports are slot restricted, this enables airlines to have a higher frequency of service (with smaller aircraft) to win market share and to attract high yield business travelers.

The notable increase in the average seats in the U.S. since 2013 is assumed to be the result of consolidation that resulted, on average, in fewer frequencies but with larger aircraft. Additionally, the significant increase in the U.S. between 2014 and 2015 can be attributed to changes in airlines’ regional fleets including the sharp reduction of the number of 45-50 seat jets that were replaced by larger aircraft in the 65-75 seat range on some routes.

3.2 Airport operations and changes in airport capacity

The system-wide and facility level performance indicators shown in Chapters 4 and 5 are driven by airport operations (demand), airport capacity and the imbalance that can occur between demand and capacity. Facilities with a) high levels of operations; b) demand that is near capacity, or c) having capacity that is highly variable, i.e. unpredictable, will tend to form the dominant contributors to system performance. Understanding changes in these factors can also help in understanding year-over-year changes. This section, along with Section 3.3 on weather, provides a quantification of these related factors influencing the reported KPIs.

Airport operations depend upon a number of factors as well as on interactions between them which all affect runway capacity to some degree. In addition to physical constraints, such as airport layout, there are “strategic” factors such as airport scheduling and “tactical” factors which include, inter alia, the sequencing of aircraft and the sustainability of throughput during specific weather conditions.

Safe operation of aircraft on the runway and in surrounding airspace is the dominant constraint of runway throughput. Airport layout and runway configuration, traffic mix, runway occupancy time of aircraft during take-off and landing, separation minima, wake vortex, ATC procedures, weather conditions and environmental restrictions – all affect the throughput at an airport.

The runway throughput is directly related to the time needed to accommodate each flight safely. The separation requirements in segregated mode²³ depend on the most constraining of any one of the three parameters: (1) wake vortex separation, (2) radar separation, or (3) runway occupancy time. The challenge is to optimize final approach spacing in line with wake vortex and radar separation requirements so that the spacing is close to runway occupancy time. For mixed mode runway operations²⁴, throughput is driven by inter arrival spacings into which departures are interleaved.

ENVIRONMENTAL CONSTRAINTS

One of the major challenges of airport communities is the need to balance airport capacity requirements with the need to manage aircraft noise and negative effects on the population in the airport vicinity. Quite a number of airports in Europe operate under some environmental constraints which invariably affect runway throughput, the level of complexity and therefore, ATM performance.

The main affecting factors are (1) Noise Preferential Routes and Standard Instrument Departure, (2) Restrictions on runway mode of operations and configurations, and (3) night noise regulations. In the early morning, night noise curfews might even result in considerable arrival holding with a negative impact on fuel burn and thence CO₂ emissions.

More work is required to better understand the differences in the impact of environmental constraints on ATM performance in Europe and the U.S. (i.e. how noise and emissions are handled in the two systems and the potential impact on performance).

3.2.1 AIRPORT LAYOUT AND OPERATIONS AT THE MAIN 34 AIRPORTS

The number of operations which can be safely accommodated at an airport not only depends on the number of runways but also to a large extent on runway layout and available configurations (many runways may not be operated independently). The choice of the configuration depends

²³ Applies to dual runway systems where runways are used exclusively for landing or departing traffic.

²⁴ Landing and departing aircraft are mixed on the same runway.

on a number of factors including weather conditions and wind direction, type of operation (arrival/departure peak) and environmental considerations such as noise constraints. The configuration, combined with environmental restrictions as well as apron and terminal airspace limitations, affect the overall capacity of the airport.

Some of the key factors determining runway throughput are the distance between runways (dependent or independent²⁵), the mode of operation (mixed²⁶ or segregated²⁷), and geographical layout (intersecting runways, crossing taxiways).

Although some airports technically have a large number of runways, operational data shows there are restrictions on the type of operations and runways to be used at any one time (i.e. wind dependency or runways out of service for extended periods).

For this reason, the number of runways used for the comparison of operations at the 34 main airports in the U.S. and in Europe in Table 3-3 was based on statistical analysis (see grey box) rather than the physical runway count. The passenger numbers are based on Airport Council International (ACI) data and refer to all operations.



Use of runways at the airports

Acknowledging that not all physical runways are available for use at any one time, a statistical methodology was used to determine the number of runways in use at each of the airports in Table 3-3.

In a first step, the number of simultaneously active runways was determined for each 15 minute interval. A runway (e.g. 09R/27L) was considered as being active if used in any of the directions.

In a second step, the upper 10th percentile of the distribution was used as the number of simultaneously active runways at the respective airport. Please note that the number of physical runways might be higher.

There were several airport development projects in the U.S. since 2008, including new runways at Chicago O’Hare (ORD), Charlotte (CLT), Seattle (SEA), and Dulles (IAD). A runway extension was also completed for Philadelphia (PHL) that resulted in improved capacity for the airport. In Europe, a fourth runway went into operation at Frankfurt (FRA) airport in October 2011.

Table 3-3: Comparison of operations at the 34 main airports in the U.S. and Europe

Main 34 airports	U.S.		Europe		U.S. vs. Europe (2017)
	2017	vs. 2015	2017	vs. 2015	
Avg. number of annual IFR movements per airport ('000)	390	2.4%	248	5.2%	+57%
Avg. number of annual passengers per airport (million)	38.7	6.8%	31.1	11.4%	+24%
Passengers per IFR movement	99	4.3%	125	5.8%	-21%
Average number of active runways per airport	3.4	0.0%	1.9	-1.5%	+76%
Annual IFR movements per runway ('000)	114	2.4%	128	6.8%	-11%
Annual passengers per runway (million)	11.3	6.8%	16.0	13.1%	-29%

Table 3-3 shows that the average number of IFR movements (+57%) and the number of annual passengers per airport (+24%) are significantly higher in the U.S. than in Europe. Consistent with

²⁵ Independent operations ensure flexibility and usually allow a higher throughput whereas dependent operations may mean that only one runway can be used at a time. In order to operate independently, ICAO safety rules require the runways to be far enough apart and/or configured so that aircraft operation on one runway does not affect the other.

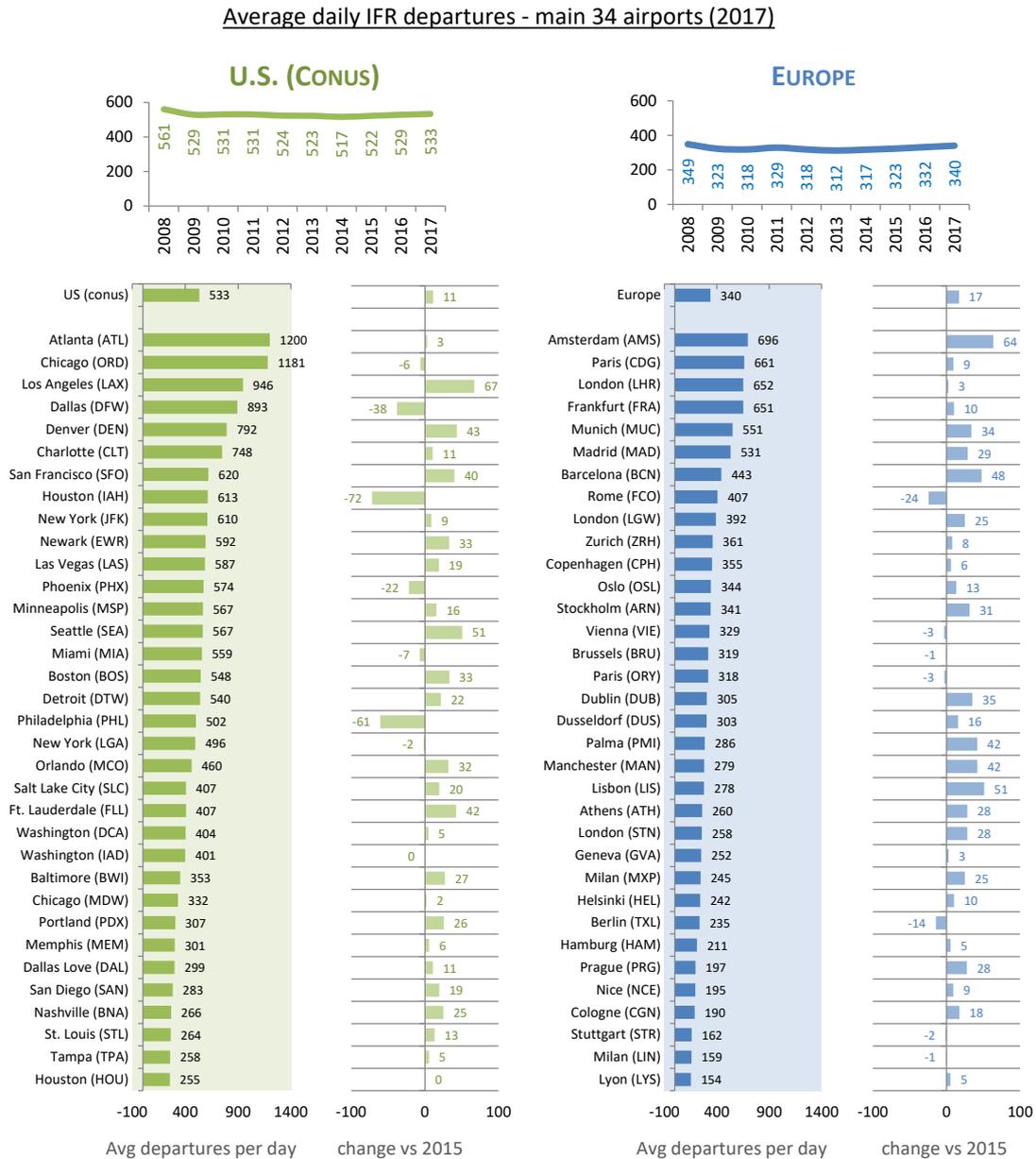
²⁶ Landing and departing traffic are mixed on the same runway.

²⁷ Applies to dual runway systems where runways are used for either landing or departing traffic only.

Figure 3-6 and Figure 3-7, the number of passengers per movement is much lower (~21%) in the U.S. due to the U.S. on average utilizing a larger share of smaller aircraft and offering fewer seats per scheduled flight.

The IFR flights are the basis for the majority of the trends and analysis presented in this report. Figure 3-8 shows the average number of daily IFR departures at the 34 main European and U.S. airports²⁸ in 2017 and the change compared to 2015.

The average number of daily IFR departures per airport (533) is considerably higher (57%) in the U.S., compared to 340 average daily departures at the 34 main airports in Europe in 2017.



Source: EUROCONTROL PRU/ FAA-ATO

Figure 3-8: Operations at the main 34 airports (2017)

²⁸ The analysis relates only to IFR flights. Some airports – especially in the U.S. – have a significant share of additional VFR traffic which has not been considered in the analysis.

In the U.S., the airports with the highest decrease in daily departures are Houston IAH (-72), Philadelphia (-61), and Dallas (-38). The top airports showing growth in departures compared to 2015 are Los Angeles (+67), Seattle (+51) and Denver (+43). Although overall traffic in the U.S. increased by only 0.2%, the average traffic level for the main 34 population increased by 2.1%.

In Europe, the airports with the highest decrease in terms of departures were Rome (-24 vs. 2015), Berlin (TXL) (-14), and Vienna (-3). The airports showing an increase in departures compared to 2015 include Amsterdam (+64), Lisbon (+51), and Barcelona (+48).

3.2.2 DECLARED CAPACITY AND PEAK THROUGHPUT

In Europe, the declared airport capacity is a limit typically set as early as six months before the day of operations through a coordination process involving the airport managing body, the airlines, and local ATC.

In the U.S., the FAA called arrival rates reflect tactical, real time values based on the number of operations scheduled, available runway configuration, and weather, among other considerations.



95th percentile airport peak arrival throughput

The peak arrival throughput is an approximation of the operational airport capacity in ideal conditions. It is the 95th percentile of the number of aircraft in the “rolling” hours sorted from the least busy to the busiest hour.

The indicator has, however, limitations when the peak throughput is lower than the peak declared capacity, in which case it is necessary to determine whether a variation in peak arrival throughput is driven by a change in demand or by a change in operational airport capacity.

Figure 3-9 provides a comparison of the two types of capacities and throughput described above. Although they are developed and used for different purposes, the values may provide some insights into the role of capacity on operational performance.

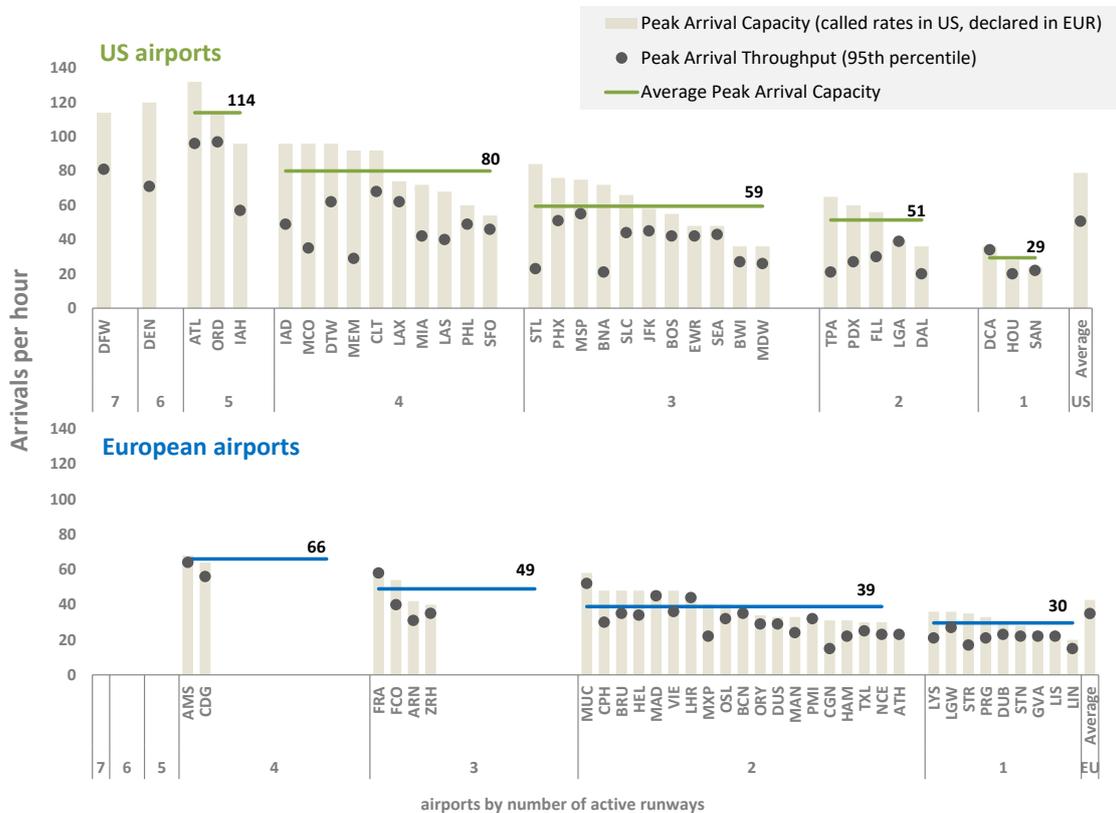


Figure 3-9: Actual airport throughput vs. declared capacity (2017)

The figure depicts the peak arrival capacity (peak called arrival rates for U.S. airports and peak declared arrival capacities for European airports) together with the airports' 95th percentile peak arrival throughput (see grey box). The airports are furthermore categorized by the number of active runways (see Section 3.2.1 for the computation of the number of active runways).

This grouping allows for a first order comparison among different airports. It is however recognized that this simplified analysis should be viewed with a note of caution as there are significant differences in runway layout among airports in the same class that can explain the variation.

In the U.S. and Europe, airports with one active runway are more comparable in terms of peak arrival capacity for the two regions. For the U.S., the two active runway case average value (51) is influenced by the ability to operate in mixed mode with independent runways for Tampa (TPA) and Portland (PDX). For airports with three or more active runways, the peak arrival capacity at U.S. airports is on average notably higher than at European airports. The majority of U.S. airports have three or more active runways whereas in Europe, most of the airports have one or two active runways.

Despite normalizing the comparison by grouping airports by number of active runways, airport capacities within the same active runway grouping can be starkly different due to differing runway layouts, runway dependencies and aircraft fleet mix. It is noted that U.S. airports with three or more active runways show more variability in peak capacity within the same runway group compared to Europe. In general, the U.S. airports with high value arrival capacity rates in the same group indicate the use of runways in mixed mode where arrivals are possible among all active runways. As such, Munich (MUC), Minneapolis (MSP), Tampa (TPA), and Portland (PDX) have a considerably higher peak arrival capacity than the other airports in their runway group.

Peak arrival throughput levels also vary in the two regions. Whereas in Europe peak arrival throughput is usually close to the peak declared capacity, in the U.S. peak arrival throughput tends to be substantially lower than the peak capacity arrival rates, with the exception of a few high impact airports (i.e., New York airports, Philadelphia) where demand and, therefore, throughput is closer to the peak capacity level. As schedule limitations dictate a close adherence of scheduled operations to pre-allocated airport slots (a surrogate for capacity), the slot-controlled airports in the U.S. and Europe tend to show a peak throughput closer to peak capacity.

There are a number of key challenges in providing a true like-with-like comparison of airport capacities and throughput for the two regions. One difficulty in this exercise is that airports within each active runway group may not be directly comparable due to differences in runway layout. Munich (MUC), having two parallel independent runways and the highest throughput in its two-runway class, is not directly comparable to LaGuardia (LGA) which also has two active runways, but in a dependent crossed configuration. The throughput values for the two airports are, therefore, very different.

More analysis is needed to better group and compare European and U.S. airports based on runway layout, runway dependency, and mixed and single mode operations. Another difficulty is that throughput is highly sensitive to peak demand which may change over the study period. High demand drives high throughput and vice-versa. Also, measuring throughput is dependent on the time interval used for the assessment. In this analysis, peak throughput was measured every five minute rolling hour. Results using a different approach may reveal a difference not seen at the five minute rolling hour level.

3.2.3 CAPACITY VARIATION AT U.S. AIRPORTS

In assessing low performing periods in the U.S., many trace to facilities that have large capacity variation between most favorable and least favorable conditions. This is coupled with demand levels that exceed the operational capacity for these off nominal periods. This section quantifies the operational capacity changes that occurred over 2015-2017 at i) the average level (Figure 3-10), ii) the demand relative to capacity (Figure 3-11) and iii) the capacity variability or resiliency at the facility (also Figure 3-11). Quantifying these changes can be useful in understanding the performance trends reported in later chapters.

Changes in capacity can in part be tied to changes in weather, and airport infrastructure (i.e. runway/taxiway construction). In Figure 3-10, the average hourly arrival ATC acceptance rates for the 34 main U.S. airports between 06:00 and 22:00 local time are shown with the percent change in arrival capacity compared to 2015 (top of Figure 3-10).

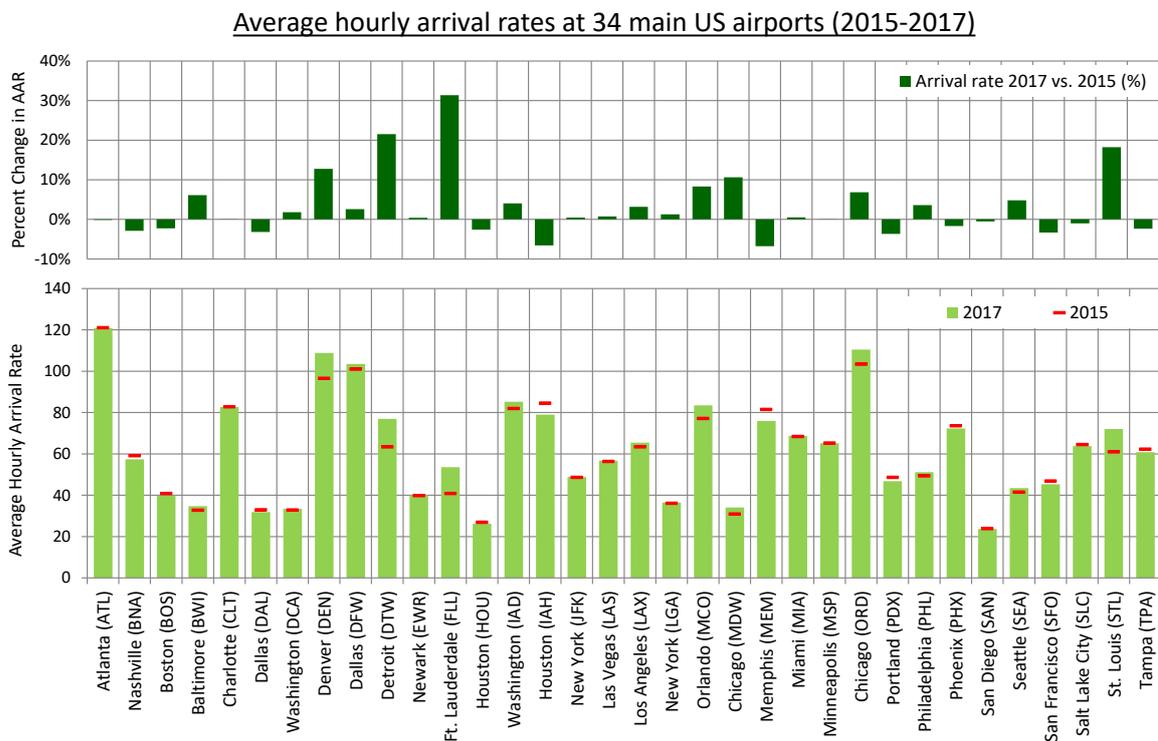


Figure 3-10: Average hourly arrival rates at 34 main U.S. airports (2015-2017)

Ft. Lauderdale (FLL) had the largest percent change from 2015 to 2017. Its increase was due to several improvement and renovation projects including a runway coming back into service and an ongoing terminal expansion that entails a significant increase in the number of gates. Denver (DEN) had a higher arrival capacity rate in 2017 compared to 2015 due to a runway rehabilitation project that took place during the summer of 2015. Detroit (DTW) had various improvement projects during 2015 including runway maintenance and taxiway construction that involved runway closures, the airport called higher arrival rates in 2017 after some of these projects were completed. Houston airports (HOU, IAH) saw a decrease in 2017 after some of these projects were completed. Houston airports (HOU, IAH) saw a decrease due to airport closures associated with hurricane Harvey that hit Texas in August 2017.

Operational capacity so far has been quantified in terms of Peak (Figure 3-9) or Average (Figure 3-10) values. However for several key U.S. airports these peaks are not sustained and are lower for a substantial portion of time largely due to unfavorable weather conditions but at times due to runway or taxiway construction. Quantifying a distribution can involve many parameters and for simplicity, this section looks at two; average and variance. For variability, the difference in

and upper and lower percentile is used as it can be more easily understood in terms of actual operational flights allowed. Specifically, a percent capacity reduction metric is presented by calculating the $(85^{th}-15^{th})/85^{th}$, with the difference between the 85th and 15th measuring the variability over the middle part of the distribution. At least 15% of the time, a facility will experience reductions equal to or lower than an upper rate that is also sustained at least 15% of the time.

Figure 3-11 combines the various elements (volume, capacity reduction, and frequency) which drive performance at U.S. airports using percentiles. The purpose is to focus on how much capacity varies from low to high values and how often this variation becomes a strain on airports due to demand levels close to or exceeding capacity. Note that capacity and demand do not have to be at a peak level for an airport to be impacted or strained. In general, it only takes a mismatch of the two entities and not necessarily high levels of each.

The top chart in Figure 3-11 shows airport capacity and demand for both 2015 and 2017 by reporting the average number of hours the demand is greater than 80% of the called rate capacity for the airport. For example, Newark (EWR) experienced a demand greater than the 80% of capacity for 13 hours per day on average during 2017. This means for the majority of the operating day, EWR’s demand exceeded 80% of called rate capacity. In relation to Figure 3-10, the operations at Seattle have not only increased but by this indicator, are becoming more comparable to the busier U.S. airports. While Fort Lauderdale traffic has grown, its congestion by this measure is less due to one of its runways coming back into service.

The metric provided in the lower part of Figure 3-11 , shows the percent capacity variability by calculating the percent decrease in capacity from the 85th to 15th percentile. Philadelphia (PHL), San Francisco (SFO), Portland (PDX), and Nashville (BNA) report the largest percent capacity variability (reduction) of the Main 34 airports. However, when coupled with high demand (top part of graphic), it is expected that SFO and PHL would be most sensitive to operational impacts to capacity.

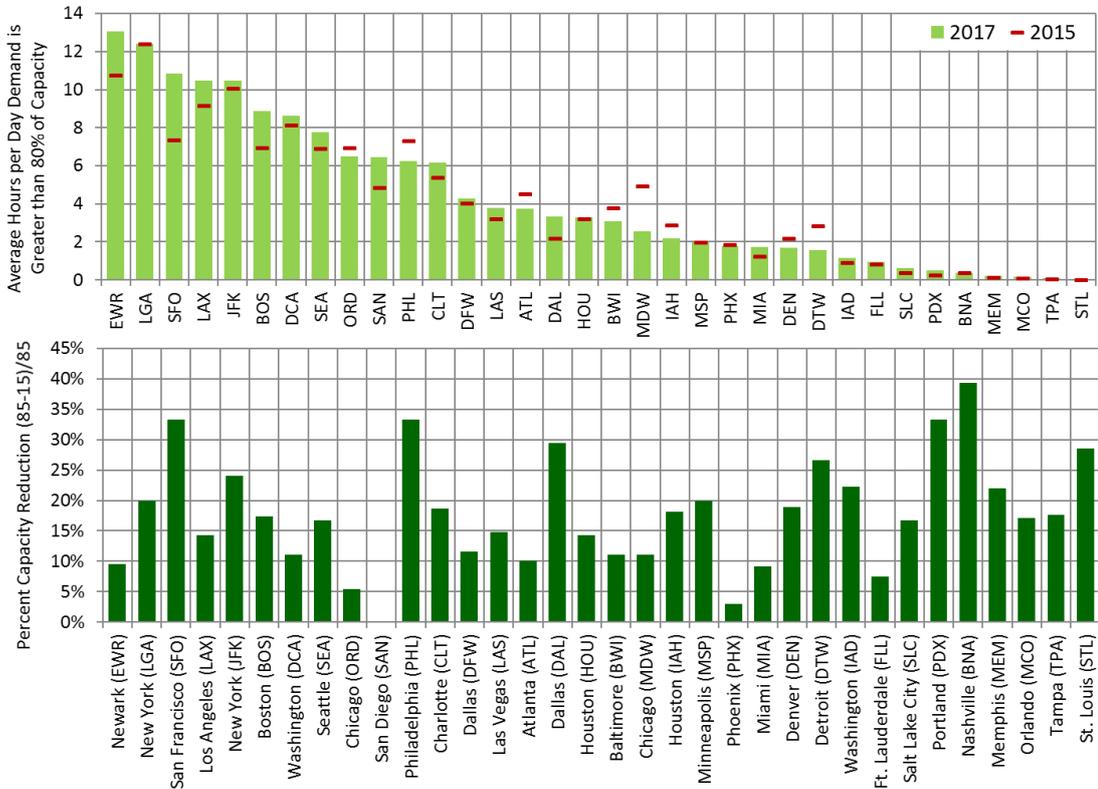


Figure 3-11: Capacity variation and impact on operations at U.S. airports

Although a percentile method was used to characterize airport capacity variation, it is still important for performance analysis groups to link these changes to causal factors. At this time, it is difficult to apply a practical automated process that can explain capacity variation across all facilities. For example, it is known that for San Francisco (SFO), variation can be tied to precipitation, haze, fog and other METAR cloud cover conditions which are not captured by ceiling/visibility alone. For Philadelphia (PHL), the capacity variation can be linked to wind effects [15]. Additional performance data development and automated procedures are needed to assess these effects across airports.

A key challenge for ATM is to ensure safe operations while sustaining a high runway throughput in the various weather conditions. Even small improvements at high density airports will yield a considerable benefit for airspace users and the entire network.

3.3 Impact of Weather Conditions on airport operations

Runway throughput at airports is usually impacted by meteorological conditions. As weather conditions deteriorate, separation requirements generally increase and runway throughput is reduced. The impact of weather (visibility, wind, convective weather, etc.) on operations at an airport and hence on ATM performance can vary significantly by airport and depends on a number of factors such as, inter alia, ATM and airport equipment (instrument approach system, radar, etc.), runway configurations (wind conditions), and approved rules and procedures.

As illustrated in Figure 3-12, movement rates depend on visibility conditions. Runway throughput can drop significantly when Low Visibility Procedures (LVP)²⁹ need to be applied.

LVPs require increased spacing between aircraft to maintain the signal integrity of the Instrument Landing System (ILS) which in turn reduces throughput.

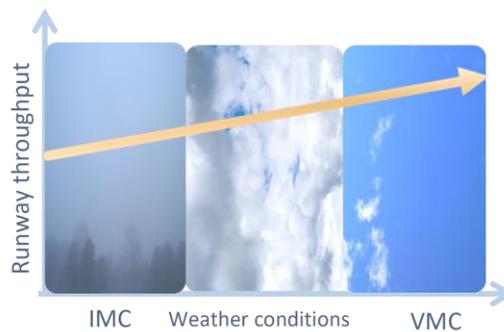


Figure 3-12: Impact of visibility on runway throughput

Wind conditions also impact runway throughput. With the separations based on distance, wind with a high headwind component lowers the ground speed of aircraft and consequently reduces the rate at which aircraft make their final approach.

The analysis of performance by meteorological condition provides an indication of how weather affects system performance and which airports are most impacted by changes in weather condition.

Section 3.3.1 provides an assessment of weather in the two regions using general criteria for ceiling and visibility.

²⁹ Low visibility procedures have been devised to allow aircraft to operate safely from and into aerodromes when the weather conditions do not permit normal operations.

3.3.1 MEASURING WEATHER CONDITIONS

Both U.S. and European performance groups use detailed weather observation reports known as METAR³⁰ and both groups have developed procedures for assessing the weather’s impact on aviation performance [Ref. [16] and [17]]. A typical METAR contains data on temperature, dew point, wind speed and direction, precipitation, cloud cover and heights, visibility, and barometric pressure.

Historically, many of the performance analysis indicators and modelling processes at the FAA segregate time periods into visual or instrument meteorological conditions (VMC/IMC). This provides a simple first-order examination of the effects of weather on performance using ceiling and visibility as the primary criteria for defining weather. Performance by VMC/IMC was also examined in the previous benchmark reports as a practical way of comparing weather changes over time and weather differences between facilities.

Precise definitions differ between the U.S. and Europe but for the analysis in the next section, a cloud ceiling of less than 1 000 feet or visibility of less than 3 miles (5 km) was used for the demarcation of IMC. Conditions better than IMC are termed visual meteorological conditions (VMC). In addition, there are airport specific thresholds where visual approaches (and typically visual separations) may be used. Conditions below such thresholds, but still better than IMC, are referred to as Marginal VMC. For simplicity, the following thresholds were used for *all airports* to provide a basic assessment of the frequency of various weather conditions.

Table 3-4: Ceiling and visibility criteria

		Visibility (miles)		
		< 3	[3, 5)	≥ 5
Ceiling (feet)	≥ 3,000	Instrument	Marginal	Visual
	[1000, 3000)	Instrument	Marginal	Marginal
	< 1,000	Instrument	Instrument	Instrument

It is important to note that VMC does not necessarily equate to favourable or perfect weather although it is often the case. METAR data contains records with weather events, such as rain showers, thunderstorms and strong winds occurring during periods with high visibility and clear skies. These weather events are currently not assessed as part of these related indicators and more work is needed in the future to develop a more comprehensive definition for weather.

Figure 3-13 shows the percent of time spent in visual, marginal, and instrument conditions in Europe and the U.S. at system level in 2015 and in 2017 between 06:00 and 22:00 local time.

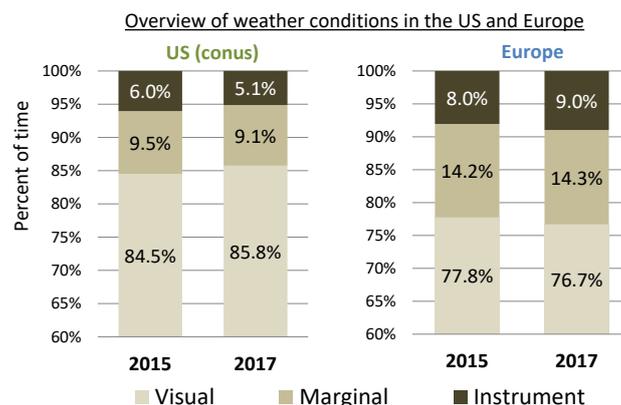


Figure 3-13: Overview of weather conditions in the U.S. and Europe

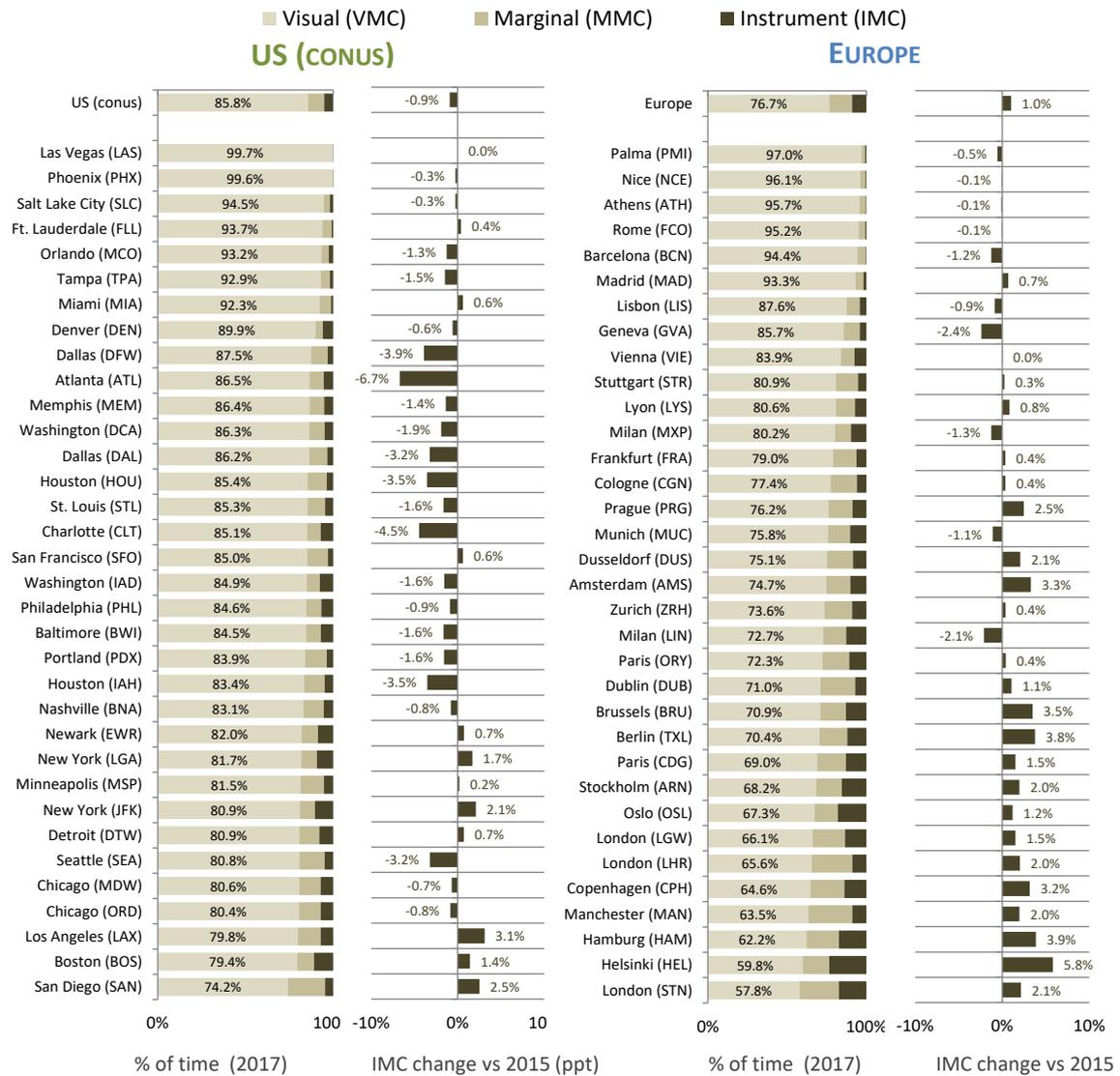
In general, weather in Europe at system level is less favorable than the U.S.

³⁰ Meteorological Terminal Aviation Routine Weather Report or Meteorological Aerodrome Report.

In 2017, 85.8% of the year at the main 34 U.S. airports was spent in VMC with 9.1% occurring in marginal and 5.1% in instrument conditions. Overall, the weather in the U.S. appears to be similar to 2015 with a slightly higher frequency of VMC in 2017 (+1.3%). The main 34 European airports spend on average 76.7% of the time in VMC, 14.3% in marginal, and 9.0% in instrument. At system level, weather conditions in Europe slightly declined in 2017 compared to 2015 with a 1.1% reduction in VMC and a 1.0% increase in instrument conditions.

At the airport level, the share of time spent in VMC, MMC, and IMC vary based on differing susceptibility to weather events which is largely based on geographic location (Figure 3-14).

Weather conditions at the main 34 airports (2017)
share of time between 06h00-22h00 local time



Source: EUROCONTROL PRU/ FAA-ATO

Figure 3-14: Percent of time by meteorological condition at the main 34 airports (2017)

European airports located in the Mediterranean region including Nice (NCE), Palma (PMI), Madrid (MAD), Rome (FCO), Athens (ATH), and Barcelona (BCN) show the highest share in VMC.

In the U.S., Las Vegas (LAS) and Phoenix (PHX) rarely experience anything other than VMC with their dry desert climate. Similarly, the Florida airports (FLL, MCO, TPA, and MIA) also spend a high percentage of time in VMC.

Figure 3-14 shows how the change in instrument conditions is broken down by airport in Europe (+1%) and the U.S. (-0.9%) in 2017. In terms of performance, the observed capacity gap, traffic volume, and frequency of IMC drive overall system performance.

The airports with considerably more time spent in marginal and instrument conditions and less time in VMC may call lower called rates more often, but performance at these airports will only be impacted if demand levels rise above the available capacity. As mentioned previously in this section, ceiling and visibility provide only a preliminary step towards measuring weather conditions. More work is needed to relate the impact of weather conditions on airport and air traffic performance.

4 COMPARISON OF AIRLINE-RELATED OPERATIONAL SERVICE QUALITY

This chapter compares U.S. and European performance using data provided by airlines and other sources. Specific KPIs provided in this section include airline-reported punctuality, airline-reported delay against the schedule, airline-reported attributable delay, and phase of flight time variability.

The section starts with a high level evaluation of the share of delayed flights compared to airline schedules, which is often used as a proxy for “service quality”. There are many factors contributing to the “service quality” of air transport. In fact, it can be seen as the “end product” of complex interactions between airlines, ground handlers, airport operators, and ANSPs, from the planning and scheduling phases up to the day of operation.

The chapter furthermore assesses trends in the evolution of scheduled block times as changes in this scheduled time can have a first order effect on punctuality KPIs. The main delay drivers are also identified by analyzing the information reported by airlines in order to get a first estimate of the ATM-related³¹ contribution towards overall air transport performance.

4.1 On-time performance

On-time performance is reported by the U.S. Department of Transportation (DOT) [Ref. [18]] and in Europe by the Central Office for Delay Analysis (CODA) [Ref. [19]]. This section compares the on-time performance, i.e. arrivals delayed by less than or equal to 15 minutes versus schedule also known as arrival punctuality. U.S. DOT definition for on-time performance counts the 15th minute as delayed. In this report, 15th minute is counted as on-time to stay consistent with EUROCONTROL and ICAO definitions of on-time performance. Also, unlike U.S. DOT reporting, cancellations and diversions are excluded in the calculation of on-time performance. The results need to be seen together with the time buffers included in airline schedules in order to achieve a certain level of on-time performance. A more detailed discussion on how increasing block time can lead to an apparent improvement in performance is included in the next section (see Section 4.2).

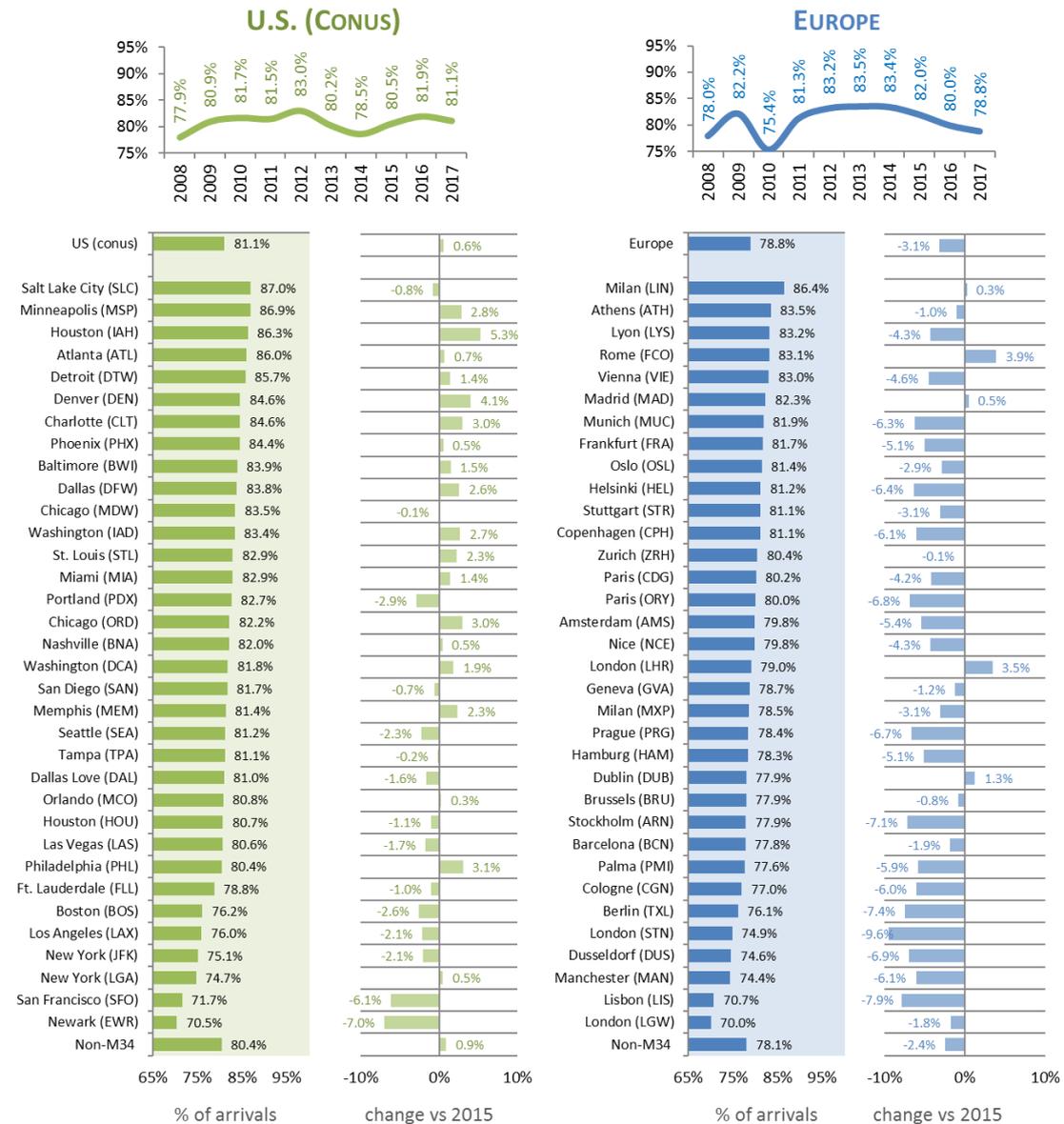
Figure 4-1 shows the arrival punctuality at the system level from 2008-2017 and airport level in 2017, including the change compared to 2015 for flights to/from the main 34 airports. Following the substantial decrease of traffic as a result of the economic crisis starting in 2008, arrival punctuality in both systems improved.

While in the U.S. performance remained stable in 2010, punctuality in Europe degraded to the worst level on record mainly due to weather-related delays (snow, freezing conditions) and strikes³² but improved again in 2011 and 2012. Punctuality in Europe improved from 2010-2013 and started to decline in 2014, punctuality in the U.S. saw a sharp decline from 2012-2014, followed by a rebound from 2014-2016 and another decline in 2017. Overall U.S. punctuality is around 81% over the study period. Analyses in previous editions of this report also showed a clear pattern of summer and winter peaks in Europe. Whereas the winter peaks are more the result of weather-related delays at airports, the summer peaks are driven by the higher level of demand and resulting congestion but also by convective weather in the en-route airspace and a lack of en-route capacity in Europe.

³¹ In this report, “ATM-related” means that ATM has a significant influence on the operations.

³² The volcanic ash cloud in April and May 2010 had only a limited impact on punctuality, as the majority of the flights were cancelled and are, thus, excluded from the calculation of on-time performance indicators.

Arrival punctuality - main 34 airports (2017)
 % of arrivals delayed by less than or equal to 15 min vs published schedule



Source: EUROCONTROL PRU/ FAA-ATO

Figure 4-1: Arrival punctuality at the main 34 airports (2017)

In the U.S., arrival punctuality improved by 0.6% points versus 2015 and the major contributor to increase in punctuality are flights departing main 34 airports and arriving at non main 34 airports. In 2017, the airports with the lowest level of arrival punctuality in the U.S. were the New York airports (LGA, EWR, JFK), San Francisco (SFO) and Los Angeles (LAX). Compared to 2015, Newark (-7.0%) and San Francisco (-6.1%) showed the highest decrease in arrival punctuality. One of the causal factors for deteriorating arrival punctuality at EWR & SFO is ATM/TMI delays increasing by 11.8 (EWR) and 6.5 (SFO) minutes per arrival compared to 2015 (Figure 5-13). Similar trends of decreasing arrival punctuality compared to increase in ATFM delay minutes are observed at LAX, JFK, and BOS (causal factors explained in section 5.3.1). ATM/TMI delay in the U.S. is a subset of the ATM system (NAS Delay) explained in section 4.3.

The continuous notable traffic growth in Europe between 2013 and 2017 (compare Figure 3-1) resulted in a steady decrease of arrival punctuality over that period. A notable contributing factor for the observed deterioration in performance in Europe was the growing lack of en-route ATC capacity, adverse weather en-route and ATC strike.

In Europe, London Gatwick (LGW), Lisbon (LIS), and Manchester (MAN) airport had the lowest level of arrival punctuality in 2017. Compared to 2015, arrival punctuality decreased at many airports, most notably at London Stansted (-9.6%) and Lisbon (-7.9%). Notable improvements compared to 2015 were observed at Rome (+3.9%) and London Heathrow (+3.5%).

As mentioned earlier, it is important to understand that on-time performance is the 'end product' of complex interactions involving many stakeholders, including ATM. Arrival punctuality is influenced by departure punctuality at the origin airport and often by delays which already occurred on previous flight legs (see also Section 4.3). Depending on the type of operation at airports (hub and spoke versus point to point) and airline route itinerary, local performance can have an impact on the entire network through ripple effects but also on the airport's own operation. The Cost Index (CI) at which aircrafts fly (determined by airlines based on fuel cost and operating cost per hour) also influences the trip time and hence the arrival punctuality [Ref. [20]].

Hence, there are interdependencies between ATM performance and the performance of other stakeholders and/or events outside the control of ATM which require a high level of cooperation and coordination between all parties involved. This may include competing goals within airlines, weather, or changes to airport infrastructure that affect capacity.

4.2 Airline scheduling

On-time performance can be linked to a number of different factors including traffic levels, weather, airport capacity, and airline scheduling preferences, such as schedule peaks and scheduled block times. Frequently, airlines add extra time ("pad") to their schedules to achieve a higher level of on-time punctuality. The inclusion of "time buffers" in airline schedules to account for a certain level of anticipated travel time variation on the day of operations and to provide a sufficient level of on-time performance may therefore mask changes in actual performance (see grey box).

Generally speaking, the wider the distribution of historic block-to-block times (and hence the higher the level of variation), the more difficult it is for airlines to build reliable schedules resulting in higher utilization of resources (e.g. aircraft, crews) and higher overall costs.

Additionally, a number of airlines operate hub and spoke systems that interconnect flights to and from spoke airports to the carriers' hubs. Therefore, disturbances at one hub airport can quickly propagate through the entire airline schedule. Operating an aircraft servicing several airports can further amplify and increase the delay propagation.



Airline scheduling

Airlines build their schedules for the next season on airport slot allocation (mainly Europe), crew activity limits, airport connecting times, and by applying a quality of service target to the distribution of previously observed block-to-block times (usually by applying a percentile target to the distribution of previously flown block times).

The level of "schedule padding" is subject to airline strategy and depends on the targeted level of on-time performance.

Nevertheless, it should be pointed out that efficiency improvements in actual flight time distributions do not automatically result in improved on-time performance, as the airline

schedules for the new season are likely to be reduced by applying the punctuality target to the set of improved flight times (block times are cut to improve utilization of aircraft and crews).

Figure 4-2 shows the evolution of airline scheduling times in Europe and the U.S. The analysis compares the scheduled block times for each flight of a given city pair with the long-term average for that city pair over the full period (DLTA metric³³). Generally speaking, the scheduled block times follow the pattern of the actual block times of the previous season.

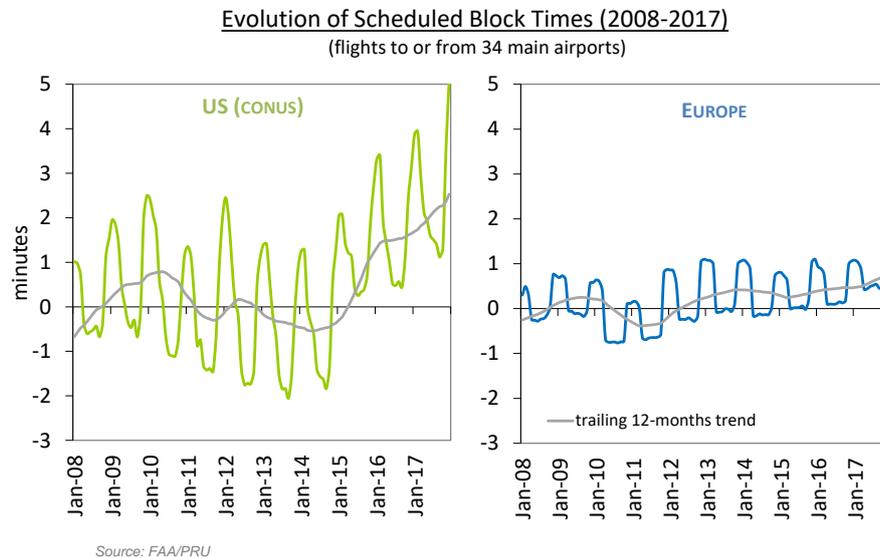


Figure 4-2: Scheduling of air transport operations (2008-2017)

Airlines in the U.S. publish multiple base schedules for a single calendar year based on seasons, travel trends, national holidays, etc. (winter, Spring Break, Labor Day, Thanksgiving, etc.). The block time between an OD (Origin and Destination) within each base schedule remains the same, however, the difference in block time between different base schedules in the same year is visible in the graph. The seasonal trends are observed because of scheduled operations in summer (June – August) and spring (March – May) being considerably high compared to winter (December – February) and fall (September – November). Airlines use approximately the same resources (aircrafts) year-round but the number of trips or operations per aircraft may differ significantly based on time of the year. Therefore, with operations coming down in fall and winter, the block time between city pairs are padded to improve on-time performance and accommodate adverse weather conditions (snow, de-icing, etc.) usually observed in winter. U.S. studies have also shown that the increase is explained by stronger winds on average during the winter [Ref. [21]].

At system level, scheduled block times remained largely stable in Europe with only a slight increase between 2010 and 2012. Although with high seasonal variations, average block time in the U.S. decreased slightly between 2010 and 2015 in the U.S. but increased significantly between 2015 and 2017. In the U.S., the on-time performance (arrival punctuality) degraded in 2013 and 2014 to below 80% which triggered an increase in block time in 2015 which improved on-time performance to just over 81% (see Figure 4-1).

³³ The Difference from Long-Term Average (DLTA) metric is designed to measure changes in time-based (e.g. flight time) performance normalised by selected criteria (origin, destination, aircraft type, etc.) for which sufficient data are available. The analysis evaluates a relative change in performance over time but does not provide an indication of the underlying performance drivers.

The block time increase from 2015-2017 is pronounced among flights flying between or to/from New York, Chicago, San Francisco, Los Angeles, and Seattle airports. The increase in block times is attributed to increasing delays because of weather and construction at these airports (Figure 5-13). However as can be seen in Figure 4-1, only ORD showed an improvement in on-time performance while EWR, JFK, SFO and LAX showed declining on-time performance, even with an increase in block time observed at certain city pairs traversing these airports. Further analysis beyond the scope of the report is required to identify the city pairs and airports contributing to the system increase in block time that caused an uptick in arrival punctuality.

4.3 Drivers of air transport performance – as reported by airlines

This section aims at identifying underlying delay drivers as reported by airlines in the U.S. and in Europe. The reported delays relate to the schedules published by the airlines.

A significant difference between the two airline data collections is that the delay causes in the U.S. relate to the scheduled arrival times whereas in Europe they relate to the delays experienced at departure. Hence, for the U.S. the reported data also includes variability from further delays or improvements in the en-route and taxi phase, which is not the case in Europe.

Broadly, the delays in the U.S. and in Europe can be grouped into the following main categories: Airline + Local turnaround, Extreme Weather, Late arriving aircraft (or reactionary delay), Security, and ATM system (ATFM/NAS delays):

- Airline + Local turnaround: Delay due to circumstances within local control including airlines or other parties, such as ground handlers involved in the turnaround process (e.g. maintenance or crew problems, aircraft cleaning, baggage loading, fueling, etc.). As the focus of the paper is on ATM contribution, a more detailed breakdown of air carrier + local turnaround delays is beyond the scope of the paper.
- Extreme Weather: Significant meteorological conditions (actual or forecast) that in the judgment of the carrier, delays or prevents the operation of a flight such as icing, tornado, blizzard, or hurricane. In the U.S., this category is used by airlines for very rare events like hurricanes and is not useful for understanding the day to day impacts of weather. Delays due to non-extreme weather conditions are attributed to the ATM system in the U.S.
- Late-arriving aircraft/reactionary delay: Delays on earlier legs of the aircraft that cannot be recuperated during the turnaround phases at the airport. Due to the interconnected nature of the air transport system, long primary delays can propagate throughout the network until the end of the same operational day.
- Security: Delays caused by evacuation of a terminal or concourse, re-boarding of aircraft because of security breach, inoperative screening equipment, and/or other security-related causes.
- ATM System: Delays attributable to ATM refer to a broad set of conditions, such as non-extreme weather conditions, airport operations, heavy traffic volume, ATC.

Figure 4-3 provides a breakdown of primary delay drivers in the U.S. and Europe. Only delays greater than 15 minutes compared to schedule are included in the analysis. Clearly, U.S. airlines attribute a larger fraction of causal delay to U.S. ATM than what is seen in Europe. Figure 4-3 includes data for flights reported by the airlines which meet U.S. DOT reporting requirements (explained in section 1.3 on data from airlines) whereas Figure 4-1 includes data for all flights for which OOOI data is available. Therefore, values of on-time performance differ between Figure 4-3 and Figure 4-1.

In the U.S., ATM system delay is largely due to weather which is attributed to the ATM system and volume. In Europe, according to airline reporting, much of the primary delay at departure is not attributable to ATM but more to local turnaround delays caused by airlines, airports, and ground handlers.

As already mentioned, the U.S. distribution relates to the scheduled arrival times and the higher share of ATM-related delay at arrival is partly due to the fact that this figure is impacted by ATM delays accrued after departure (i.e taxi-out, en-route, terminal).

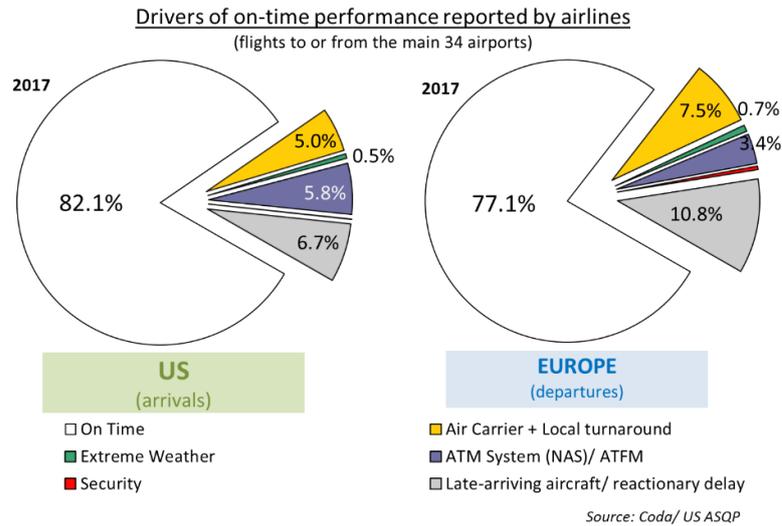


Figure 4-3: Drivers of on-time performance in Europe and the U.S. (2017)

It should be noted that the ATM system-related delays in Figure 4-3 result from not only en-route and airport capacity shortfalls but also include weather effects which negatively influence ATM and aircraft operations (IMC approaches, convective weather). According to FAA analysis, by far the largest share of ATM system-related delay is driven by weather in the U.S. [Ref. [22]].

Figure 4-4 provides an analysis of how the duration of the flight phases (gate departure delay³⁴, taxi-out, airborne, taxi-in, total) have evolved over the years in Europe and the U.S. It is based on the DLTA Metric (see footnote 33) and compares actual times for each city pair with the long-term average for that city pair over the full period (2005-2017). For example, in the U.S. at the end of the curve in January 2017, average actual flight time of the flight phases among city pairs had decreased over 3 minutes since 2008 and was 0.25 minutes below the long-term average. In other words, the average (trailing 12 month period from February 2016 to January 2017) actual time of flight phases in January 2017 was -0.25 minutes compared to 3.2 minutes in January 2008 (trailing 12 month period average from February 2007 to January 2008).

The trends in the U.S. show that the average actual flight time of the flight phases follows a close pattern with the gate departure delay phase which signifies that the average actual flight time increases or decreases with increase or decrease in gate departure delay. The other phases of flight like taxi-out time, airborne time, and taxi-in time do not have a big impact on the average actual time of flight phases until January 2017. From January 2017, the taxi-out and taxi-in time phase increased in the U.S. which contributed to the overall increase in the average actual time of the flight phases.

³⁴ Gate departure delay is defined as the difference between the actual gate out time and the schedule departure time published by the operators.

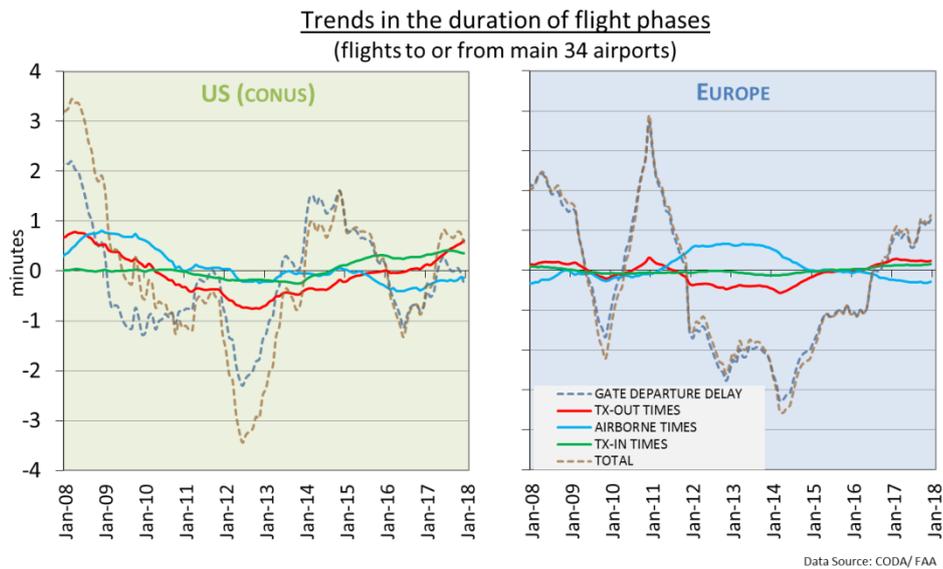


Figure 4-4: Trends in the duration of flight phases (2008-2017)

In Europe, performance is clearly driven by gate departure delays with only very small changes in the gate-to-gate phase (i.e. there is only a very small gap between departure time and total). The drop in gate departure delay in 2009 when traffic levels fell as a result of the economic crisis is significant. In 2010, despite a traffic level still below 2008, gate departure delays increased again significantly mainly due to exceptional events (strikes, extreme weather, technical upgrades). Since 2010, performance in almost all phases of flight improved again but started to increase again in 2014.

In the U.S., the trailing 12-month average of actual time of flight phases began to decline at the beginning of 2008. Similar to Europe, departure delay was the largest component associated with the change in average flight time. Between 2008 and 2010, most flight components went back to their long-term average and improved even further between 2010 and 2012 before they increased again from 2013-2015. The trailing 12-month average showed an improvement from 2016-2017 because of decrease in departure delays in 2015 and increased again starting from 2017 because of increase in taxi-out and taxi-in time. Overall, the average actual time of the flight phases more than doubled between December 2015 and 2017 (0.25 vs 0.58) compared to long term average.

4.4 Variability by phase of flight

This section looks at the Key Performance Area of Predictability or variability by phase of flight using airline-provided data for gate “out,” wheels “off,” wheels “on,” and gate “in” data. This out, off, on, in data is often referred to as OOOI data and is almost entirely collected automatically using a basic airline data-link system (see also Section 1.3 on data sources).

Due to the multitude of variables involved, a certain level of variability is natural. However, variations of high magnitude and frequency can become a serious issue for airline scheduling departments as they have to balance the utilization of their resources and the targeted service quality.

Variability

The “variability” of operations determines the level of predictability for airspace users and hence has an impact on airline scheduling. It focuses on the variance (distribution widths) associated with the individual phases of flight as experienced by airspace users.

The higher the variability, the wider the distribution of actual travel times and the more costly time buffer is required in airline schedules to maintain a satisfactory level of punctuality. Reducing the variability of actual block times can potentially reduce the amount of excess fuel that needs to be carried for each flight in order to allow for uncertainties.

Predictability evaluates the level of variability in each phase of flight as experienced by the airspace users³⁵. In order to limit the impact from outliers, variability is measured as the difference between the 85th and the 15th percentile for each flight phase. This captures 70% of flights and is approximately the same fraction of flights that are within one standard deviation of the average if travel times were normally distributed and not skewed due to delay. In targeting high levels of punctuality, airlines may in fact require “certainty” around a broader population of flights than 70% and therefore view the system as more “variable” and less predictable than what is shown below. However, the focus on this report is to compare the U.S. and Europe using a common methodology.

Figure 4-5 shows that in both Europe and the U.S., arrival predictability is mainly driven by gate departure predictability. Variability in all flight phases is higher in the U.S. than in Europe.

Historically, the differences between the U.S. and Europe have been largest on the ground both at the gate and in taxi-out. Despite the lower level of variability, improvement in the gate-to-gate phase – especially in the taxi-out and terminal airborne phase – can provide substantial savings in direct operational and indirect strategic costs for the airlines.

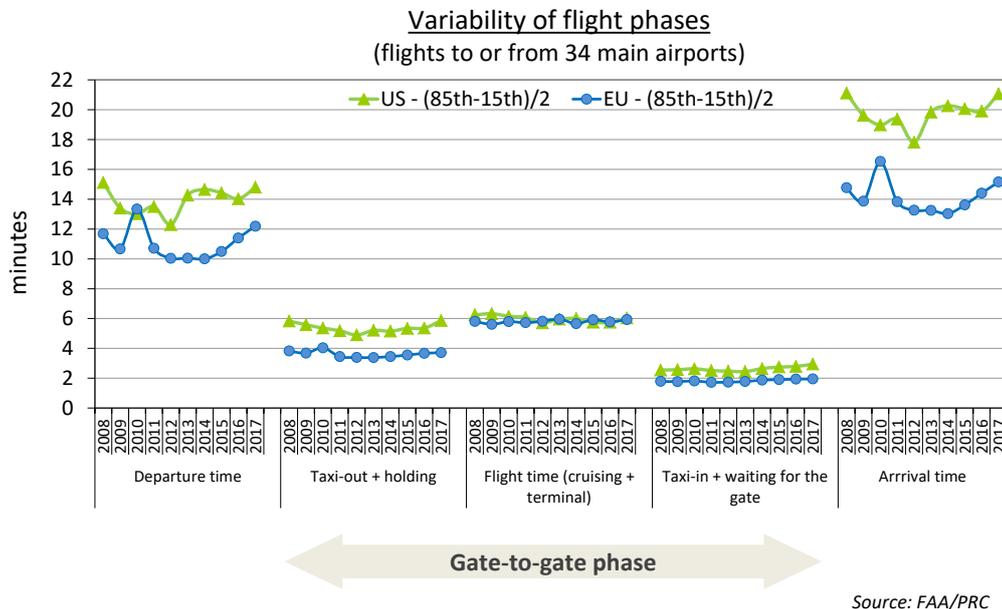


Figure 4-5: Variability of flight phases (2008-2017)

Figure 4-6 shows a clear link between the various seasons and the level of variability in the U.S. and in Europe. The higher variability in the winter is mainly due to weather effects. The higher airborne flight time variability in the winter in the U.S. and in Europe is caused by wind effects and also partly captured in airline scheduling (see Figure 4-2).

In the departure phase, ATM can contribute to the variability through ATM-related departure holdings and subsequent reactionary delays on the next flight legs. The ATM-related departure delays are analyzed in more detail in Section 5.3.1. Due to the interconnected nature of the aviation system, variability originating at constrained airports can propagate throughout the entire network.

³⁵ Intra flight variability (i.e. monthly variability of flight XYZ123 from A to B). Flights scheduled less than 20 times per month are excluded.

Monthly variability of flight phases [(85th-15th)/2]
(flights to or from 34 main airports)

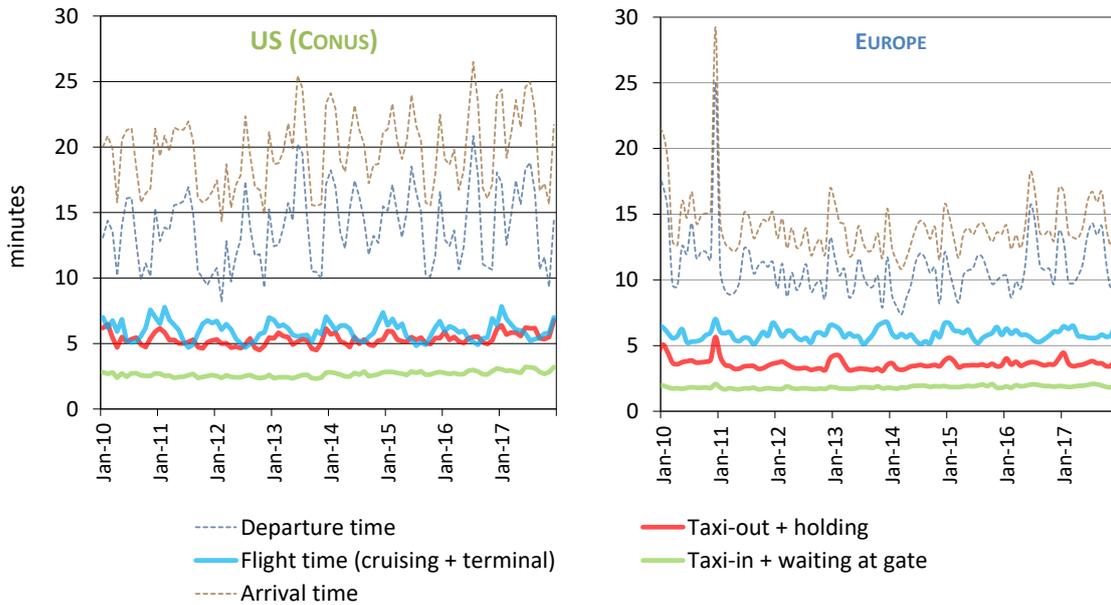


Figure 4-6: Monthly variability of flight phases (2010-2017)

The gate-to-gate phase is affected by a multitude of variables including congestion (queuing at take-off and in TMA), wind, and flow management measures applied by ATM.

For the airborne phase of flight, it is important to note that wind can have a large impact on day-to-day predictability compared to a planned flight time for scheduling purposes. Understanding the ATM, airline, and weather influences on predictability is a key element of baselining system performance. The strong jet stream winds in the winter and convective weather in the summer impact overall predictability statistics.

At U.S. airports, winter delays are believed to be driven to some extent by the higher frequency of instrument meteorological conditions (IMC) combined with scheduling closer to visual meteorological conditions (VMC). Summer delays result from convective weather blocking en-route airspace. The high level of variability may be related to scheduling and seasonal differences in weather.

In Europe where the declared airport capacity is assumed to be closer to IMC capacity, the overall effects of weather on operational variability are expected to be generally less severe.

After a high level analysis of operational performance from the airline point of view, the next chapter provides an assessment of performance evaluated from the ATM perspective. The following analysis of ATM-related service quality is indicative of what can be influenced by improvements or actions taken by the ANSP.

5 COMPARISON OF ATM-RELATED OPERATIONAL SERVICE QUALITY

Although the analysis of performance compared to airline schedules (on-time performance) in Section 4.1 is valid from a passenger point of view and provides valuable first insights, the involvement of many different stakeholders and the inclusion of time buffers in airline schedules require a more detailed analysis for the assessment of ATM performance.

This section compares U.S. and European performance using Key Performance Indicators (KPIs) calculated using data available to the ANSP. Specific KPIs include ATM-reported attributable delay, flight plan additional distance, and additional time in the various phases of flight including taxi-out, en-route, descent and arrival, and taxi-in.

The evaluation of ATM-related operational service quality will focus on the Key Performance Areas of efficiency of actual operations by phase of flight in order to better understand the ATM contribution and differences in traffic management techniques between the U.S. and Europe. The KPA of environmental sustainability is addressed as it relates to efficiency when evaluating additional fuel burn.

The FAA-ATO and EUROCONTROL have been sharing approaches to performance measurement over the past years. Both have developed similar sets of operational Key Performance Areas and indicators. The specific KPIs used in this report were developed using common procedures on comparable data from both the FAA-ATO and EUROCONTROL (see Section 1.3).

5.1 Approach to comparing ATM-related service quality

Figure 5-1 shows the conceptual framework applied in the subsequent sections of this report for the analysis of ATM-related service quality by phase of flight. The high-level passenger perspective (on-time performance) is shown at the top together with the airline scheduling. The various elements of ANS performance analyzed in more detail in the following sections are highlighted in blue in Figure 5-1.

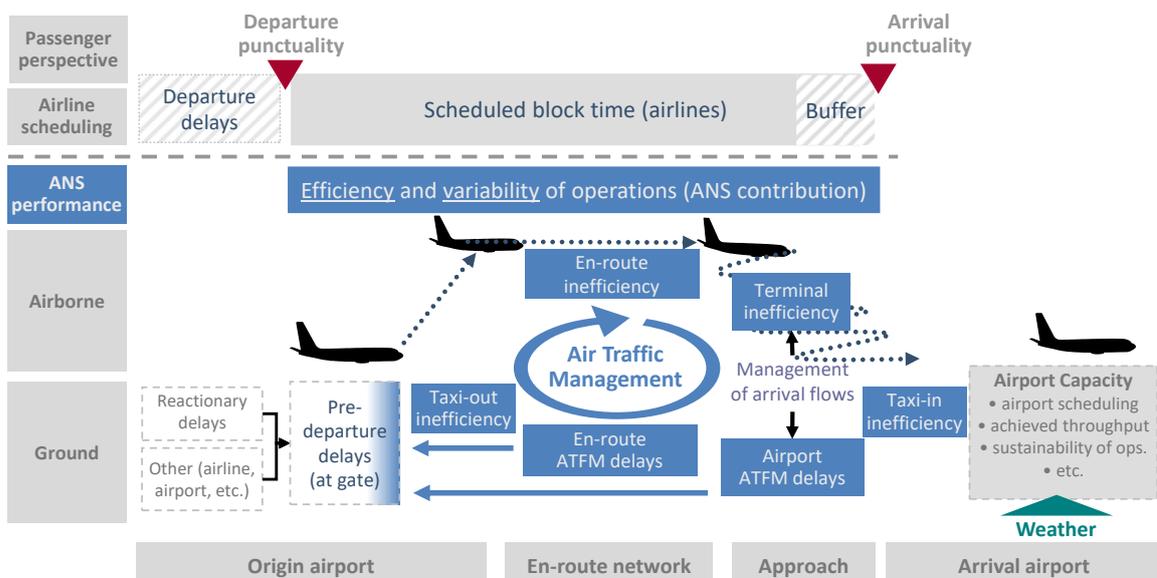


Figure 5-1: Conceptual framework to measuring ATM-related service quality

The evaluation of ATM-related service quality in the remainder of this report focuses on the efficiency (time, fuel) of actual operations by phase of flight (see information box).

ATM may not always be the root cause for an imbalance between capacity and demand (which may also be caused by other stakeholders, weather, military training and operations, noise and environmental constraints, etc.).

However, depending on the way traffic is managed and distributed along the various phases of flight (airborne vs. ground), ATM has a different impact on airspace users (time, fuel burn, costs), the utilization of capacity (en-route and airport), and the environment (emissions).

The overarching goal is to minimize overall direct (fuel, etc.) and strategic (schedule buffer in the form of added block time, etc.) costs whilst maximizing the utilization of available en-route and airport capacity.

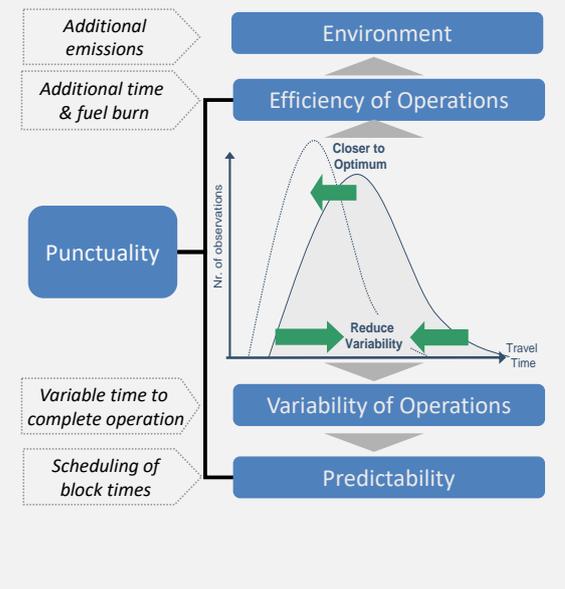
While maximizing the use of scarce capacity, there are trade-offs³⁶ to be considered when managing the departure flow at airports (holding at gate vs. queuing at the runway with engines running).

Similarly, the management of arrival flows needs to find a balance between the application of ground holding, terminal airborne holdings and en-route sequencing and speed control [Ref. [23]].

 **Efficiency**

“Efficiency” in this report measures the difference between actual time/distance and an unimpeded reference time/distance. “Inefficiencies” can be expressed in terms of time and fuel and also have an environmental impact.

Due to inherent necessary (safety) or desired (noise, capacity, cost) limitations, the reference values are not necessarily achievable at system level and therefore ATM-related “inefficiencies” cannot be reduced to zero.



³⁶ It should be noted that there may be trade-offs and interdependencies between and within Key Performance Areas (i.e. Capacity vs. Cost-efficiency) which need to be considered in an overall assessment.

5.2 Specific Analysis of Air Traffic Flow and Capacity Management

5.2.1 INTRODUCTION

ANS performance analyses often focus on quantifying the performance outcome in terms of delays and flight efficiency. This section draws on the specific analyses introduced in the 2015 report of this series, aimed at evaluating the more complex performance issues associated with Air Traffic Flow and Capacity Management (ATFCM) in both systems. The general objective is to deepen the understanding of Capacity Management (CM) and Demand Capacity Balancing (DCB) methods used in the U.S. and Europe, and to better understand the differences and similarities between both regions.

This report focuses on the Traffic Management Initiatives (TMI) portion of the overall process shown in Figure 5-2. To that effect we have:

- Conducted a conceptual analysis of the various TMI types and their application on both sides of the Atlantic. The results can be found at the end of this report in ANNEX II - DEMAND CAPACITY BALANCING.
- Identified suitable (comparable) data in U.S. and European data archives to support TMI analysis. In this edition we are covering the full calendar years 2015-2016-2017, and the same geographical scope as used in rest of the U.S./Europe Comparison Report.
- Extracted and interpreted the data.
- Prepared the data for benchmarking (mapping U.S. and European data).
- Conducted various analyses which are presented below.

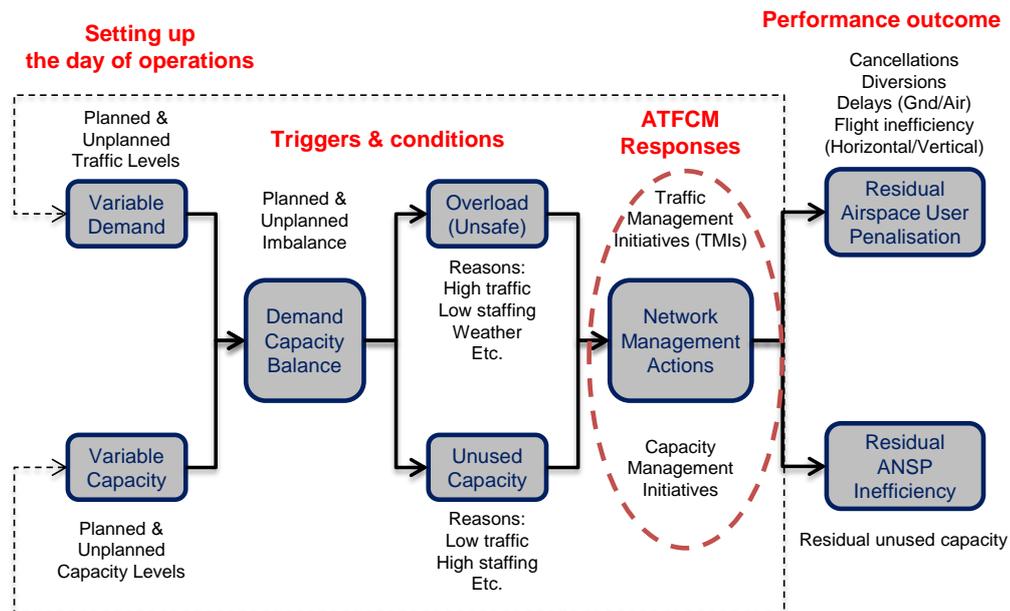


Figure 5-2: Overview of ATFCM study areas

5.2.2 DEFINITIONS AND CONCEPTUAL FRAMEWORK

The term *Traffic Management Initiative* (TMI) has been borrowed from the U.S. For this report it is generalized to describe any *technique used to manage demand with respect to capacity in the airspace system*.

For the purpose of this report, a TMI is *a traffic flow measure applied to airspace(s) and/or airport(s) on a permanent or temporary basis, with the aim to prevent predicted or resolve current demand/capacity imbalances*.

For common U.S./Europe benchmarking, the term covers a broader scope than just the set of ATFM measures. Conceptually the definition covers the whole range of measures ranging from seasonal airport slot allocation to real-time ATC sequencing and metering. Therefore the term *TMI* is not synonymous with the European term *ATFM regulation* nor how FAA defines TMIs applied tactically to balance demand/capacity. ATFM regulations are a specific kind of TMI.

The actors creating TMIs include parties such as airport slot coordinators, network managers (e.g. ATFM facilities, route network designers, scenario designers etc.) and ATC facilities. These actors have a toolbox filled with a variety of TMI types, which they may use to achieve the desired effect. Conceptually, we have grouped TMIs into four levels and have also defined a special DEP category:

	Description	Examples	Consideration in study
TMI-L1	“Latent” TMIs which have been created during the strategic and pre-tactical ATFCM phases. They affect scheduling and/or flight planning.	Airport slot reservation programs, route programs and restrictions, permanent altitude segregation	Not yet quantitatively analyzed
TMI-L2	ATFM TMIs applied on the day of operations, which may result in the allocation of a take-off slot (ATFM slot) and/or a rerouting, after flight plan filing but in principle prior to pushback. Most of the benchmarking focuses on this level.	Ground Stops (GS), Ground Delay programs (GDP), Departure Stops (DS), Airspace Flow Programs (AFP), Collaborative Trajectory Options Programs (CTOP), Severe Weather Avoidance Programs (SWAP), voluntary and required rerouting	Well covered by data in the U.S. and in Europe. A limitation of the U.S. data is that only flights delayed by 15 minutes or more are reported (reportable delay). In Europe, the data contains all delays as of 1 minutes and also flights regulated by the TMI but without attributable delay.
TMI-L3	Sequencing and metering measures that are used by ATC to fine-tune the traffic flow and that may have a delay impact on traffic prior to take-off.	Miles In Trail (MIT), Minutes In Trail (MINIT), Minimum Departure Interval (MDI), Metering (Time Based Metering, TBM), Departure/En-route/Arrival Spacing (DSP, ESP, ASP)	Available for U.S. but not yet available for Europe
TMI-L4	Longitudinal (sequencing and metering, including airborne holding), lateral (load balancing) and vertical (level off) tactical measures that are used by ATC after take-off with the objective to fine-tune the traffic flow.		Available for U.S. but not yet available for Europe. U.S. TMI-L4 data covers airborne holding.
DEP	Flow restrictions resulting in departure delay of flights not otherwise involved in a TMI. Such departure delays are attributed to conditions at the departure airport, and are associated with longer than normal taxi times or holding at the gate.		Data available for the U.S. but not consistently available for Europe.

5.2.3 DELAY AND DELAYED FLIGHTS

In the U.S. the term *delay* refers to (flights with) reportable delay (≥ 15 minutes). The smaller delays are not recorded. When delay is discussed in Europe, the published delay indicators include all delay (including the small delays < 15 minutes). To compare like-with-like in this report, we have split the European delayed flights into a group that is subject to *reportable delay* according to the U.S. definition, and the remaining ones which experience only minor delay (1-14 minutes).

In the subsequent sections the terms *delayed flight* and *delay* refer to (flights with) reportable delay (≥ 15 minutes) attributable to ATFM or ATC unless otherwise specified. Likewise, unless otherwise specified all numbers cover all traffic, delay and TMIs in both regions, except those outside the geographical scope of the study³⁷.

Figure 5-3 shows a comparison of annual TMI delay and delayed flights in the U.S. and Europe. With the available data, benchmarking is possible for flights subject to TMI-L2 (ATFM) delay ≥ 15 min (the dark blue bars on the chart). For completeness, Europe-only data (delays less than 15 minutes) and U.S.-only data (delay generated by the other TMI-levels) are also shown.

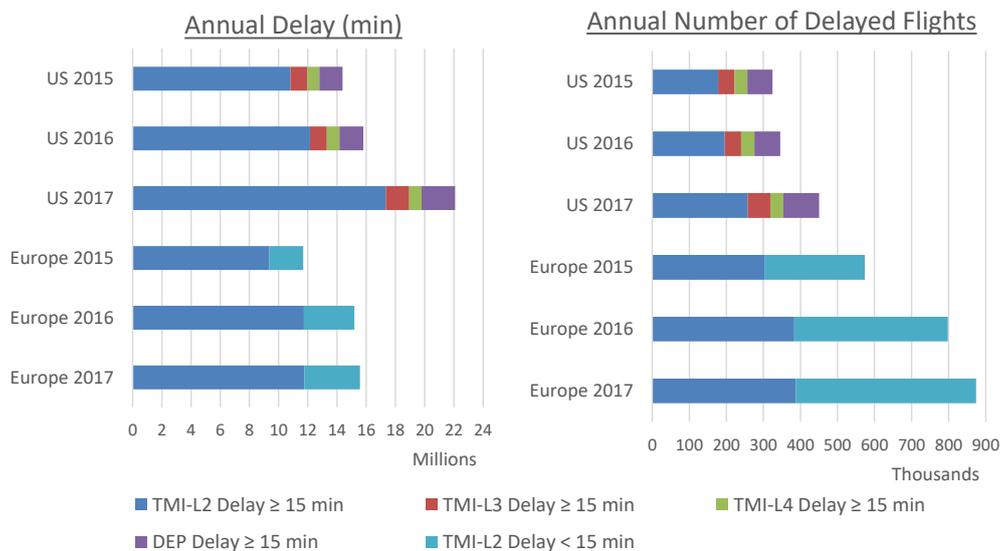


Figure 5-3 Annual TMI delay and delayed flights in the U.S. and Europe

As a general observation, we see that in Europe, more flights are subject to delay than in the U.S. However, when looking at the total annual delay, there is higher delay per delayed flight in the U.S. Over the past few years there is a trend towards more delayed flights and more delay, and this is happening on both sides of the Atlantic.

³⁷ The TMI analysis uses the same geographical same scope as the rest of the U.S./Europe comparison report, but is different in terms of flights considered: whereas the remainder of the comparison report only considers delay of flights between the top 34 airports, this section considers all TMIs, all delay and all flights in each region. For this reason the results are not identical to those shown in in the remaining sections of Chapter 5.

In terms of decomposition of the overall delay and number of delayed flights³⁸, we note that for the U.S.:

- 10% of the recorded delay is DEP delay, however this involves a far bigger proportion (20%) of the delayed flights;
- 10-15% of the recorded delay is ATC-related (TMI-L3 and TMI-L4); this is imposed on 25% of the delayed flights.
- 75-80% of the recorded delay is ATFM-related (TMI-L2); only slightly more than half (55%) of the delayed flights are affected by this type of delay.

In Europe:

- Approximately half (45-55%) of the delayed flights are subject to reportable delay (≥ 15 minutes). The other half of the delayed flights experiences only small delays.
- Despite the large number of affected flights the ‘small delays’ account for only 20-25% of the total annual delay.
- As a result, the vast majority (75-80%) of the total recorded delay is reportable delay.

Figure 5-4 shows the same data in a different way with the annual number of delayed flights along the horizontal axis and the annual delay along the vertical axis. The red lines represent lines of equal delay per delayed flight, with steeper slopes representing higher values.

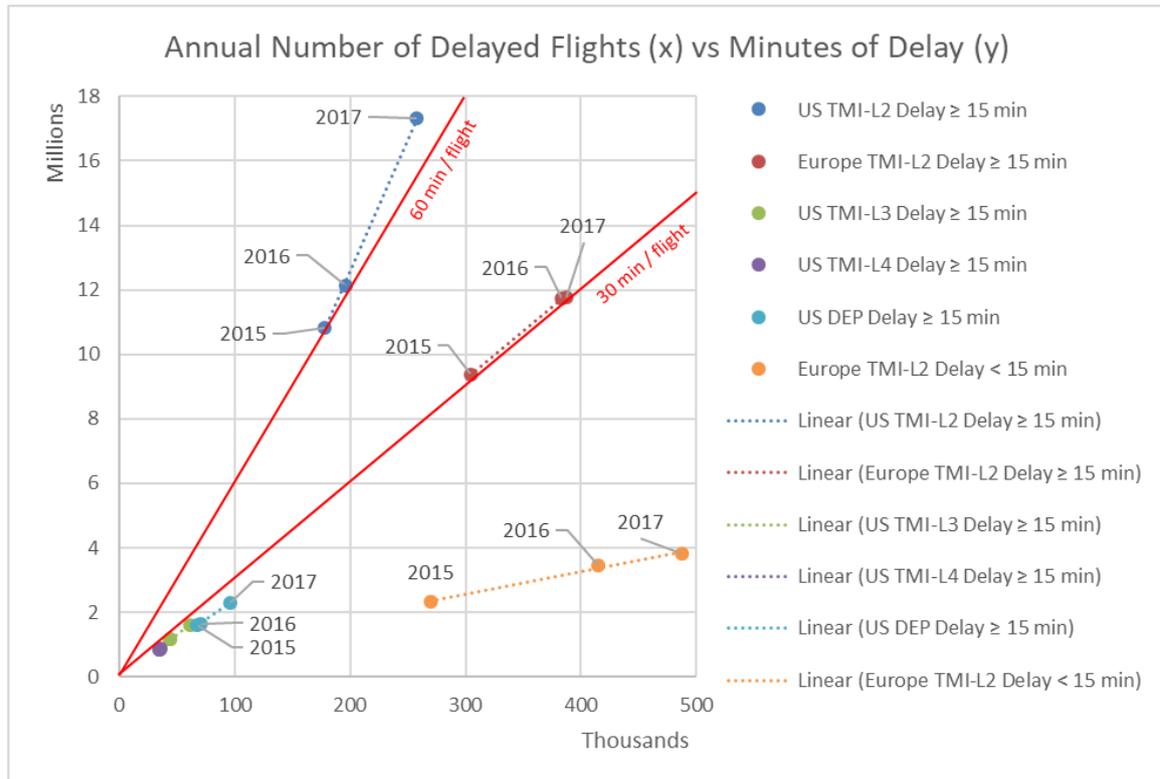


Figure 5-4 Evolution of TMI delay and delayed flights in the U.S. and Europe

Over the three years, we generally see an increase in reportable ATFM delay (TMI-L2). The total delay increase tracks with an increase of the *number* of flights delayed by 15 minutes or more with delay per delayed flight in the U.S. increasing by $\sim 10\%$ from 2015-2017 (see Figure 5-5).

³⁸ Some percentages are expressed as ranges to reflect the variations observed in the 2015-2017 period.

Between 2016 and 2017 the U.S. saw a significant increase in reportable delay and flights delayed by 15 minutes or more, whereas Europe managed to keep both these variables stable. However, this does not mean that Europe's total ATFM delay did not increase, rather, the number of flights with small ATFM delay (<15 min) increased significantly. Apparently, the European approach for dealing with the traffic increase has changed even more towards applying small delays to many flights.

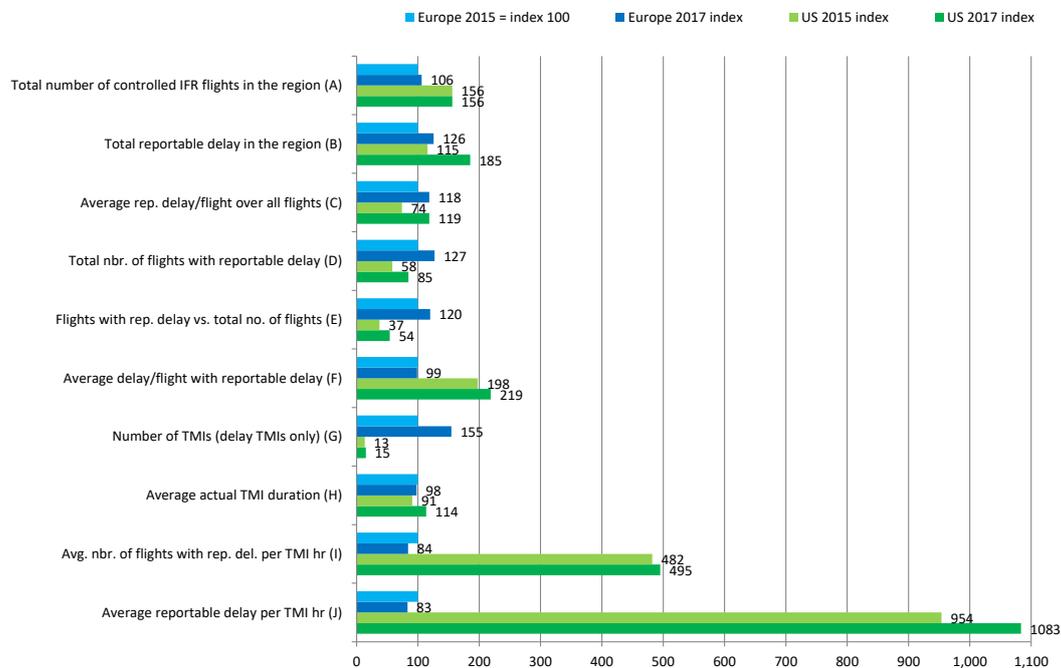


Figure 5-5 U.S./Europe comparison of TMI-L2 (delay TMIs only)

Figure 5-5 visualizes the application of only ATFM TMIs (TMI-L2) in the U.S. and Europe. For comparison purposes, all values have been normalized to index 100 for Europe (2015 values), meaning that the U.S. index values show the relative magnitude compared to Europe. For both the U.S. and Europe, the graph also shows how the 2017 values compare against 2015. Hereafter the differences are explained in terms of absolute values for 2017 (each list item below corresponds to a group of bars in Figure 5-5):

- A. The total number of controlled IFR flights in the region was 10.4 million in Europe, vs. 15.3 million in the U.S. (47% more).
- B. The total reportable ATFM delay in the region was 11.8 million minutes in Europe, vs. 17.3 million in the U.S. (also 47% more).
- C. This resulted in an equal average reportable delay of 1.13 minutes/flight over all flights, for both regions. This is the traditional indicator used for ATFM delay comparison. According to this indicator the performance of both regions was the same in 2017.
- D. The total number of flights with reportable delay was 387 000 in Europe, vs. 258 000 in the U.S. This means that 50% more flights are delayed in Europe than in the U.S.
- E. This implies that 3.7% of all flights incurred a reportable ATFM delay in Europe, while in the U.S. only 1.7% is delayed. In other words, a much larger proportion of flights is delayed in Europe. If we were to also include the flights with only a small ATFM delay, another 487 000 flights would need to be added to the European value, bringing the proportion of delayed flights to 8.4%.

- F. Relating the reportable delay to the number of delayed flights shows an average delay per delayed flight of 67 minutes in the U.S., more than twice the European value (30 minutes). This is also clearly visible in Figure 5-4.
- G. This delay is generated by 3 700 TMIs in the U.S., and 38 400 in Europe (rerouting and level capping TMIs excluded). Europe uses ten times more delay-generating TMIs.
- H. The average duration of the TMIs is roughly comparable: 3.0 hours in the U.S. vs. 2.6 hours in Europe (only 16% difference U.S. vs. Europe).
- I. Switching from TMIs to TMI-hours and considering the difference in number of TMIs, the data shows that each TMI-hour in the U.S. delays 22.6 flights versus 3.9 flights in Europe (6 times less).
- J. Finally, the average impact of delay TMIs on traffic in terms of reportable delay (the delay production rate of TMIs) is 1 560 delay minutes per TMI-hour in the U.S., which is 13 times higher than the European value (120 delay minutes per TMI-hour).

In summary, at the surface it looks as if the performance of ATFM on both sides of the Atlantic was the same in 2017 (1.13 minutes ATFM delay per flight, across all flights), but when looking deeper there are substantial differences in operating practice:

- In the U.S. the delay outcome is generated with only a fraction of the European number of TMIs (10 times less). When looking at the percentage of total annual traffic being delayed ≥ 15 minutes, the difference is much smaller (1.7% in the U.S. vs. 3.7% in Europe, a difference of just a factor 2.2).
- In other words: ATFM TMIs are used less frequently in the U.S. and affect fewer flights, but when they are used they penalize far more flights per TMI-hour and the delay per delayed flight is even higher (on average 67 min/flight in the U.S. vs. 30 min/flight in Europe).

The above analysis looked at both regions at system level (airports and airspace combined). To better understand the operational differences between the U.S. and Europe, it is also useful to look at the ATFM approach to managing airport and airspace constraints separately.

5.2.4 AIRPORT-RELATED TMIS

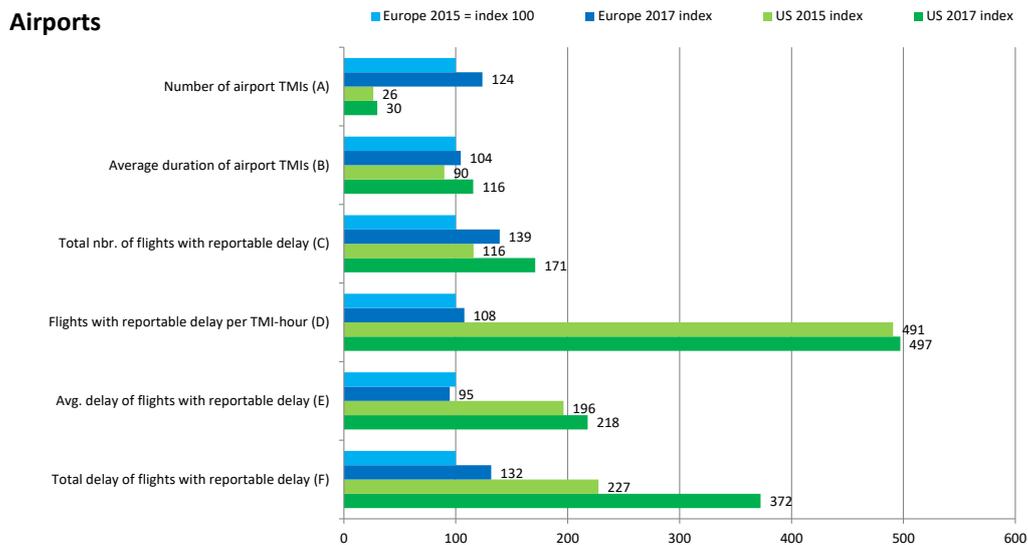


Figure 5-6 Airport-related TMI-L2 (delay TMIs only)

Figure 5-6 compares the use of airport-related ATFM TMIs in the U.S. and Europe:

- A. Airport-related ATFM uses 3 200 TMIs annually in the U.S., and 13 400 in Europe. So Europe uses four times more airport-related TMIs. 86% of the total delay-generating TMIs in the U.S. are airport TMIs; in Europe this is only 35%.
- B. The average duration of these TMIs is very comparable: 3.5 hours for the U.S. vs. 3.1 hours in Europe (only 11% difference U.S. vs. Europe).
- C. The total number of flights with reportable delay due to airport TMIs was 156 000 in Europe, vs. 192 000 in the U.S. This means that 23% more flights are delayed in the U.S. than in Europe. Airport TMIs account for 74% of the flights with ATFM-related reportable delay in the U.S., and only for 40% in Europe.
- D. There is a significant difference in impact per TMI-hour: the U.S. delays 17.3 flights/TMI-hour, in Europe this is only 3.7 flights/TMI-hour (a factor 4.6 less).
- E. These TMIs generated an average delay per delayed flight of 75 minutes in the U.S., which is 2.3 times the European value (33 minutes).
- F. In total, this resulted in 14.4 million minutes of reportable delay in the U.S., compared to 5.1 million minutes in Europe (nearly three times less). Airports account for 83% of the reportable ATFM delay in the U.S., and only for 43% in Europe.

5.2.5 AIRSPACE-RELATED TMIS

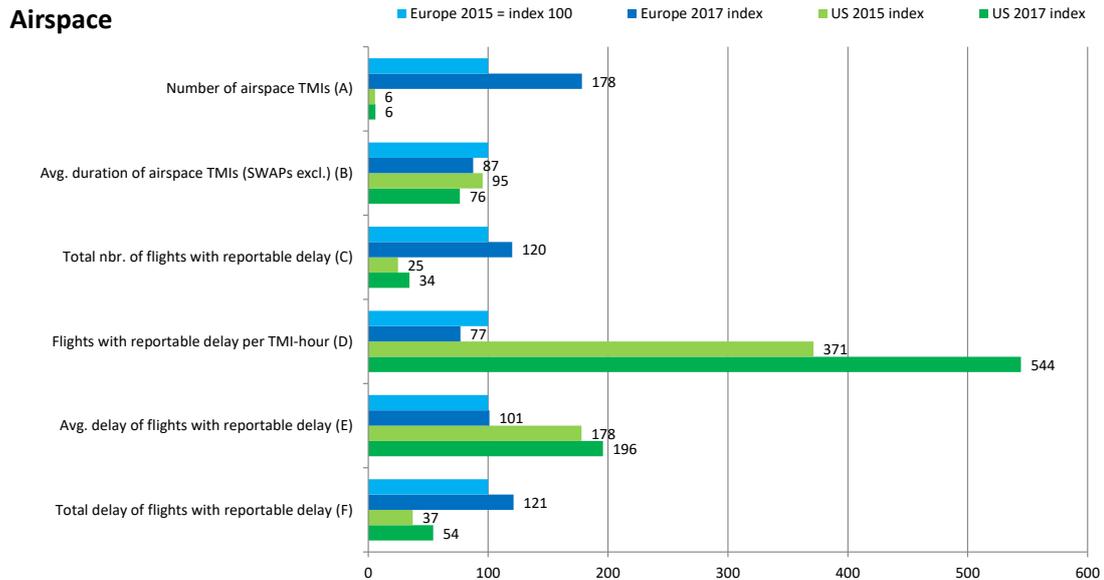


Figure 5-7 Airspace-related TMI-L2 (delay TMIs only)

Figure 5-7 compares the use of airspace-related ATFM TMIs in the U.S. and Europe:

- Airspace-related ATFM uses 840 TMIs annually in the U.S., and 25 000 in Europe. So Europe uses 30 times more airspace-related TMIs. Only 22% of the TMIs in the U.S. are airspace TMIs; in Europe this is 65% of the delay-generating TMIs.
- The average duration of these TMIs is very comparable: 1.7 hours for the U.S. vs. 2.0 hours in Europe (only 13% difference U.S. vs. Europe). In general, airspace TMIs are much shorter than airport TMIs (only half as long in the U.S.).
- The total number of flights with reportable delay due to airspace TMIs was 230 000 in Europe, vs. 66 000 in the U.S. This means that 3.5 times more flights incur airspace-related ATFM delay in Europe than in the U.S. Airspace TMIs account for 26% of the flights with ATFM-related reportable delay in the U.S., and 60% in Europe.
- When looking at impact per TMI-hour, we see a significant difference: the U.S. delays 33.1 flights per TMI-hour, in Europe this is only 4.7 flights per TMI-hour (a factor 7 less). Compared to airport TMI-hours, airspace TMI-hours impact twice the number of flights in the U.S., while in Europe there is no difference.
- These TMIs generated an average delay per delayed flight of 56 minutes in the U.S., which is nearly twice the European value (29 minutes).
- In total, this resulted in 3.0 million minutes of reportable delay in the U.S., compared to 6.6 million minutes in Europe (more than twice the U.S. value). Airspace accounts for only 17% of the reportable ATFM delay in the U.S., and for slightly more than half (56%) in Europe.

5.2.6 USE OF REROUTING AND LEVEL CAPPING TMIs IN EUROPE

In addition to grouping into levels, TMI types are categorized according to their primary purpose:

- Delay
- Rerouting and level capping.

Although the focus of the analysis is on delay TMIs, it was possible to look at rerouting and level capping because ATFM regulations in Europe are used for both purposes. Rerouting and level capping are used when a section of airspace has significantly decreased capacity or is predicted to have excessive occupancy. In the U.S., reroutes are issued as an advisory from the ATCSCC. The analysis of archived advisories is not yet part of the current analysis scope. Hence no results on rerouting in the U.S. are available at this stage.

In Europe, for each area expected to have a critical demand/capacity imbalance, a number of flows may be identified for which other routings may be suggested, that follow the general scheme, but avoid the critical area. These measures are known as scenarios. There are four types:

- Level capping scenarios (FL): carried out by means of zero-rate ATFM regulations with level restrictions, or through dynamic routing restrictions (e.g. Route Availability Document (RAD) restrictions, EURO restrictions).
- Rerouting scenarios (RR): diversion of flows to off-load traffic from certain areas; implemented by means of zero-rate ATFM regulations or through dynamic routing restrictions.
- Alternative routing scenarios (AR): alternative routes which are exceptionally made available to off-load traffic from certain areas, implemented by ATFM regulations with a low rate. The other option is the application of dynamic routing restrictions.
- EU Restrictions: restrictions that affect the flight planning phase based on route or airspace closures.

As mentioned above, the rerouting (RR), level capping (FL) and Alternative Routing (AR) scenarios which are implemented through the ETFMS show up in the data as ATFM regulations. They are translated into the TMI types 'AFP RR', 'AFP FL' and 'AFP AR' respectively. 'AFP RR' and 'AFP FL' TMIs are zero-rate regulations. There is also a small number of zero-rate regulations in the data which could not be classified as rerouting or level capping; these are labelled 'AFP ZR' TMIs.

In principle, zero-rate regulations do not generate any delay; they just force traffic to fly around or above/below the protected location/airspace. 'AFP AR' rerouting TMIs have a non-zero rate; these can generate some delay. As can be seen in Figure 5-8, the use of 'AFP ZR' and 'AFP AR' TMIs is very limited. They serve to solve specific problems, but at European level their use is negligible.

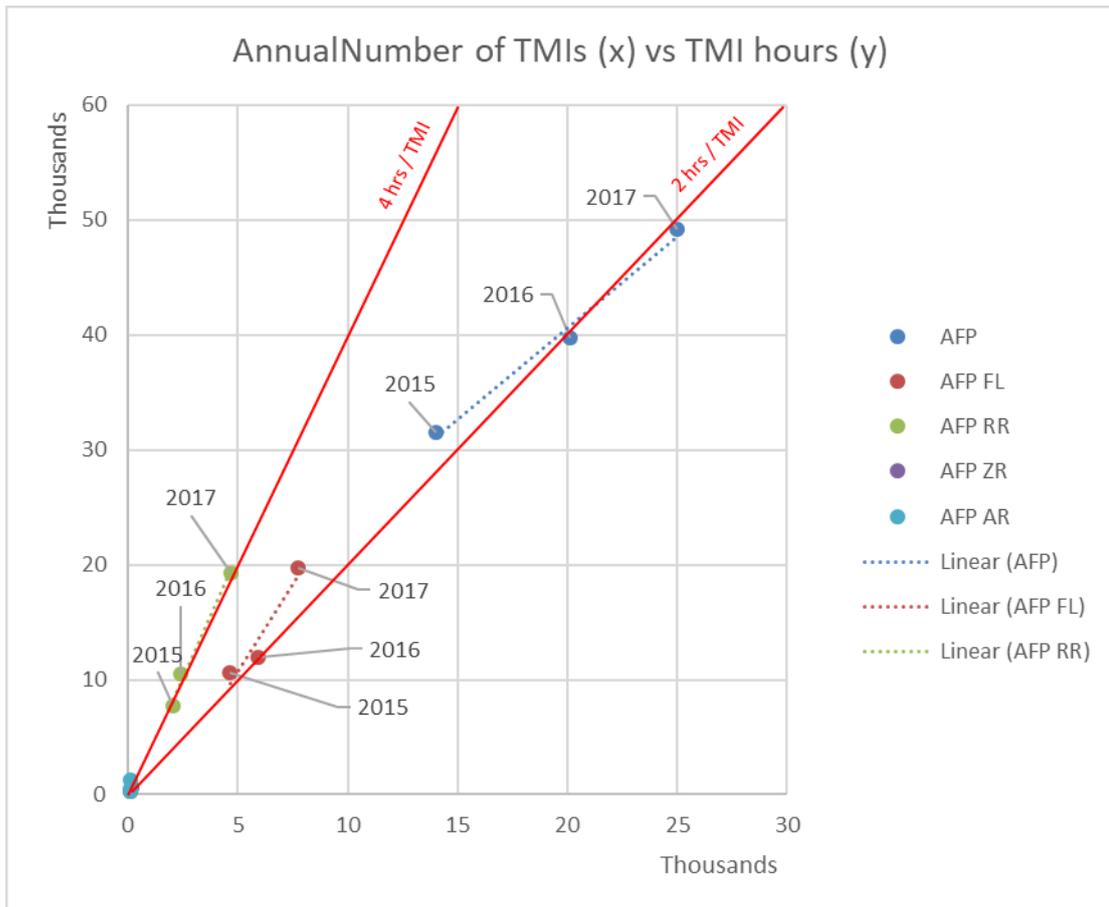


Figure 5-8 Use of TMI-L2 Airspace TMIs in Europe

There is a steady increase in the number of TMIs from 2015 through 2017 for AFPs, as well as level capping (AFP FL) and rerouting (AFP RR):

- the number of AFPs increased by 78%;
- level capping TMIs increased by 68%;
- rerouting TMIs even increased by 129%.

The average duration of AFPs decreased from just above 2 hours to just below 2 hours (-13%). Rerouting TMIs stayed more or less at 4 hours/TMI (+9%), while the average level capping duration increased from 2.3 to 2.6 hours (+12%).

In 2017, this resulted in nearly 20 000 TMI-hours of rerouting and equally close to 20 000 TMI-hours of level capping. This needs to be seen in the context of nearly 50 000 TMI-hours of delay-generating AFPs. So level capping and rerouting makes up 45% of all European TMI-hours, a fact which is not visible when limiting the analysis to ATFM delay.

5.3 ATM-related efficiency by phase of flight

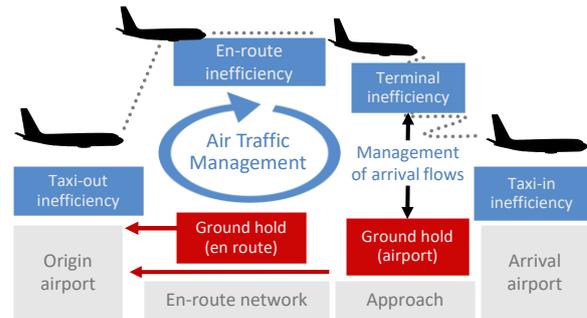
Efficiency generally relates to fuel efficiency or reductions in flight times of a given flight. The analyses in this chapter consequently focus on the difference between the actual travel times and an optimum time of the various phases of flight illustrated in Figure 5-1. For the airborne phase of flight, this “optimum” may be a user-preferred trajectory which would include both the vertical and horizontal profile.

5.3.1 ATM-RELATED DEPARTURE RESTRICTIONS (ATM/TMI DELAYS)

Both the U.S. and Europe report ATM-related delay imposed on departing flights through Traffic Management Initiatives (TMIs) by the ANSP in order to achieve required levels of safety as well as to most effectively balance demand and capacity. In Europe such delays are generally referred to as Air Traffic Flow Management (ATFM) delays.

TMIs imposed at the departure airport can have various ATM-related (ATC capacity, staffing, etc.) and non-ATM-related (weather, accident, etc.) reasons. The categories of delay cause codes differ in the U.S. and Europe; however, five general categories were developed to encompass the varying causal factors (see grey box). Both systems track the constraining facility which allows delay to be reported as either due to terminal/airport or en-route constraints.

Whereas in Europe all flights with a delay of 1 minute or more are reported, in the U.S. only flights delayed by 15 minutes or more are reported (reportable delay)³⁹.



Mapping of delay causes

The table shows how the differing delay codes for EU and U.S. were mapped to produce the analysis in this section.

EUR Code	ATFM reason code (CFMU)	Example	US CODE
C	C-ATC Capacity	Demand exceeds capacity	VOLUME
S	S-ATC Staffing	Illness; Traffic delays on highway	VOLUME
G	G-Aerodrome Capacity	Demand exceeds the declared apt. capacity	VOLUME
V	V-Environmental Issues	Noise restrictions	RUNWAY
I	I-Industrial Action (ATC)	Controllers' strike	OTHER
R	R-ATC Routing	Phasing in new procedures	OTHER
T	T-Equipment (ATC)	Radar failure; RTF failure	EQUIPMENT
W	W-Weather	Low Visibility; crosswinds	WX
D	D-De-icing	De-icing	WX
A	A-Accident/Incident	RWY23 closed due to accident	RUNWAY
E	E-Equipment (non-ATC)	Runway or taxiway lighting failure	EQUIPMENT
M	M-Military activity	Brilliant Invader; ODAX	OTHER
N	N-Industrial Action (non-ATC)	Firemen's strike	OTHER
O	O-Other	Security alert	OTHER
P	P-Special Event	European Cup Football	OTHER

For comparability reasons, only delays equal or greater 15 minutes were included in the analyses. The delays were calculated with reference to the estimated take-off time in the last submitted flight plan (not the published departure times in airline schedules).

The ATM/TMIs shown for the U.S. in this section include all TMI delays. The TMIs included are Ground Stops (GS), Ground Delay Program (GDP), Collaborative Trajectory Options Program (CTOP), Airspace Flow Programs (AFP), Severe Weather Avoidance Plan (SWAP), Miles in Trail (MIT), Minutes in Trail (MINIT), Departure Stops, Metering, Departure/En-Route/Arrival Spacing Programs (DSP/ESP/ASP).

³⁹ In the U.S., ATM delay by Causal Factor is recorded in the FAA OPSNET database. FAA requires facilities to report all delay equal or greater than 15 minutes.

Figure 5-9 shows average ATM/TMI delay (en-route and terminal) per flight between 2008 and 2017. More detailed analyses of causal reasons for changes between 2015 and 2017 are provided in later figures for both U.S. and Europe.

In Europe, average ATM/TMI delay continuously decreased until 2013, following the historically bad performance due to weather and strikes in 2010. Between 2015 and 2017, average ATM/TMI delay minutes per flight equal or greater than 15 minutes increased in Europe by 33.9% whereas traffic only increased by 5.0% over the same period.

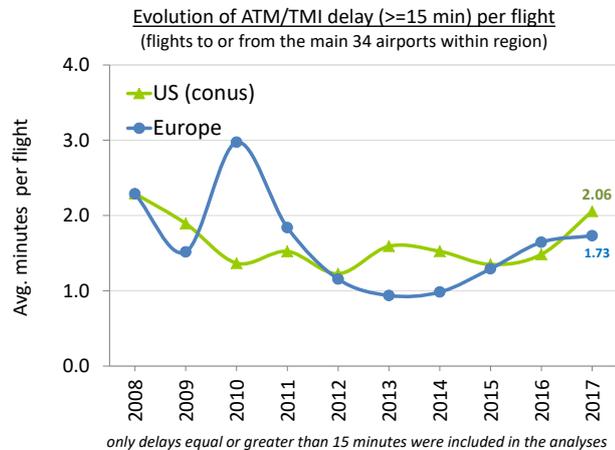


Figure 5-9: Evolution of ATM/TMI delay per flight (2008-17)

The U.S. has also shown a decline since 2008. However, between 2015 and 2017, average ATM/TMI delay minutes per flight increased by 52.3% with traffic levels to/from the main 34 airports within region increasing by 2.2%. Newark (17.9%) and San Francisco (11%) contributed to more than half (28.9%) of the increase between 2015 and 2017 (52.3%).

Table 5-1 compares ATM/TMI delays between the U.S. and Europe. The total delay per flight (min.) is similar in 2008 and 2015, whereas in 2017 it is 19% higher in the U.S. Flights in Europe are more likely to be held at the gate but with half of the delay per delayed flight.

Only ATM/TMI delays >= 15 min. are included.		EUROPE			US (CONUS)		
		2008	2015	2017	2008	2015	2017
IFR flights (M)		5.5 M	5.0 M	5.2 M	9.3	8.2	8.4
Total delays >=15min. (ATM/TMI)	% of flights delayed >=15 min.	7.8%	4.3%	5.8%	3.6%	2.4%	3.4%
	delay per flight (min.)	2.29	1.29	1.73	2.29	1.35	2.06
	delay per delayed flight (min.)	29	30	30	64	55	61
Airport related delays >=15min. (ATM/TMI)	% of flights delayed >=15 min.	2.8%	2.3%	2.7%	2.6%	1.8%	2.4%
	delay per flight (min.)	0.90	0.74	0.84	1.90	1.11	1.70
	delay per delayed flight (min.)	32	32	31	74	63	71
En route related delays >=15min. (ATM/TMI)	% of flights delayed >=15 min.	5.0%	2.0%	3.2%	1.0%	0.7%	1.0%
	delay per flight (min.)	1.39	0.56	0.89	0.39	0.24	0.35
	delay per delayed flight (min.)	28	28	28	38	35	36

Table 5-1: ATM/TMI departure delays (flights to or from main 34 airports within region)

The difference in ATFM strategy between the U.S. and Europe is clearly visible. In the absence of en-route sequencing in Europe, reducing ATFM delays (by releasing too many aircraft) at the origin airport when the destination airport's capacity is constrained potentially increases delays in the gate to gate phase. On the other hand, applying excessive ATFM delays risks underutilization of capacity and thus, increases overall delay.

Figure 5-10, shows a breakdown of the ATM/TMI delays by facility (en-route vs. airport) and by attributed delay cause. A significant difference between the U.S. and Europe is the location causing the delays (charged facility).

In the U.S. the majority of ATM/TMI delays are due to airports (82.8%) while in Europe it is more equality distributed between airports (48.4%) and en-route (51.6%) facilities. By far the main reason for delays in the U.S. is adverse weather (77.8%). In Europe, the main cause is ATC capacity and staffing constraints (including ATC strike) accounting to 44.5% closely followed by

adverse weather accounting to 41.9%. More analysis is needed to evaluate how the moderation of demand with “airport slots” in Europe impacts on the significant difference in ATM/TMI delay attribution between the U.S. and Europe.

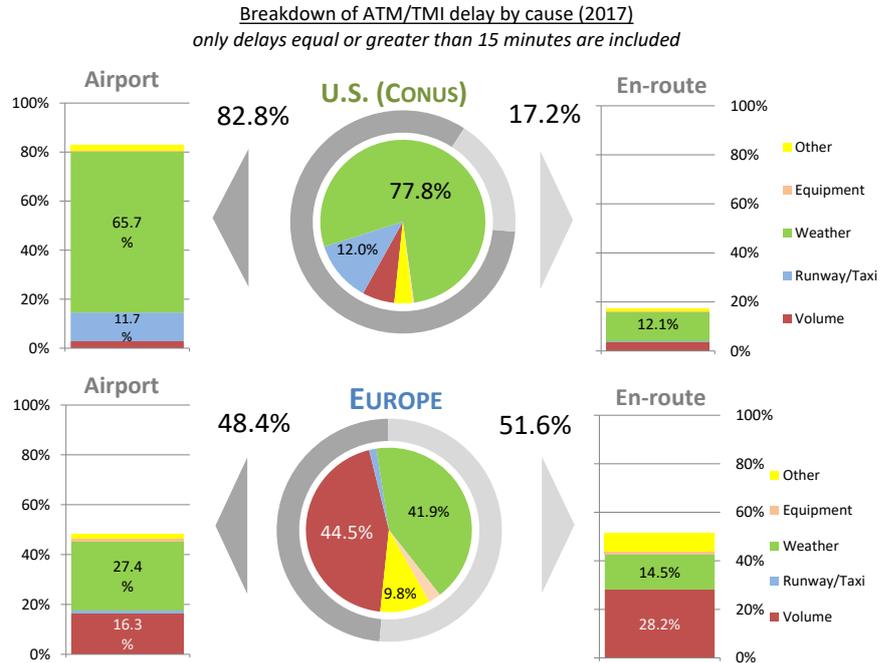


Figure 5-10: Breakdown of ATM/TMI delay by cause and location (2017)

Figure 5-11 shows this change from 2015 to 2017 by causal factor. In the U.S., three airports (Newark, San Francisco, & Los Angeles) were responsible for 58% of the increase with 30% of the increase attributable to Newark. This was largely due to weather (wind and visibility quantified in Figure 5-14) and runway/taxiway (construction projects explained in delay by destination airport) as well as increased demand at Newark in key time periods after the expiration of IATA Level 3 schedule limitations. For EWR, these increased peaks require use of all three runways which is not possible in the most prevalent weather conditions. Under US reporting, these delays are largely attributed to wind.

Change in ATM/TMI delay by cause 2017 vs. 2015 (%)
Only delays equal or greater than 15 minutes were included

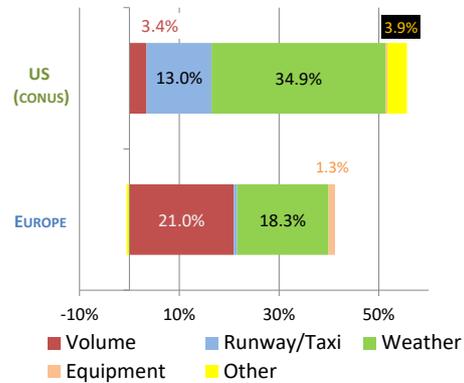


Figure 5-11: Change in ATM/TMI delay by cause (2017 vs. 2015)

In Europe, the performance deterioration between 2015 and 2017 was due to a significant increase in ATFM delays attributed to capacity (volume) and adverse weather.

Figure 5-12 provides breakdown of the ATM/TMI delay by charged facility in 2017. The analysis in Figure 5-12 highlights the substantial difference in charged facilities between the U.S. and Europe.

In 2017, seven U.S. airports generated 68% of all ATM/TMI delay in the U.S. with only 17% attributable to en-route facilities. Weather-related constraints (wind, thunderstorms, and low ceilings) at the New York airports (EWR, LGA, & JFK) in 2017 constituted 33% of the total delay

minutes. Runway/Taxiway construction projects at San Francisco (SFO), New York (JFK), Boston (BOS), and Los Angeles (LAX) in 2017 contributed to 11% of the total delay minutes.

In Europe this is more equally distributed between en-route and airport facilities but also between airports. In 2017, 52% of all ATM/TMI delays were caused by en-route facilities whereas the five most constraining airports accounted for 23% of total ATM/TMI delay.

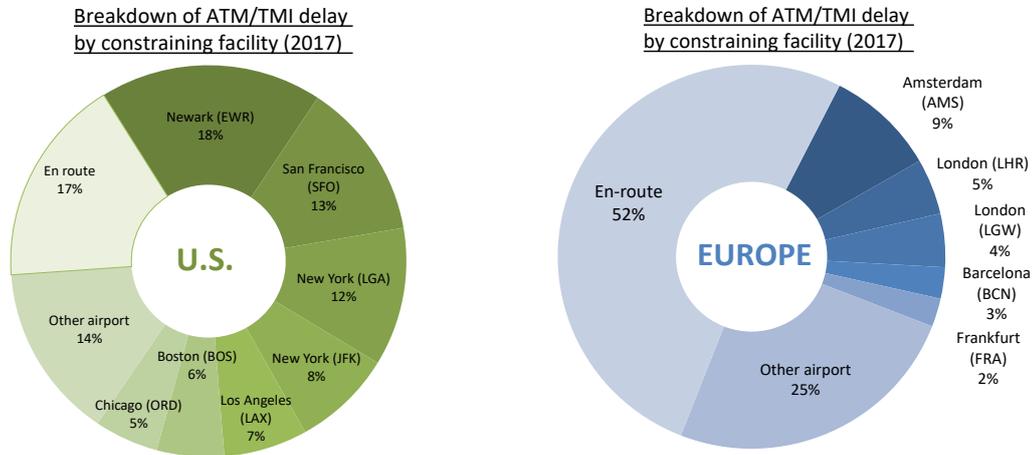


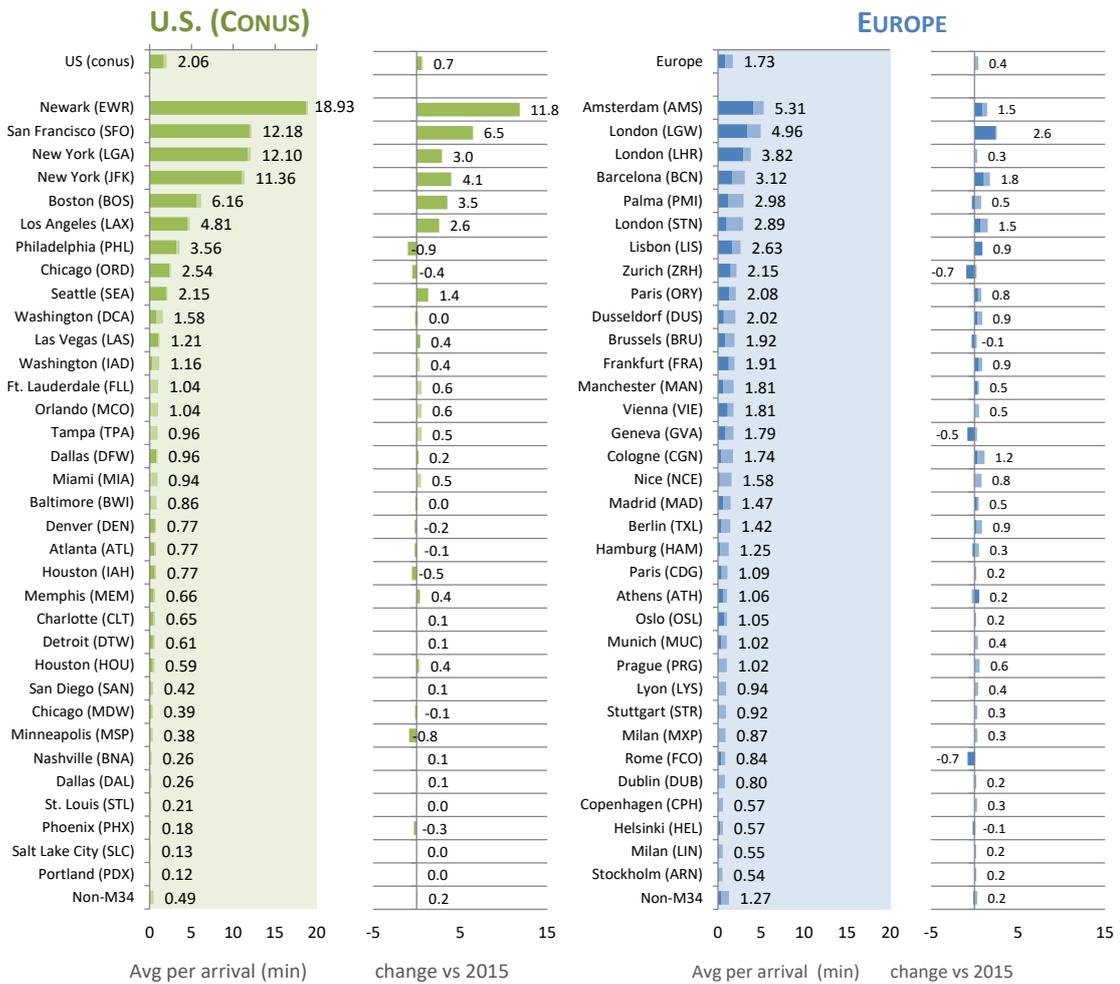
Figure 5-12: Breakdown of ATM/TMI delay by charged facility (2017)

Figure 5-13 compares the average minutes of ATM/TMI delays on flights arriving at the top 34 airports in 2017. As already shown in Figure 5-12, in Europe, ATM/TMI delays are more evenly spread across airports with Amsterdam (AMS), London (LHR), and London Gatwick (LGW) generating the highest amounts of airport ATFM delay in 2017 in absolute terms.

Figure 5-13 indicates that flights to Newark (EWR) have an average ATFM delay which is three times higher than Amsterdam (AMS). The observed increase in the U.S. between 2015 and 2017 was mainly driven by a substantial increase at Newark and San Francisco airport.

ATM/TMI delay by destination airport (2017)

ATM/TMI delays >= 15 min by arrival airport



Source: EUROCONTROL PRU/ FAA-ATO

Figure 5-13: ATM/TMI delay by destination airport (2017)

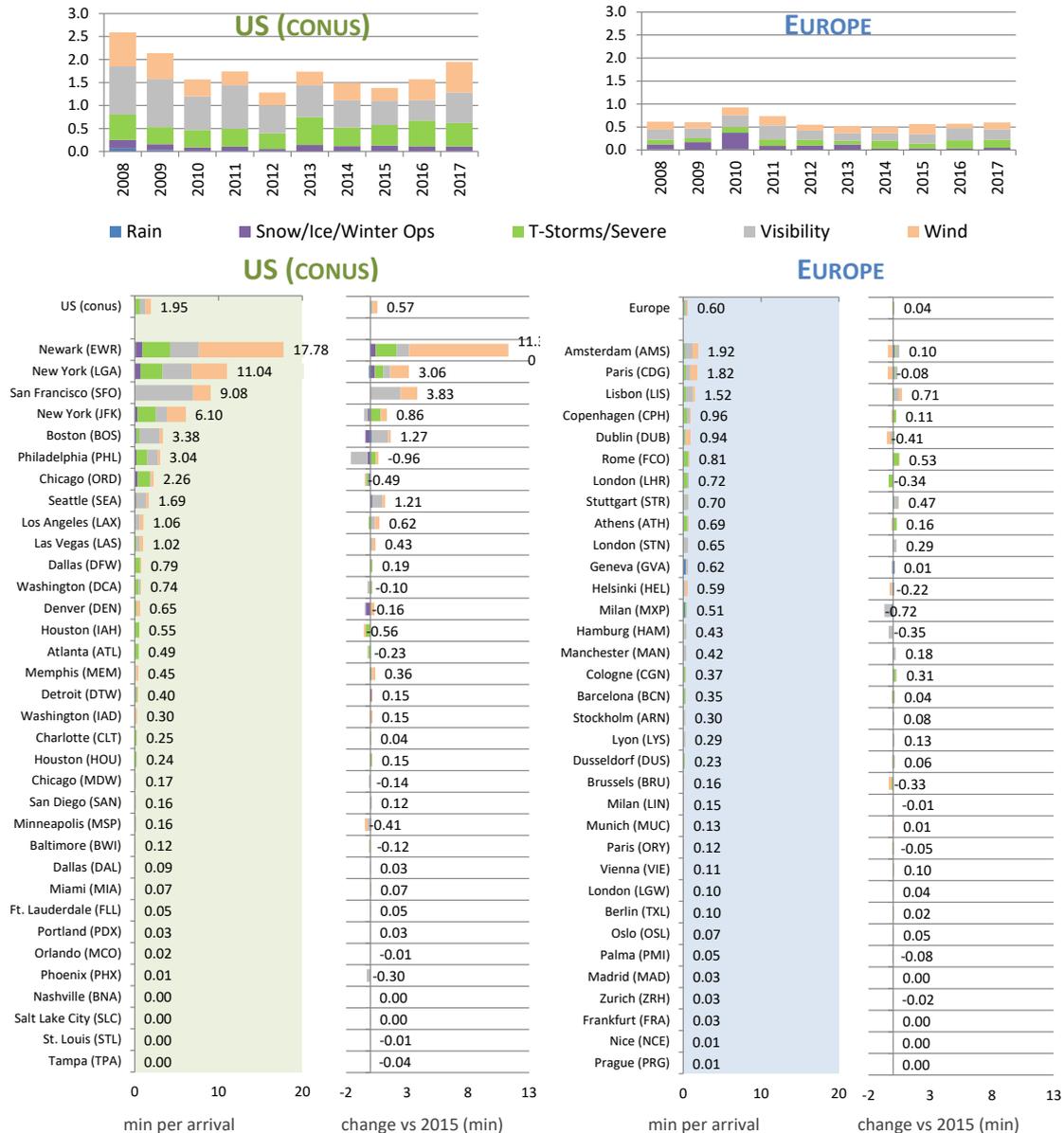
As weather is a major factor influencing runway throughput and airport capacity, Figure 5-14 shows a complementary analysis to Figure 5-13 focusing on weather attributed ATM/TMI delays⁴⁰ charged to airports only.

Figure 5-13 and Figure 5-14 show that the ATM/TMI trends in the U.S. do not change as a result of dissecting the data by destination airport or by constraining facility (charged facility). As mentioned earlier, 68% of all TMI delays in the U.S. is generated at seven airports and the primary causal factors of all TMI delays is weather (65.7%) shown in Figure 5-10. As also stated earlier for Newark (EWR), the increase in peak traffic after expiration of IATA Level 3 schedule limitations requires the use of all 3 runways which is not possible in the most prevalent wind conditions. Under US reporting, these delays increases are largely attributed to wind.

⁴⁰ Please note that for Europe all ATFM delays are included whereas for the U.S. only delays equal or greater than 15 minutes are included. ATFM delays include all TMI delays.

Airport charged weather-related ATM/TMI delay (34 airports (2017))

Avg. weather related delay per arrival (min)



Source: EUROCONTROL PRU/ FAA-ATO

Figure 5-14: Causes of weather-related airport ATFM delays (2008-2017)

The comparison of airport-charged weather-related delays and destination airport delays at EWR (17.78 out of 18.70), LGA (11.04 out of 11.71), SFO (9.08 out of 11.96), JFK (6.10 out of 10.99), BOS (3.38 out of 5.64), PHL (3.04 out of 3.21), and ORD (2.26 out of 2.38) clearly show the contribution of weather-related delays at the seven airports.

A high average weather-related airport arrival delay is usually the result of a notable capacity reduction in bad weather combined with a high level of demand (i.e. peak throughput close to or higher than the declared capacity). For the U.S., airports with high demand and highly variable capacity are shown in section 3.2.3 with Figure 3-11.

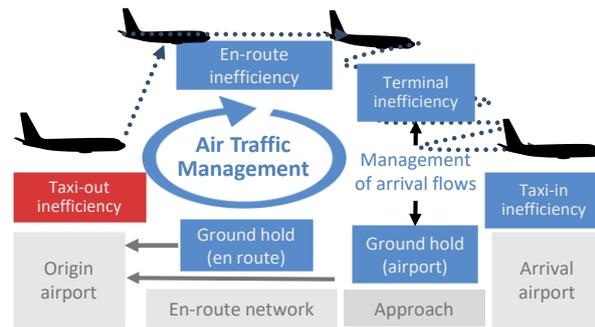
Overall, relatively higher ATFM delays per arrival are observed in the U.S. compared to Europe when weather-related restrictions are present. This may be due to European capacities being set more conservatively (according to IFR conditions in the strategic phase) to allow for unforeseeable events whereas the U.S. operates with very little schedule limitations.

In the U.S. the primary driver for the increase in weather attributed ATM/TMI delays charged to airports between 2015 and 2017 was wind. A few notable U.S. airports experience delay levels that are magnitudes higher than other airports in the country or in Europe. The New York area airports (EWR, LGA, and JFK) experience high average ATFM weather-related delays. Wind-related delays at Newark (EWR) increased significantly between 2015 (two minutes per arrival) and 2017 (10 minutes per arrival). Slight changes in winds at Newark (EWR) cause change in runway configuration (shifting to two parallels; one each for departure/arrival) resulting in capacity reduction. On average, EWR's demand exceeds 80% of capacity for 13 hours of the operating day compared to approximately 11 hours in 2015 (explained in section 3.2.3). High demand at peak hours (IATA slot level downgrade from Level 3 to 2 in winter 2016) resulted in flights being delayed at origin airports to reconcile demand with capacity at EWR due to wind. In 2017, approximately 15% of the flights destined to EWR had TMI delays due to wind-related constraints.

On the West Coast, fog and low visibility are the most impactful weather cause for ATFM delays at San Francisco (SFO). Low ceilings, wind, and runway/taxiway construction at SFO resulted in increased ground delays for flights destined to SFO. In 2017, SFO's demand exceeds 80% of capacity for 11 hours of the operating day (compared to approximately eight hours in 2015) and peak throughput is close to peak capacity. Therefore, a weather disruption (wind and low ceiling due to fog) at SFO causes ground delays at origin airports to reconcile demand with capacity at SFO. In 2017, approximately 12% of flights destined to SFO had ground delays due to wind and low ceilings.

5.3.2 ATM-RELATED TAXI-OUT EFFICIENCY

This section aims at evaluating the level of inefficiencies in the taxi-out phase. The analysis of taxi-out efficiency refers to the period between the time when the aircraft leaves the stand (actual off-block time) and the take-off time. The additional time is measured as the average additional time beyond an unimpeded reference time.



In the U.S., the additional time observed in the taxi-out phase also includes some delays due to ATM/TMI and departure delays taken after pushback from the gate due to constraints at the departure airport and en-route (at local TRACON and ARTCC). The TMIs associated to local en-route constraints are SWAP, MIT, MINIT, DSP/ESP/ASP, etc. In Europe, the additional time might also include a small share of ATFM delay which is not taken at the departure gate, or some delays imposed by local restriction, such as Minimum Departure Interval (MDI).

The taxi-out phase and hence the performance indicator is influenced by a number of factors such as take-off queue size (waiting time at the runway), distance to runway (runway configuration, stand location), downstream departure flow restrictions, aircraft type, and remote de-icing, to name a few. Of these aforementioned causal factors, the take-off queue size⁴¹ is considered to be the most important one for taxi-out efficiency [Ref. [24]].

Although the impact of ANSPs on total additional time is limited when runway capacities are constraining departures, in Europe, Airport Collaborative Decision Making (A-CDM) initiatives try to optimize the departure queue by managing the pushback times. The aim is to keep aircraft at the stand to reduce additional time and fuel burn in the taxi-out phase to a minimum by providing only minimal queues and improved sequencing at the threshold to maximize runway throughput. These departure delays at the gate are reflected in the departure punctuality indicators. However, the ATM part due to congestion in the taxiway system is presently difficult to isolate with the available data.

Two different methodologies were applied for the analysis of taxi-out inefficiencies. While the first method used for Figure 5-15 is simpler, it allows for the application of a consistent methodology. The method uses the 20th percentile of each service (same operator, airport, etc.) as a reference for the “unimpeded” time and compares it to the actual times. This can be easily computed with U.S. and European data.

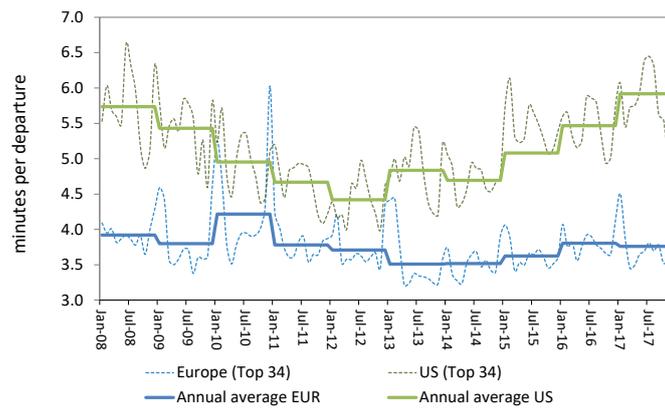
On average, additional times in the taxi-out phase are higher in the U.S. than in Europe with a maximum difference of approximately 2 minutes more per departure in 2008 and again in 2017. Between 2008 and 2012, U.S. performance improved continuously while European performance only improved gradually which narrowed the gap between the U.S. and Europe.

The Europe/U.S. gap reduced from 2008 to 2012 and then has been increasing back to 2008 levels. The historical differences are largely driven by changes in scheduling caps in the U.S. Other causal factors for recent increases such as runway or taxiway construction in the U.S. are described below.

⁴¹ The queue size that an aircraft experienced was measured as the number of take-offs that took place between its pushback and take-off time.

Additionally, airlines in the U.S. have incentives for on-time gate departures to adhere to the published schedule times. Additional delay if necessary is absorbed in the taxi-out phase. Between 2015 and 2017 the performance in Europe only slightly deteriorated whereas in the U.S. average additional times in the taxi-out phase increased by approximately one minute per departure.

Additional time in the taxi-out phase compared to 20th perc. of each service (service = same operator, same airport, monthly)



Source: FAA/PRC analysis

Figure 5-15: Additional times in the taxi-out phase (system level)

Runway/Taxiway construction projects at San Francisco (SFO), Los Angeles (LAX), and New York (JFK) contributed to an increase in additional taxi-out time. The increase in additional taxi-out times in the U.S. is also linked to worsening weather attributable delay for specific areas of the country as a result of which airport and local en-route TMI delays (SWAP, MIT, MINIT, Metering, DSP/ESP/ASP, etc.) were taken on the ground after pushback.

Seasonal patterns emerge, but with different cycles in the U.S. and in Europe. Whereas in Europe the additional times peak during the winter months (due to weather conditions), in the U.S. the peak is in the summer which is linked to congestion.

The analysis of additional taxi-out time by airport in Figure 5-16 and the time series between 2008 and 2017 is based on the more sophisticated methodologies by each of the performance groups in the U.S. and Europe⁴². It illustrates the contrasted situation among airports and the change compared to 2015.

In the U.S., the system level additional times in the taxi-out phase increased by approximately one minute from 2015 to 2017. San Francisco, Los Angeles, Newark, and Seattle contributed to almost 50% of the increase in additional taxi-out time. In addition to delays due to runway/taxiway construction in 2017, flights departing from SFO were delayed after pushback because of noise abatement techniques deployed to sequence traffic (Departure Spacing Programs) out of San Francisco by the Northern California TRACON. Surface congestion at LAX due to runway/taxiway construction projects followed by increase in departure operations at Newark and Seattle were the major causal factors for increase in system additional taxi-out time.

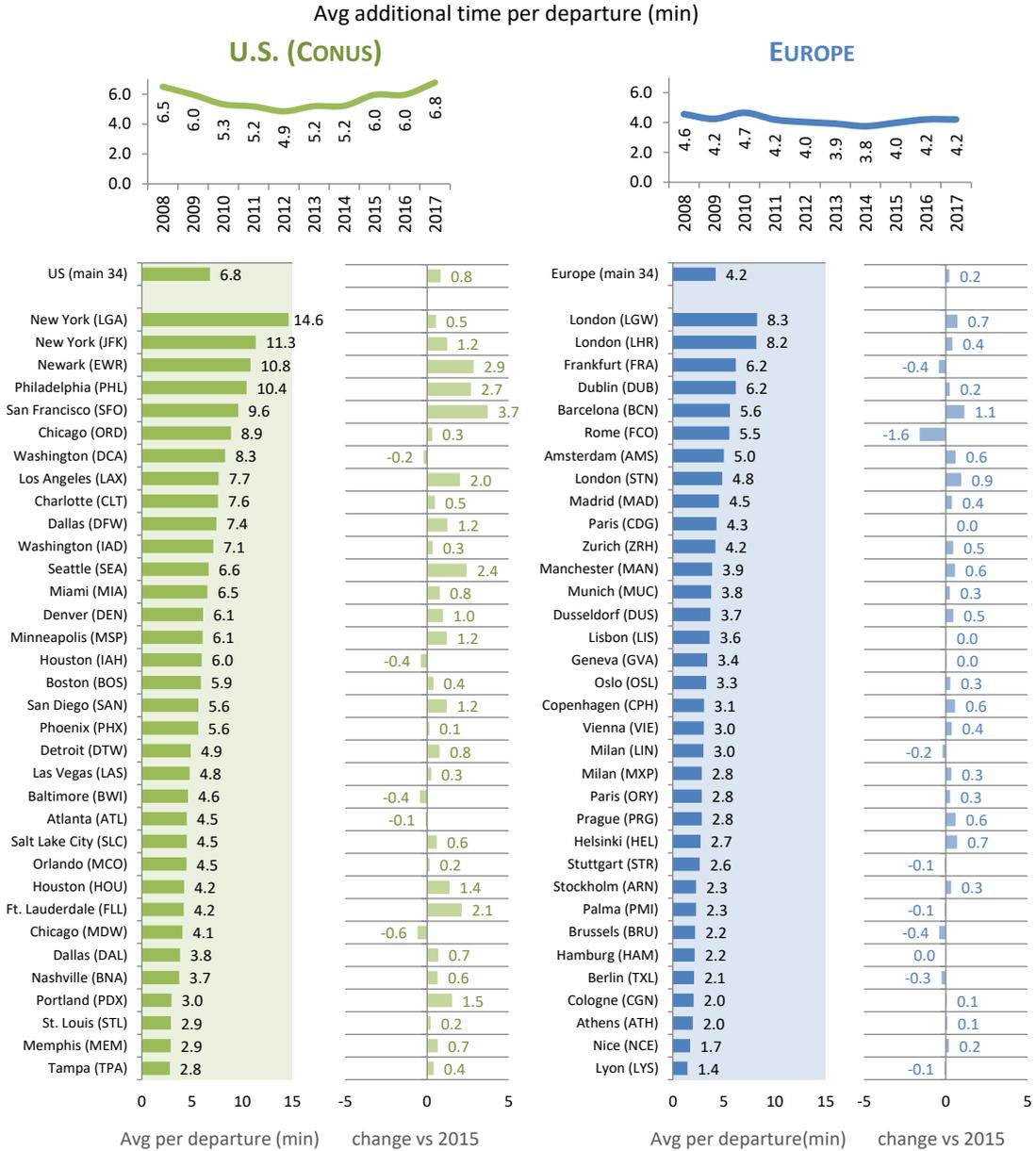
The four airports listed are IATA level 2 with demand close to capacity and Newark was downgraded to level 2 from level 3 in winter 2016 which increased departure operations in 2017. Seattle became IATA level 2 with an increase in operations and the preferential usage of a certain runway (16C for departures in south flow) away from the terminals at Seattle in 2017 also contributed to system increase in additional taxi-out time.

The New York airports, Philadelphia (PHL), and San Francisco (SFO) showed the highest average additional time in 2017. In addition to runway/taxiway construction at JFK, flights departing from New York airports (EWR, JFK, & LGA) and PHL experienced departure delays after pushback due to en-route constraints (New York TRACON and New York ARTCC) during the convective weather

⁴² A description of the respective methodologies can be found in the Annex of the 2010 comparison report.

season. In 2017, en-route constraints (SWAP delays because of thunderstorms and MIT delays because of volume) along with airport constraints (volume) increased rapidly at PHL. The close proximity of the three New York airports and PHL along with high demand in the New York ARTCC creates volume based delays for departing aircraft during extreme weather conditions.

Additional time in the taxi out phase - departures from main 34 airports (2017)



Source: EUROCONTROL PRU/ FAA-ATO

Figure 5-16: Additional time in the taxi-out phase by airport (2017)

In Europe, the two London airports (LHR, LGW), and Frankfurt (FRA) showed the highest average additional taxi-out time in 2017. Overall, additional taxi-out time in 2017 was 2.5 minutes higher per departure in the U.S. than in Europe which is largely driven by different flow control policies and the high variability in capacity at some airports either due to weather or construction. In contrast to Europe, there is also an absence of scheduling caps at most U.S. airports. While in Europe the inefficiencies are more evenly spread among airports, in the U.S. half of taxi-out inefficiency is driven at eight airports (Chicago ORD, New York LGA, Dallas DFW, New York JFK,

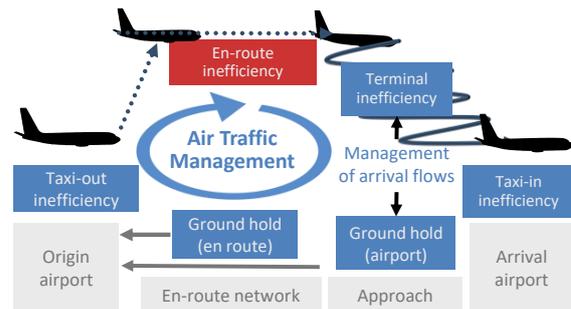
Los Angeles, Atlanta, Charlotte, and Newark). These airports have high contributions to system totals due to both high averages and the large number of operations at the facility.

Although some care should be taken when comparing the two indicators due to slightly differing methodologies, Figure 5-16 tends to confirm the trends seen in Figure 5-15. Overall, additional taxi-out times appear to be higher in the U.S. Although the gap closed between 2008 and 2011, U.S. performance started to deteriorate again in 2013 whereas the performance in Europe only worsened moderately between 2013 and 2017.

5.3.3 EN-ROUTE FLIGHT EFFICIENCY

This section evaluates en-route flight efficiency in the U.S. and Europe. The indicators assess actual flight trajectories or filed flight plans against an ideal or benchmark condition.

From an operator’s perspective, this ideal trajectory would be a User-Preferred Trajectory that would have a horizontal (distance) and a vertical (altitude) component.



Ideal altitudes are highly affected by external factors such as aircraft specific weight and performance as well as turbulence and other weather factors. For this reason, much more detailed data from airlines and tactical responses to weather would be needed to establish an efficiency criterion for altitude. Furthermore, the horizontal component is, in general, of higher economic and environmental importance than the vertical component across Europe as a whole [Ref. [25]].

Nevertheless there is potential for further improvement in the vertical profile, and Section 5.3.5 in this report provides an initial comparison of vertical flight efficiency in the arrival phase between the U.S. and Europe which will help to provide a more complete picture in the future.

The focus of this section is on the horizontal component of the en-route phase. Two KPIs are reported. The first one compares the lengths of the en-route section of the last filed flight plan to a benchmark “achieved distance” (apportionment of great circle distance). The second KPI compares actual trajectories against “achieved distance.”

For a flight, the “inefficiency” is the difference between the length of the analyzed trajectory (filed flight plan or actual flown) and an “achieved” reference distance (see also grey box). Where a flight departs or arrives outside the reference airspace, only that part inside the airspace is considered.



Horizontal en-route flight efficiency

Horizontal en-route flight efficiency compares the length of flight plan or actual trajectories (A) to the “achieved” distance (H).

The achieved distance apportions the Great Circle Distance between two airports. If the origin/destination airport is located outside of the reference airspace, the entry/exit point into the airspace is used for the calculation.

The refined methodology enables to better differentiate between local inefficiency (deviations from GCD between local entry and exit points) and the contribution to the network.

More information on horizontal en-route flight efficiency in Europe is available at www.ansperformance.eu.

“En-route” is defined as the portion between a 40 NM radius around the departure airport and a 100 NM radius around the arrival airport. The indicator is calculated as the ratio of the sum, over all flights considered. The methodology used for the computation of horizontal en-route flight

efficiency in this report is consistent with the flight efficiency indicators used in the Single European Sky performance scheme.

The flight efficiency in the last 100 NM before landing which also includes airborne holdings is addressed in the next section of this report 5.3.4.

It is acknowledged that this distance-based approach does not necessarily correspond to the “optimum” trajectory when meteorological conditions or economic preferences of airspace users are considered for specific flights. However when used at the strategic level, the KPI will point to areas where track distance is increasing or decreasing over time.

OPPORTUNITIES AND LIMITATIONS TO IMPROVING HORIZONTAL FLIGHT-EFFICIENCY

While there are economic and environmental benefits in improving flight efficiency, there are also inherent limitations. Trade-offs and interdependencies with other performance areas such as safety, capacity, and environmental sustainability as well as airspace user preferences in route selection due to weather (wind optimum routes), route availability, or other reasons (differences in route charges⁴³, avoidance of congested areas) affect en-route flight efficiency.

En-route flight inefficiencies are predominantly driven by (1) route network design (2) route availability, (3) route utilization (route selection by airspace users) and (4) ATC measures such as MIT in the U.S. (but also more direct routings).

Although a certain level of inefficiency is inevitable, there are a number of opportunities for improvement. The following limiting factors should be borne in mind for the interpretation of the results:

- Basic rules of sectorisation and route design. For safety reasons, a minimum separation has to be applied between aircraft;
- Systematisation of traffic flows to reduce complexity and to generate more capacity;
- Strategic constraints on route/ airspace utilization.
- Impact of Special Use Airspace (SUA) on flight efficiency.
- Interactions with major airports. Major terminal areas tend to be more structured. As traffic grows, departure traffic and arrival traffic are segregated and managed by different sectors. This TMA organization affects en-route structures as over-flying traffic has to be kept far away, or needs to be aligned with the TMA arrival and departure structures.
- Route availability and route planning. Once routes are made available for flight planning, their utilization is in the hand of flight dispatchers and flow managers. Many airlines prepare flight plans based on fixed route catalogues and do not have the tools/resources to benefit from shorter routes when available. Aircraft operators often rely on tactical ATC routings.
- In Europe, en-route flight efficiency is also affected by the fragmentation of airspace (airspace design remains under the auspices of the States).
- For the U.S., the indicator includes the effect of en-route holding and vectoring.
- Lastly, planned cruise speeds or altitudes are not known by ATC systems and may require detailed performance modelling or information on airline intent.

⁴³ In Europe, the route charges differ from State to State.

While technologies, concepts, and procedures have helped to further optimize safety, add capacity, and increase efficiency (e.g. Reduced Vertical Separation Minima, RNAV) over the past years, it will remain challenging to maintain the same level of efficiency while absorbing forecast demand increases over the next 20 years.

Figure 5-17 shows the evolution of horizontal en-route flight efficiency (actual and flight plan) compared to achieved distance between 2008 and 2017. An “inefficiency” of 5% means for instance that the extra distance over 1 000 NM was 50 NM. Due to data availability, the KPIs for Europe are only shown as of 2011.

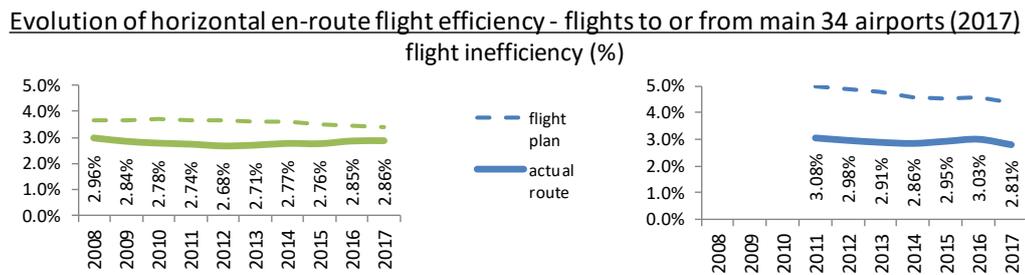


Figure 5-17: Evolution of horizontal flight efficiency (actual and flight plan) (2008-2017)

Both systems show a comparable level of flight “inefficiency” in actual trajectories in the en-route phase. Due to a notable improvement in 2017, actual flight efficiency is for the first time slightly better in Europe than in the U.S. at system level. The level of total horizontal en-route flight inefficiency for flights to or from the main 34 airports in Europe in 2017 was 2.81% compared to 2.86% in the U.S.

Although much smaller in the U.S., there is a notable gap between flight plan and actual flight inefficiency in the U.S. and in Europe. The difference between planned and actual operations reveals that in general flights fly more direct than their flight plan in both systems. This is most likely due to more direct tracks provided by ATC on a tactical basis when traffic and airspace availability permits.

Despite an improvement over time, the inefficiency in filed flight plans in Europe in 2017 was 4.40% which is significantly higher than in the U.S. (3.42%). The narrower gap in the U.S. could be due to the fact that many of the heaviest travelled city pairs such as San Francisco to Los Angeles or Chicago to the New York area both file direct flight and achieve direct flight for the majority of flights.

Figure 5-18 shows the actual en-route extension on flights arriving at the main U.S. and European airports in terms of additional miles per arrival in 2017.

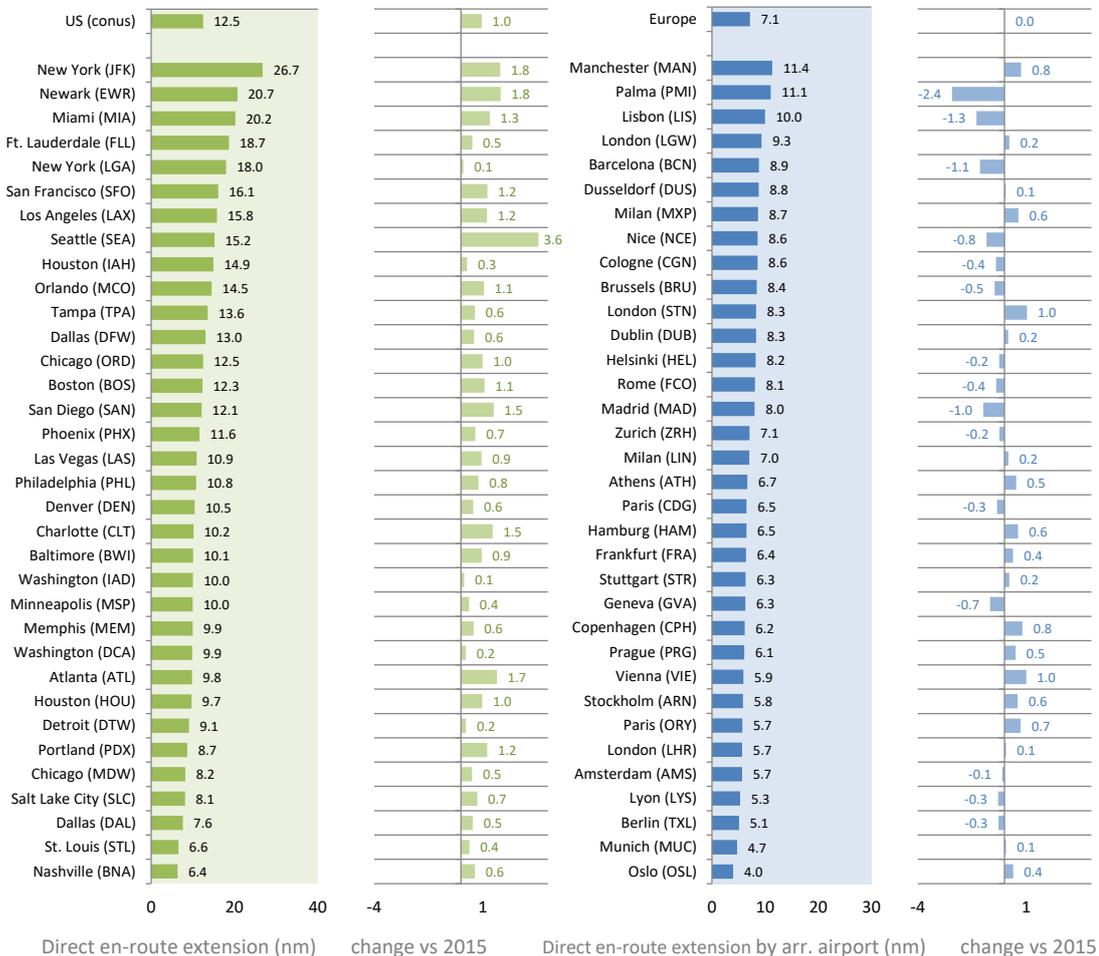
Seattle (SEA) showed the biggest change (3.6 NM) compared to 2015. This 3.6 NM change at Seattle was driven by flights arriving from Los Angeles, San Francisco, and non main34 airports. U.S. CONUS arrivals at SEA grew 10% compared to 2015 and departures were primarily from the West Coast airports. U.S. airports show some clustering and patterns when values are summed by destination airport, particularly for New York Area and Florida airports. In assessing specific city pairs for these facilities, three causal reasons emerge. These include 1) Traffic into New York Area especially from Texas and Florida, 2) Effects of Special Activity Airspace on East Coast and West Coast and 3) Transcontinental Flights.

Almost all direct flights between the New York area and Florida airports would require flight through special use airspace. Many of the flights to East Coast and West Coast airport destinations involve long transcontinental flight where large values do not translate into high percentages. Furthermore, these transcontinental flights require much more scrutiny as the ideal flight would consider winds and not be limited to direct flight.

Lastly, existing route design into the New York area does not allow for direct flights for some key city pairs (DFW and IAH to New York Area). This may be due to congestion caused by high traffic and the presence of major airports located close together. In the future, it may be possible to fly more direct to the New York area as the FAA makes continued improvements to airspace design and more advanced traffic flow management is implemented.

In absolute terms, the average additional mileage in the U.S. is higher due to the longer flights but in relative terms the level of flight inefficiency is lower (i.e. inefficiency per flown distance).

Horizontal en-route flight extension by destination airport (2017)
Actual trajectory - NM by arrival airport (main 34)



Source: EUROCONTROL PRU/ FAA-ATO

Figure 5-18: Direct en-route extension by destination airport (2017)

As traffic and the underlying network has changed, the increase is a product of both increasing distance and the distribution of flights among the network. In the U.S., key city pairs contributing to the increase in traffic are in the East Coast (FLL-EWR & MCO-EWR) and West coast (LAX-SEA & LAX-PDX). The East Coast and West Coast have special activity airspaces and more traffic between city pairs along the coast causes an uptick in horizontal flight efficiency.

Figure 5-19 shows flights tracks for LAX-SEA in 2015 and 2017 with actual en-route extension (Actual-Direct) greater than or equal to 17 NM. The average Actual-Direct was 17 NM in 2017 and was used to visually compare the flight tracks with 2015. As can be seen from the figure, the number of flights with Actual-Direct greater than or equal to 17NM increased significantly between 2015 and 2017. In fact, the number doubled from 2,387 in 2015 to 4,966 in 2017.

Improvements to en-route design are, by definition, a network issue which requires a holistic, centrally coordinated approach. Uncoordinated, local initiatives may not deliver the desired objective, especially if the airspace is comparatively small.

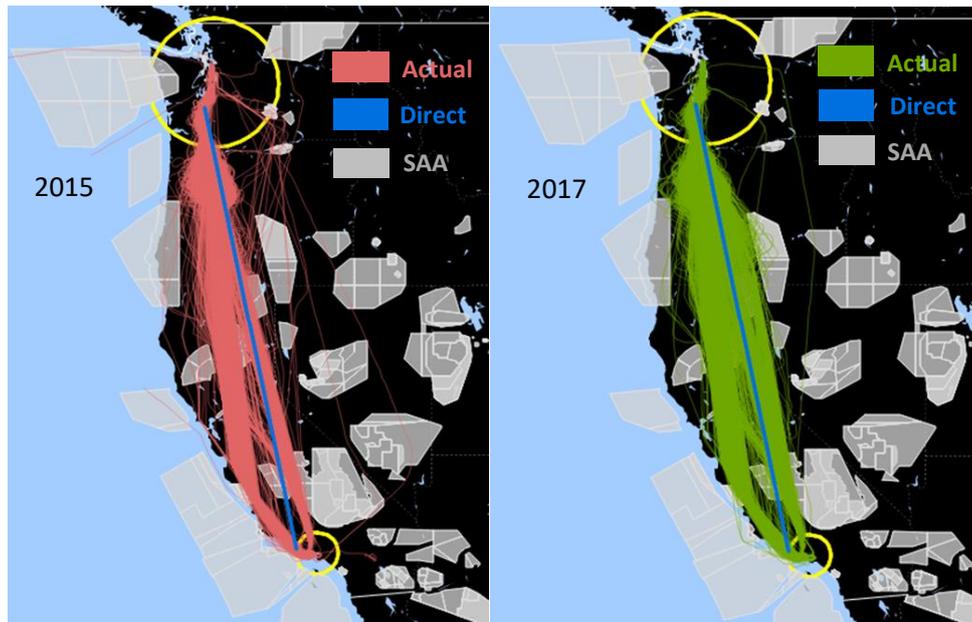


Figure 5-19: Los Angeles to Seattle flights affecting horizontal flight efficiency

Figure 5-20 illustrates how Special Use Airspace (SUA) (blue area) and Free Route Airspace (FRA) (green area) affect horizontal en-route flight efficiency in Europe.

The implementation of Free Route Airspace mandated by EU legislation leads to more choices for airspace users and a more flexible environment (civil/military coordination) responding more dynamically to changes in traffic flows.

It aims at enhancing en-route flight efficiency with subsequent benefits for airspace users in terms of time and fuel as well as a reduction of CO₂ emissions for the environment.

Although flight efficiency will never be 100%, the benefits — especially in the core area of Europe where FRA is not yet fully implemented — are expected to be substantial but depend, inter alia, on traffic volume, complexity and other factors.



Free Route Airspace (FRA) Concept

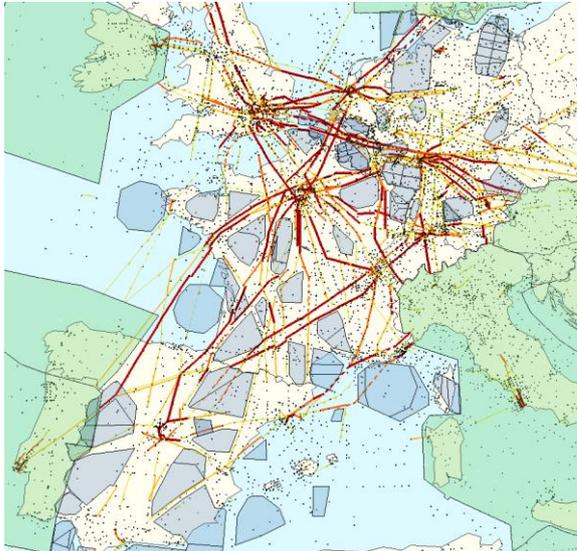
Free route airspace (FRA) is a key development with a view to the implementation of shorter routes and more efficient use of the European airspace.

FRA refers to a specific portion of airspace within which airspace users may freely plan their routes between an entry point and an exit point without reference to the fixed Air Traffic Services (ATS) route network. Within this airspace, flights remain at all times subject to air traffic control and to any overriding airspace restrictions.

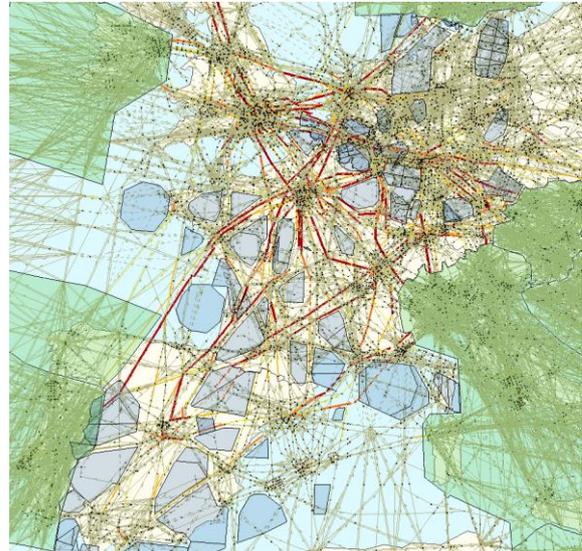
Deployment is ongoing, and EU Implementing Regulation 716/2014 (the Pilot Common Project regulation) stipulates that the Network Manager, air navigation service providers and airspace users shall operate direct routing (DCT) as from 1 January 2018 and FRA as from 1 January 2022 in the airspace for which the EU Member States are responsible at and above flight level 310 in the ICAO EUR region.

The left side of Figure 5-20 only shows route network segments with more than 75 daily flights. It is clearly visible that some major flows circumnavigate around special use airspace in the European core area which results in a lower level of flight efficiency.

The right side of Figure 5-20 shows the same map but with all trajectories included. The higher degree of flexibility in the Free Route Airspace is clearly visible as the trajectories are much more scattered in those areas which in turn improves overall flight efficiency.



17-Nov-2017 (showing only flows >75 flights)



17-Nov-2017 (showing all flights)

Figure 5-20: Free route airspace and special use airspace affecting flight efficiency in Europe (2017)

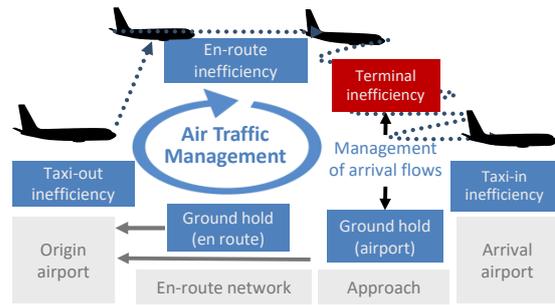
The deployment of Flexible Airspace Management and Free Route functionality in Europe needs to be coordinated due to the potential network performance impact of delayed implementation in a wide geographical scope involving a number of stakeholders. From a technical perspective the deployment of targeted system and procedural changes is synchronized to ensure that the performance objectives are met. This synchronization of investments involves multiple civil/military air navigation service providers, airspace users and the Network Manager. Furthermore, synchronization during the related industrialization phase needs to take place, in particular among the supply industry.

5.3.4 FLIGHT EFFICIENCY WITHIN THE LAST 100 NM

This section aims at estimating the level of inefficiencies that occur during the arrival/descent phase of flight. These inefficiencies are seen through larger downwinds or final “S-turns”, or, in the worst case, airborne holding patterns within the last 100 NM of flight.

For this exercise, the locally defined Terminal Manoeuvring Area (TMA) is not suitable for comparisons due to variations in shape and size of TMAs and the ATM strategies and procedures applied within the different TMAs.

Hence, in order to capture tactical arrival control measures (sequencing, flow integration, speed control, spacing, stretching, etc.) irrespective of local ATM strategies, a standard Arrival Sequencing and Metering Area (ASMA) was defined (see grey box for explanation). For the analyses, the 100 NM ring was used.



Arrival Sequencing and Metering Area (ASMA)

ASMA (Arrival Sequencing and Metering Area) is defined as two consecutive rings with a radius of 40 NM and 100 NM around each airport.

This incremental approach is sufficiently wide to capture effects related to approach operations. It also enables a distinction to be made between delays in the outer ring (40-100 NM) and the inner ring (40 NM-landing) which have a different impact on fuel burn and hence on environmental performance.

More information and data on additional ASMA time in Europe is available at www.ansperformance.eu.

The actual transit times within the 100 NM ASMA ring are affected by a number of ATM and non-ATM-related parameters including, inter alia, flow management measures (holdings, etc.), airspace design, airports configuration, aircraft type environmental restrictions, and in Europe, to some extent the objectives agreed by the airport scheduling committee when declaring the airport capacity.

The “additional” time is used as a proxy for the level of inefficiency within the last 100 NM. It is defined as the average additional time beyond the unimpeded transit time. The unimpeded times⁴⁴ are developed for each arrival fix, runway configuration and aircraft type combination.

Figure 5-21 shows the evolution of average additional time within the last 100 NM for the U.S. and Europe at system level between 2008 and 2017 (top) and the breakdown by airport in 2017 complemented by the year-on-year change compared to 2015 (bottom).

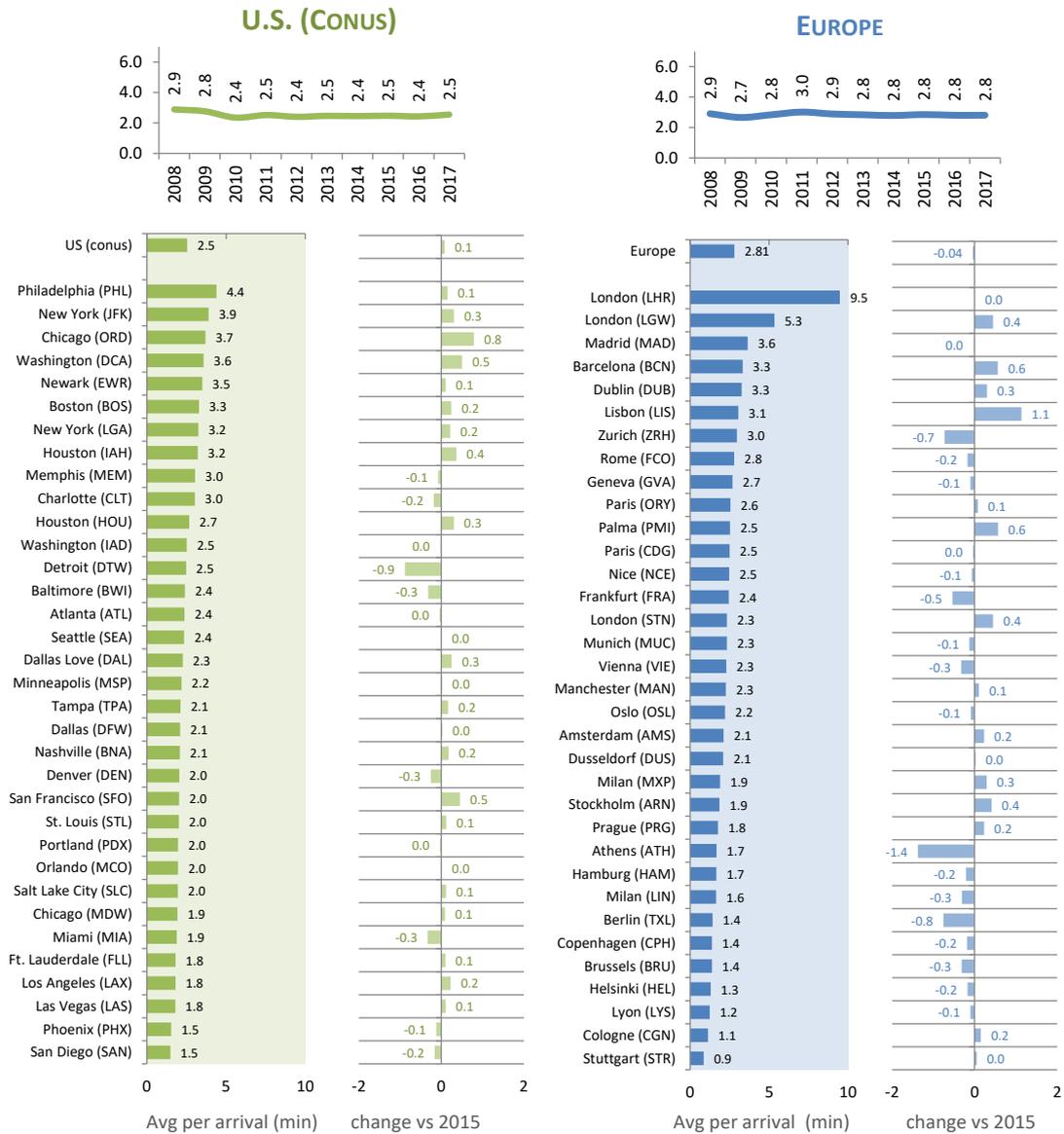
At system level, the additional time within the last 100 NM was similar in the two regions in 2008 but declined in the U.S. between 2008 and 2010. Over the same period, additional time within the last 100 NM increased in Europe.

Although at different levels, performance in the U.S. and in Europe remained relatively stable since 2013 with only a slight increase in the U.S. in 2017. However, the picture is contrasted across airports.

⁴⁴ Although the methodologies are expected to produce rather similar results, due to data issues, the calculation of the unimpeded times in Europe and the US is based on the respective “standard” methodologies and the results should be interpreted with a note of caution.

Additional time within the last 100 NM - main 34 airports (2017)

Avg additional time per arrival



Source: EUROCONTROL PRU/ FAA-ATO

Figure 5-21: Estimated average additional time within the last 100 NM (2017)

At system level, average additional time within the last 100 NM remained stable over the past years with Europe showing a slightly higher level which is mainly driven by London Heathrow (LHR), a clear outlier in Europe⁴⁵.

In the U.S., similar to taxi-out performance, there is still a notable difference for the airports in the greater New York area, which show the highest level of additional time within the last 100 NM. A notable increase in additional time within the last 100 NM in 2017 was observed for Chicago (ORD), it had the largest impact on the system-wide trend due to the large number of

⁴⁵ It should be noted that performance at London Heathrow airport (LHR) is consistent with decisions taken during the airport scheduling process regarding average holding in stack. The performance is in line with the 10 minute average delay criterion agreed.

operations. Similar to en-route efficiency, the increases are seen at airports with an increase in operations such as SFO, DAL, and LAX. These increases were balanced at the system level with improvements at Detroit (DTW), Denver (DEN), Charlotte (CLT), Miami (MIA), and Baltimore (BWI) with Atlanta (ATL) contributing the most to stabilizing the system average with its large number of operations.

Due to the large number of variables involved, the direct ATM contribution towards the additional time within the last 100 NM is difficult to determine. One of the main differences of the U.S. air traffic management system is the ability to maximize airport capacity by taking action in the en-route phase of flight, such as in trail spacing. Larger ATFM delay in the U.S. also may indicate that much of this additional time is pushed back to the departure airport and taken on the ground.

In Europe, the support of the en-route function is limited and rarely extends beyond the national boundaries. Hence, most of the sequencing and holding is done at lower altitudes around the airport. Additional delays beyond what can be absorbed around the airport are taken on the ground at the departure airports.

On both sides of the Atlantic, the operations at high density traffic airports are vulnerable to adverse weather conditions and cause high levels of delay to airspace users.

There is a potential trade-off between additional time in terminal airspace (additional ASMA time) and airport capacity utilization. This can be observed for London Heathrow (LHR) and the congested U.S. airports. Although not quantified in this report, quantifying capacity utilization and assessing this trade-off would be a worthwhile subject for further study. However, benchmarking the two systems would require a common understanding of how capacity and throughput is measured for comparable airports.

5.3.5 VERTICAL FLIGHT EFFICIENCY

Over the past years, focus has shifted to address the identification and measurement of ATM-related constraints on **vertical** flight profiles. In particular the analysis of fuel-efficient continuous descent operations has gained a higher momentum as they are seen by ICAO as one of the key improvement steps to further efficiency gains (fuel, emissions and noise).



Vertical flight efficiency (arrival/departure)

The underlying conceptual model of vertical flight operations is an abstraction of the flight profile in distinct portions (i.e. segments). This profile is based on measured trajectory data (4D position) of aircraft operations. A trajectory is therefore represented by the time-ordered set of 4D measurements associated to one flight, typically describing the flight path from the airport of departure to the airport of destination.

Based on the jointly agreed criteria for describing level flight, the trajectory is mapped to level segments for further analysis.

More information and data on vertical flight efficiency in Europe is available at www.ansperformance.eu.

Complementary to the analysis of additional time within the last 100 NM in the previous section, this section provides a comparison of vertical flight efficiency in the arrival and departure phase between the U.S. and Europe to get a more complete picture on ANS-related constraints ranging from airspace and procedure design through tactical interventions by air traffic controllers, including arrangements between adjacent air traffic units. The analysis focused on the departure and arrival phases of a flight within a 200 NM radius around the departure/arrival airport.

Figure 5-22 shows the average distance flown level per arrival for the 34 airports in the U.S. and in Europe. It is interesting to note that the average level distance in the U.S. is almost double the average distance flown level in Europe.

Between 2015 and 2017, the U.S. showed an overall improvement of -2.6 miles per arrival at the 34 main airports, with the highest improvement observed at Charlotte (CLT) airport. In Europe, the average distance flown level increased by +1.5 miles per arrival with the highest increase being observed for Cologne (CGN) airport.

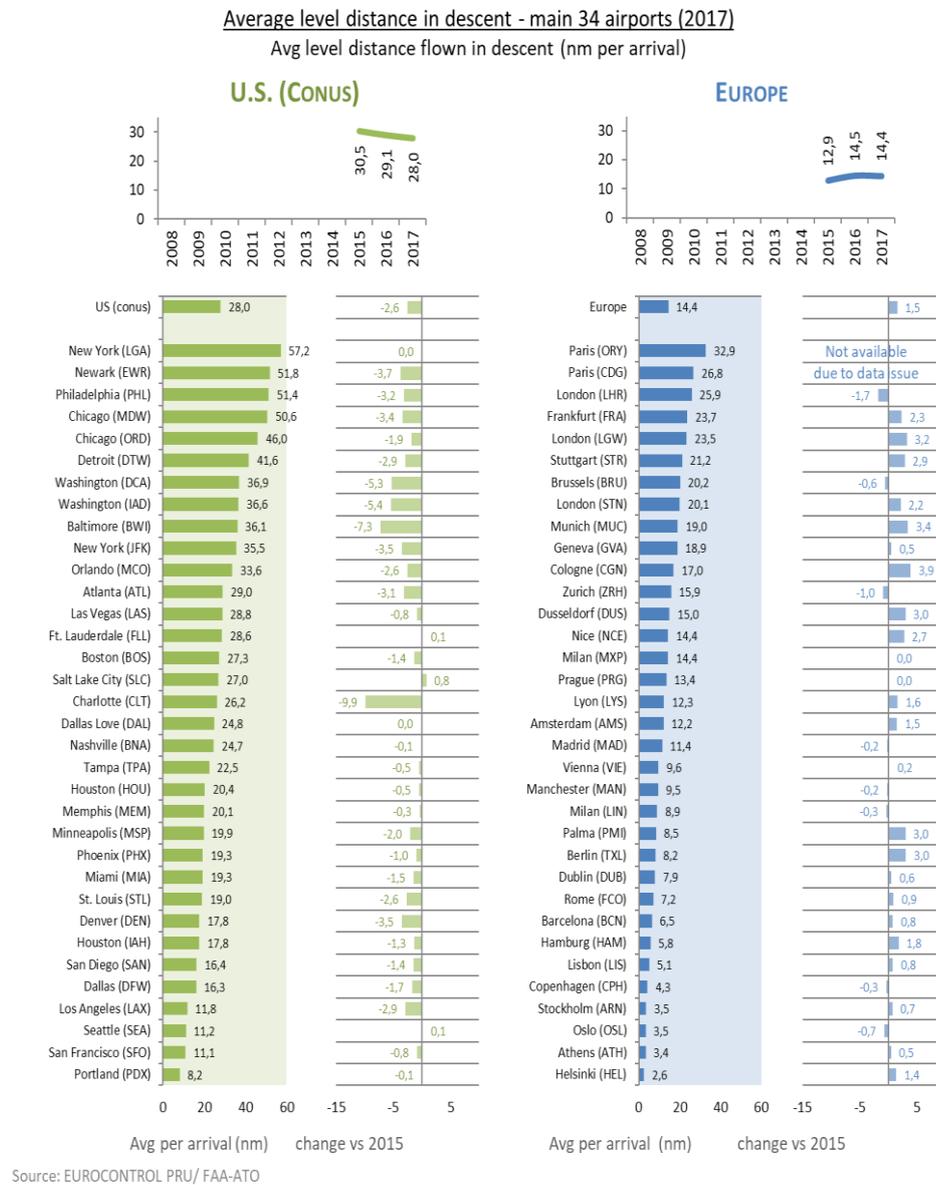


Figure 5-22: Vertical flight efficiency - estimated average level distance (descent, 2017)

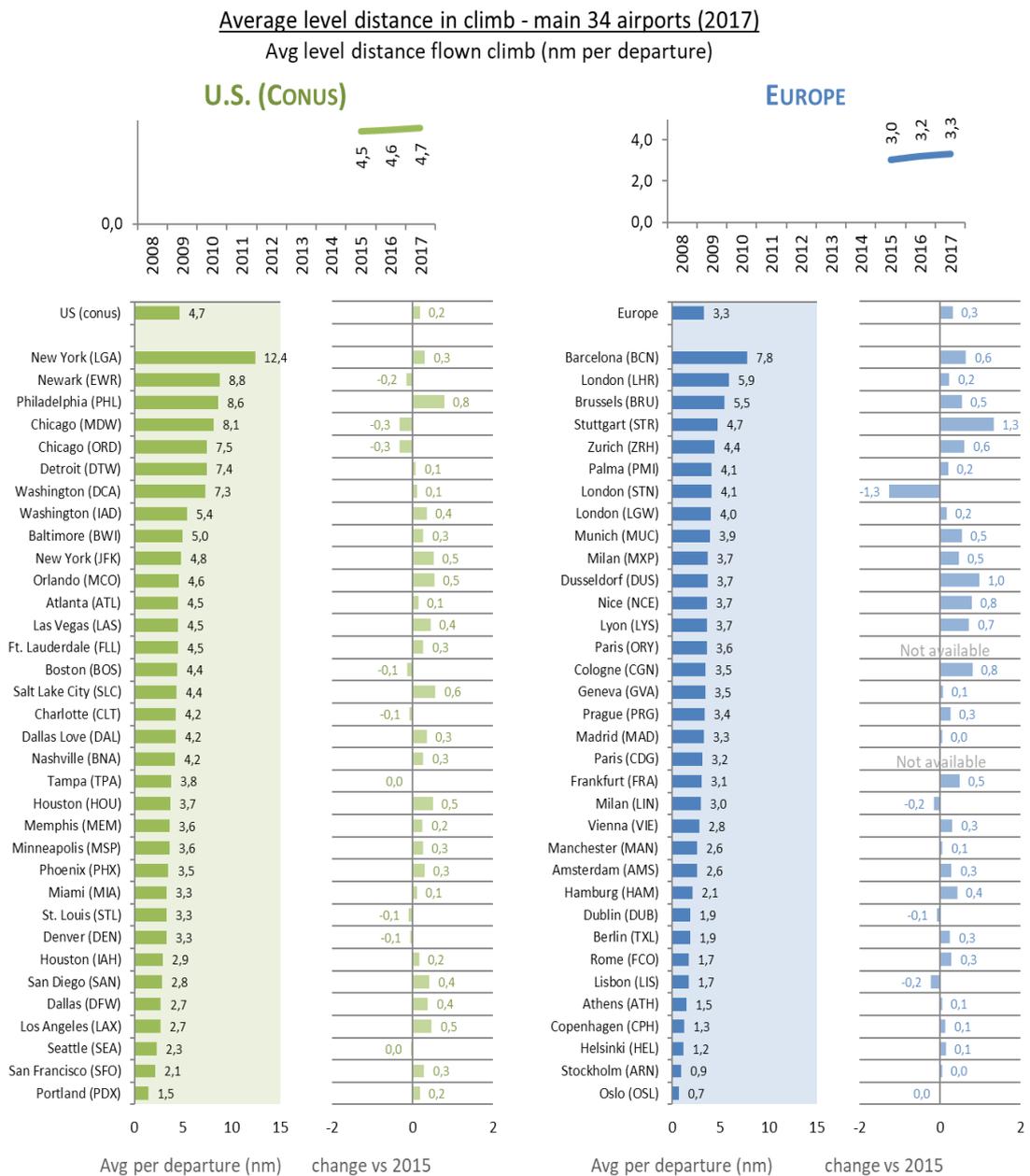
With the results presented above and considering level flight increases the fuel burn, it follows that improvements in reducing the amount of level segments for approaching aircraft can contribute to a lower fuel-burn by airspace users. However it must be stressed that these results present a hypothetical upper bound. No attempt has been made to assess the airspace complexity to determine the degree level flight is necessary to keep aircraft separated as this would require a detailed review of airspace design. For the US, much of this “benefit” is ascribed to the complex Northeast Corridor or Chicago O’Hare/Midway region and a significant reduction of this KPI may not be feasible.

Both in the U.S. and Europe a significant share of the level flight is accrued below FL245. This is directly linked with the procedural airspace for final approach at the different airports. Nuances

apply for the level bands between FL70 and FL245 that may be linked with specific cut-off altitudes for operations or hand-overs between adjacent control sectors. Level segments below FL70 can typically be mapped to procedure altitudes for the local traffic patterns at airports and the associated vectoring to ensure synchronization and separation of arriving traffic.

It follows that for this heavily procedurally characterized portion of the flight, a significant high level of inefficiencies in the vertical profile applies. This also describes the major challenge and opportunity for mitigating the inefficiency during this phase of the arrival. Improving the observed performance in terms of reducing the number of level segments requires advanced synchronization and separation of the air traffic which may or may not be feasible for some systems. Progress and the feasibility of improving this KPI can be tracked in future reports.

Figure 5-23 shows the average distance flown level per departure for the 34 airports in the U.S. and in Europe in 2017.



Source: EUROCONTROL PRU/ FAA-ATO

Figure 5-23: Vertical flight efficiency - estimated average level distance (climb, 2017)

The observed level distance in climb is much below the level distance in descent and the results in the U.S. and in Europe are much closer together.

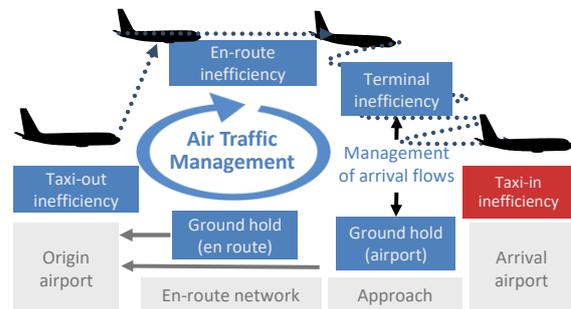
In the U.S., New York (LGA) showed the highest average distance in the climb phase followed by Newark (EWR), Philadelphia (PHL) and the two Chicago airports.

In Europe, Barcelona showed the highest distance flown level per departure in 2017, followed by London (LHR), Brussels (BRU) and Stuttgart (STR) airport.

The total potential fuel savings for flights arriving at the main 34 airports is 10 times higher than the potential savings for flights departing from the 34 airports.

5.3.6 TAXI-IN EFFICIENCY

The analysis of taxi-in efficiency in this section refers to the period between the time when the aircraft lands and the time it arrives at the stand (actual in-block time). The additional time is measured as the average additional time beyond an unimpeded reference time.



The analysis in Figure 5-24 mirrors the methodology applied for taxi-out efficiency in Figure 5-15.

The method uses the 20th percentile of each service (same operator, airport, etc.) as a reference for the “unimpeded” time and compares it to the actual times. This can be easily computed with U.S. and European data.

As can be observed in Figure 5-24, at system level, additional time in the taxi-in phase is higher in the U.S. than in Europe and remained relatively stable over time in both systems until 2015.

Since 2015, a notable increase can be observed in the U.S. Some seasonal patterns are visible (particularly in the U.S.) where an increase can be noted during summer.

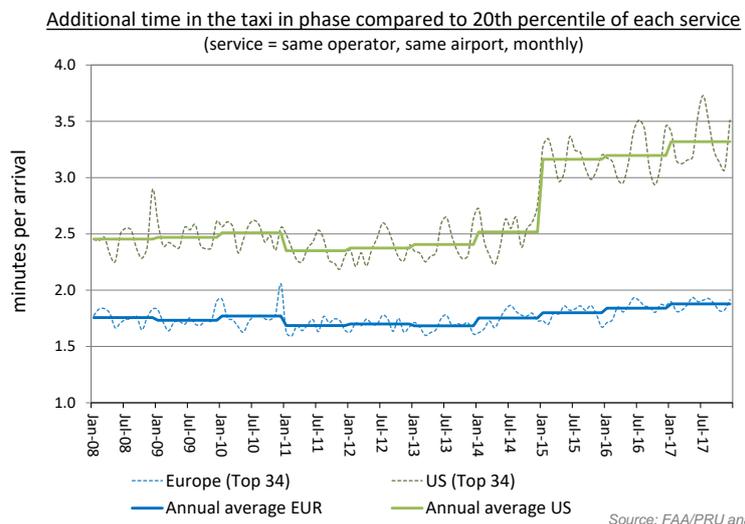


Figure 5-24: Additional times in the taxi-in phase (system level) (2008-2017)

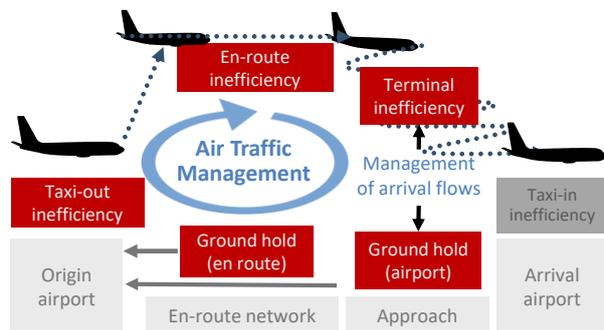
The taxi-in phase and hence the performance indicator is influenced by a number of factors, most of which cannot be directly influenced by ATM (i.e. airport/airline staffing, gate availability, apron limitations etc.).

The taxi-in phase was included in the comparison for completeness reasons but, due to the number of factors outside the direct control of ATM, it was not included in the theoretical maximum “benefit pool” actionable by ATM in Chapter 5.4.

5.4 Main results & theoretical maximum “benefit pool” actionable by ATM

There is value in developing a systematic approach to aggregating ATM-related inefficiencies. Since there are opportunities for many trade-offs between flight phases, an overall indicator allows for high-level comparability across systems.

This section provides a summary of the theoretical maximum “benefit pool” for a typical flight, based on the analysis of traffic from and to the 34 main airports in Europe and the U.S.



Although included in this report for completeness reasons, due to the number of factors outside the direct control of ATM, the taxi-in phase was not included in the theoretical “benefit pool” actionable by ATM. For the interpretation of the theoretical maximum “benefit pool” actionable by ATM in this section, the following points should be borne in mind:

- Not all delay is to be seen as negative. A certain level of delay is necessary and sometimes even desirable if a system is to be run efficiently without underutilization of available resources.
- Due to the stochastic nature of air transport (winds, weather) and the way both systems are operated today (airport slots, traffic flow management), different levels of delay may be required to maximize the use of scarce capacity. There are lessons however to be learned from both sides.
- A clear-cut allocation between ATM- and non ATM-related causes are often difficult. While ATM is often not the root cause of the problem (weather, etc.) the way the situation is handled can have a significant influence on the distribution of delay between air and ground and thus on costs to airspace users (see also Table 5-2 on page 79).
- The approach measures performance from a single airspace user perspective without considering inevitable operational trade-offs, and may include dependencies due to environmental or political restrictions, or other performance affecting factors such as weather conditions.
- ANSP performance is inevitably affected by airline operational trade-offs on each flight. The indicators in this report do not attempt to capture airline goals on an individual flight basis. Airspace user preferences to optimize their operations based on time and costs can vary depending on their needs and requirements (fuel price, business model, etc.).
- Some indicators measure the difference between the actual situation and an ideal (uncongested or unachievable) situation where each aircraft would be alone in the system and not subject to any constraints. This is the case for horizontal flight efficiency which compares actual flown distance to the great circle distance. Other indicators, such as ASMA flight efficiency, compare actual performance to an ideal scenario that is based on the best performance of flights observed in the system today. More analysis is needed to better understand what is and will be achievable in the future.

However, when used at a strategic level, the indicators do provide clear indications of regions, city-pair markets and facilities where additional time and distance are increasing or decreasing. In this way, ANSPs have a clear and stable procedure for identifying the constraints in their system, as well as a means of benchmarking performance on a global level.

5.4.1 THEORETICAL MAXIMUM “BENEFIT POOL” ACTIONABLE BY ATM

By combining the analyses for individual phases of flight in Section 5.3, an estimate of the theoretical maximum “improvement pool” actionable by ATM can be derived. It is important to stress that this “benefit pool” is based on a theoretical optimum (averages compared to unimpeded times), which is not achievable at system level due to inherent necessary (safety) or desired (capacity) limitations⁴⁶. Moreover, the inefficiencies in the various flight phases (airborne versus ground) have a very different impact on airspace users in terms of predictability (strategic versus tactical – percent of flights affected) and fuel burn (engines on versus engines off).

Table 5-2 provides an overview of the ATM-related impact on airspace users’ operations in terms of time, fuel burn and associated costs.

Table 5-2: Impact of ATM-related inefficiencies on airspace users’ operations

ATM-related impact on airspace users’ operations			Impact on punctuality	Engine status	Impact on fuel burn/ CO ₂ emissions	Impact on airspace users’ costs
ATM-related inefficiencies	At stand	Airport ATM/TMI	High	OFF	Quasi nil	Time
		En-route ATM/TMI				
	Gate-to-gate	Taxi-out phase	Low/moderate	ON	High	Time + fuel
		En-route phase				
		Terminal area				

For ATM-related delays at the gate (ATM/TMI departure restrictions) the fuel burn is quasi nil but the level of predictability in the scheduling phase for airspace users is low as the delays are not evenly spread among flights. Hence, the impact of those delays on on-time performance and associated costs to airspace users is significant but the impact on fuel burn and the environment is negligible. It is however acknowledged that – due to the first come, first served principle⁴⁷ applied at the arrival airports – in some cases aircraft operators try to make up for ground delay encountered at the origin airport through increased speed which in turn may have a negative impact on total fuel burn for the entire flight.

ATM-related inefficiencies in the gate-to-gate phase (taxi, en-route, terminal holdings) are generally more predictable than ATM-related departure restrictions at the gate as they are more related to inefficiencies embedded in the route network or congestion levels which are similar every day or season to season. From an airspace user point of view, the impact to on-time performance is usually low as those inefficiencies are usually already embedded in the scheduled block times by airlines. However, the impact in terms of additional time, fuel, associated costs, and the environment is significant.

The environmental impact of ATM on climate is closely related to operational performance which is largely driven by inefficiencies in the 4-D trajectory and associated fuel burn. There is a close link between user requirements to minimize fuel burn and reducing greenhouse gas emissions⁴⁸.

⁴⁶ The CANSO report on “ATM Global Environmental Efficiency Goals for 2050” also discusses interdependencies in the ATM system that limit the recovery of calculated “inefficiencies.” These interdependencies include capacity, safety, weather, noise, military operations, and institutional practices requiring political will to change.

⁴⁷ “First come, first served” is generally applied to manage air traffic flows, as provided for in Annex 11 — Air Traffic Services and in the Procedures for Air Navigation Services — Air Traffic Management (PANS-ATM, Doc 4444) regarding the relative prioritisation of different flights.

⁴⁸ The emissions of CO₂ are directly proportional to fuel consumption (3.15 kg CO₂ /kg fuel).

Clearly, keeping an aircraft at the gate saves fuel but if it is held and capacity goes unused, the cost to the airline of the extra delay may exceed the savings in fuel cost by far. Since weather uncertainty will continue to impact ATM capacities in the foreseeable future, ATM and airlines need a better understanding of the interrelations between variability, efficiency, and capacity utilization.

Previous research [Ref. [26]] shows that at system level, the total theoretical maximum “benefit pool” actionable by ATM and associated fuel burn are of the same order of magnitude in the U.S. and Europe (approx. 6-8% of the total fuel burn).

Figure 5-25 shows a summary of the operational performance on flights to or from the main 34 airports in the U.S. and in Europe for four of the key indicators addressed in more detail in the previous sections of the report.

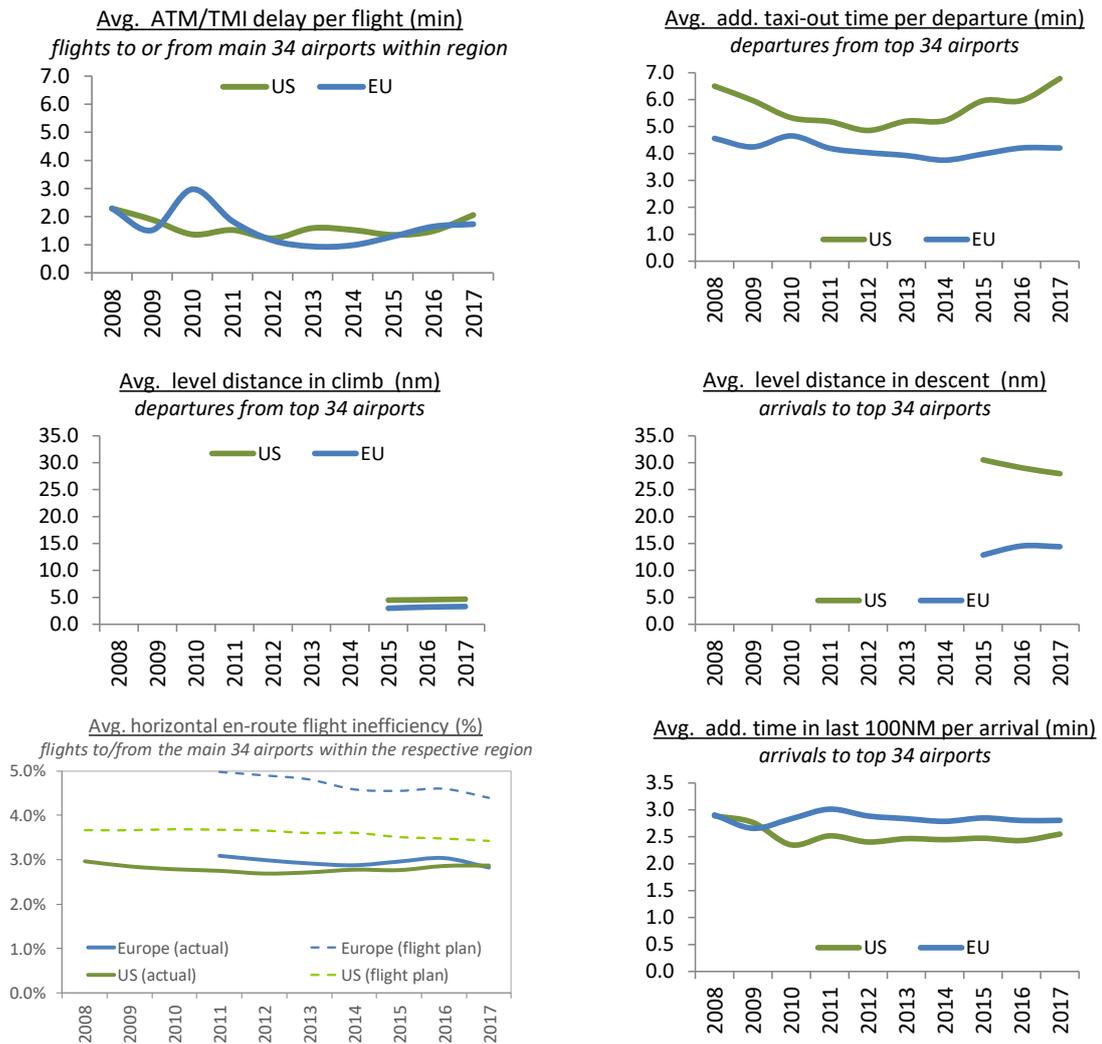


Figure 5-25: Evolution of operational performance in U.S./Europe between 2008 and 2017

Building on the results shown in Figure 5-25, Table 5-3 summarizes the current best estimate of the ATM-related impact on operating time. Actual fuel burn depends on the respective aircraft mix (including mix of engines on the same type of aircraft, operating procedures) and therefore varies for different traffic samples.

For comparability reasons, the theoretical maximum benefit pool actionable by ATM in Table 5-3 is based on the assumption that the same aircraft type performs a flight of 450 NM in the en-

route phase in the U.S. and the European ATM system (see also grey box for more information).

Although in a context of increasing traffic, system-wide ATM performance deteriorated in the U.S. and in Europe between 2015 and 2017.

The degradation in Europe between 2015 and 2017 was mainly driven by an increase in ATFM delay in a limited number of en-route facilities combined with an increase in additional taxi time. In the U.S., traffic increased at a more moderate rate than in Europe but the level of ATM-related inefficiencies increased at a higher rate compared to Europe between 2015 and 2017. The increase in the U.S. is mainly related to a limited number of key airports which experienced higher levels of weather-related ATFM delays. Runway/taxiway construction at certain airports such as San Francisco and Los Angeles along with increase in departure operations at Newark and Seattle contributed to the increase of additional time in the taxi-out phase from 2015-2017.



Theoretical maximum “benefit pool” actionable by ATM

As outlined in Section 3.1, the two ATM systems differ in terms of average flight lengths and aircraft mix (see Figure 3-6 on page 22).

Such differences lead to different results, as the “inefficiencies” depend on travelled distance and aircraft type.

For comparability reasons, the calculations in Table 5-3 are based on averages representing a “standard” aircraft in the system.

The calculations assume that a standard aircraft (A320) travels an average distance of 450 NM in each ATM system.

The typical average fuel burn, was equally applied to the U.S. and Europe (Taxi ≈ 15kg/min., Cruise ≈ 46kg/min., TMA holding 41kg/min.).

Table 5-3: Theoretical maximum “benefit pool” actionable by ATM (2017 vs. 2015)

Theoretical maximum “benefit pool” actionable by ATM for a typical flight (A320) (flights to or from the main 34 airports)		Estimated average additional time (min.)						Fuel burn engines	Estimated excess fuel burn (kg) ⁴⁹			
		EUR			U.S.				EUR		U.S.	
		2015	2017		2015	2017		2015	2017	2015	2017	
Holding at gate per departure (only delays >15min. included)	En-route-related (% of flights)	0.6 (2.0%)	0.9 (3.2%)	↑	0.2 (0.7%)	0.4 (1.0%)	↑	OFF	≈0	≈0	≈0	≈0
	airport-related (% of flights)	0.7 (2.3%)	0.8 (2.7%)	↑	1.1 (1.8%)	1.7 (2.4%)	↑	OFF	≈0	≈0	≈0	≈0
Taxi-out phase (min. per departure)		4.0	4.2	↑	6.0	6.8	↑	ON	60	63	89	102
Horizontal en-route flight efficiency		1.8	1.8	→	1.7	1.8	↑	ON	85	81	80	83
Terminal areas (min. per arrival)		2.8	2.8	→	2.5	2.5	→	ON	117	115	101	105
Total theoretical “benefit pool”		10.0	10.5	↑	11.5	13.2	↑		261	259	271	289

It is an open research question on whether current performance databases capture the full “benefit pool” as there may be additional efficiencies gained from using ideal cruise speeds or from making operations more predictable. Estimating these inefficiencies would require more information on aircraft performance and airline intent than is currently available to both groups.

Inefficiencies in the vertical flight profile for en-route and in the TMA departure phase (40 NM ring around the departure airport) were not considered in the theoretical benefit pool but will be included in the next edition of the report.

However, just as there are facets of the benefit pool which are not covered, there are system constraints and interdependencies that would prevent the full recovery of the theoretical optimum identified in this section. Performance groups will need to work with all stakeholders to quantify these contrasting effects on the fuel benefits actionable by ATM.

6 CONCLUSIONS

This report is the sixth in a series of joint ATM operational performance comparisons between the U.S. and Europe. It represents the third edition under the Memorandum of Cooperation between the United States and the European Union.

The report provides a comparative operational performance assessment between Europe and the U.S. using Key Performance Indicators (KPIs) that have been harmonized by both groups. The KPIs used in this report provide demonstrated examples of 14 of the 19 KPIs listed in the ICAO Global Air Navigation Plan (GANP) which can be used to assess the benefits of the global implementation of Aviation System Block Upgrades (ASBUs).

The indicators used are those proven to meet key Air Navigation Service Provider (ANSP) objectives of identifying system constraints through delay/capacity measures and improving flight efficiency by measuring actual trajectories against an ideal. The report also includes punctuality and block time indicators that relate performance more directly to the airline/passenger perspective. The ability to work with harmonized KPIs fosters a unique opportunity for both groups to learn each other's strengths and identify opportunities for improvement across all phases of flight.

The first part of the report examines commonalities and differences in terms of air traffic management and performance influencing factors, such as air traffic demand characteristics and weather, which can have a large influence on the observed performance.

Overall, air navigation service provision is clearly more fragmented in Europe with more ANSPs and physical facilities than in the U.S. The European area comprises 37 Air Navigation Service Providers (ANSPs) with 62 en-route centers and 16 stand-alone Approach Control (APP) units (total: 78 facilities). The U.S. CONUS has 20 en-route centers supplemented by 26 stand-alone Terminal Radar Approach Control (TRACON) units (total: 46 facilities), operated by one ANSP.

Although the U.S. CONUS airspace is 10% smaller than the European airspace, the U.S. controlled approximately 47% more flights operating under Instrument Flight Rules (IFR) with 32% fewer full time Air Traffic Controllers (ATCOs) than in Europe in 2017. However, this percentage narrows to 22% more controllers in Europe when FAA developmental controllers and European on-the-job trainees are also considered. U.S. airspace density is, on average, higher and airports tend to be notably larger than in Europe.

In terms of traffic evolution, there was a notable decoupling between the U.S. and Europe in 2004 when the traffic in Europe continued to grow while U.S. traffic started to decline to reach a plateau in 2011. Between 2000 and 2017, traffic in Europe grew by 23.1% but declined in the U.S. by -14.7% during the same time. Over the past two years (2015-2017), U.S. CONUS traffic remained almost unchanged but traffic at the main 34 airports reported a growth of 2.6%. In Europe, traffic increased by 6.6% between 2015 and 2017 with a slightly lower increase of 5.2% at the main 34 airports.

At system level, the U.S. has a notably higher share of general aviation than Europe which accounted for 19% and 3.5% of total traffic in 2017, respectively. The share of general aviation declined in the U.S. to 19% from 22% in 2015. In order to improve comparability of datasets, the

⁴⁹ Fuel burn calculations are based on averages representing a "standard" aircraft in the system.

more detailed analyses were limited to controlled flights either originating from or arriving at the main 34 U.S. and European airports. The samples are more comparable as this removes a large share of the smaller piston and turboprop aircraft (general aviation traffic), particularly in the U.S. Air traffic to or from the main 34 airports account for approximately 64% and 66% of the controlled flights in Europe and the U.S., respectively.

There are a number of differences between the two systems. In the US, the Air Traffic Control System Command Center - which is the equivalent of Network Manager Operations Centre in Europe, is in a stronger position than its European counterpart with more active involvement of tactically managing traffic on the day of operations.

Each system has areas that are highly impacted by Special Use Airspace (SUA), often due to operations of a military nature. For Europe, SUA permeates all regions and adds complexity in some of the most densely traveled areas. For the U.S., those areas are more concentrated, particularly in coastal regions. The impact of SUA on flight efficiency indicators can be clearly seen but its unique impact is not quantified in this report.

Europe shows more airports operating closer to their declared capacity with more IFR flights per active runway. The U.S. operates many airports with complex runways with highly variable capacity and several are operating at close to peak capacity. For airports with more than 3 runways, U.S. declared rates are in general higher than Europe. The U.S. also operates with fewer airports applying schedule limitations which may lead to a better utilization of available airport capacity in ideal weather conditions. The analysis of meteorological reports suggests that weather conditions at the main 34 airports in Europe are, on average, less favorable than in the U.S. In 2017, 85.8% of the year at the main 34 U.S. airports was spent in visual meteorological conditions compared to 76.7% in Europe.

Building on established operational Key Performance Indicators, the second part of the comparison report evaluates operational performance in both systems from an airline and from an ANSP point of view. The airline perspective evaluates efficiency and predictability compared to published schedules whereas the ANSP perspective provides a more in-depth analysis of ATM-related performance by phase of flight compared to an ideal benchmark distance or time. For the majority of indicators, trends are provided from 2008 to 2017 with a focus on the change in performance from 2015 to 2017.

Punctuality is generally considered to be the industry standard indicator for air transport service quality. Following the substantial decrease of traffic as a result of the economic crisis starting in 2008, arrival punctuality in both systems improved. While in the U.S. performance remained stable in 2010, punctuality in Europe degraded to the worst level on record mainly due to weather-related delays (snow, freezing conditions) and strikes⁵⁰ but improved again in 2011 and 2012. Punctuality in Europe improved from 2010-2013 and started to decline in 2014, while punctuality in the U.S. saw a sharp decline from 2012-2014, followed by a rebound from 2014-2016 and another decline in 2017.

In 2017, the level of punctuality in the U.S. saw 81.1% of flights arriving within 15 minutes of their scheduled arrival time, which was higher than in Europe (78.8%). Between 2015 and 2017, performance improved slightly in the U.S. (0.6% points versus 2015) whereas arrival punctuality in Europe degraded by 3.1% points versus 2015. The major contributor to increase in arrival punctuality are flights departing main 34 airports and arriving at non main 34 airports.

⁵⁰ The volcanic ash cloud in April and May 2010 had only a limited impact on punctuality, as the majority of the flights were cancelled and are, thus, excluded from the calculation of on-time performance indicators.

The DLTA block time measure in the U.S. more than doubled at the system level between December 2015 (trailing 12 month average of 1.2 minutes) and December 2017 (trailing 12 month average of 2.5 minutes). The increase in block time from 2015 to 2017 in the U.S. is tied to certain airports which have delays because of weather and construction. While the evaluation of air transport performance compared to airline schedules provides valuable first insights, the involvement of many different stakeholders and the inclusion of time buffers in airline schedules limit the analysis from an air traffic management point of view.

Hence, the evaluation of ATM-related performance in this comparison aims to better understand and quantify constraints imposed on airspace users through the application of air traffic flow measures and therefore focuses more on the efficiency of operations by phase of flight compared to an unconstrained benchmark distance or time.

Air Traffic Flow and Capacity Management

In order to minimize the effects of ATM system constraints, the U.S. and Europe use a comparable methodology to balance demand and capacity. This is accomplished through the application of an “ATFM planning and management” process, which is a collaborative, interactive capacity and airspace planning process, where airport operators, ANSPs, Airspace Users (AUs), military authorities, and other stakeholders work together to improve the performance of the ATM system.

ATM-RELATED DEPARTURE RESTRICTIONS (ATM/TMI delays)

Both the U.S. and Europe report ATM-related delay imposed on departing flights through Traffic Management Initiatives (TMIs) by the ANSP in order to achieve required levels of safety as well as to most effectively balance demand and capacity. In Europe those delays are generally referred to as Air Traffic Flow Management (ATFM) delays. TMIs imposed at the departure airport can have various ATM-related (ATC capacity, staffing, etc.) and non-ATM-related (weather, accident, etc.) reasons. For comparability reasons, only delays equal or greater 15 minutes were included in the analyses.

In Europe, average ATM/TMI delay continuously decreased until 2013, following the historically bad performance due to weather and strikes in 2010. Between 2015 and 2017, average ATM/TMI delay minutes per flight equal or greater than 15 minutes increased in Europe by 33.9% whereas traffic only increased by 5.0% over the same period. The U.S. has also shown a decline since 2008. However, between 2015 and 2017, average ATM/TMI delay minutes per flight increased by 52.3% with traffic levels to/from the main 34 airports within region increasing by 2.2%.

Newark (17.9%) and San Francisco (11%) contributed to more than half (28.9%) of the increase between 2015 and 2017 (52.3%). This was largely due to increase in weather (wind at Newark and visibility at San Francisco) and runway/taxiway (construction projects at San Francisco) related delays as well as increased demand at EWR in key time periods after the expiration of IATA Level 3 schedule limitations.

In the U.S. the majority of ATM/TMI delays in 2017 are due to airports (82.8%) while in Europe it is more equally distributed between airports (48.4%) and en-route facilities (51.6%). In 2017, seven U.S. airports generated 68.4% of all ATM/TMI delay in the U.S. with only 17.2% attributable to en-route facilities. In Europe on the other hand 40% of total ATFM delays was generated by seven en-route facilities and the five most constraining airports accounted for only 23% of total ATM/TMI delay.

Weather-related constraints (wind, thunderstorms, and low ceilings) at the New York airports (EWR, LGA, & JFK) in 2017 constituted 33% of the total ATM/TMI delay. Runway/Taxiway construction projects at San Francisco (SFO), New York (JFK), Boston (BOS), and Los Angeles (LAX) in 2017 contributed to 11% of the total ATM/TMI delay.

Overall, the total delay minutes per flight is similar between the U.S. and Europe in 2008 and 2015, whereas in 2017 it is 19% higher in the U.S. (2.06 vs 1.73 in Europe). Flights in Europe are more likely to be held at the gate (5.8% vs 3.4% in the U.S.) but with half of the delay per delayed flight (30 minutes vs 61 minutes in the U.S.). By far the main reason for delays in the U.S. is adverse weather (77.8%). In Europe, the main cause is ATC capacity and staffing (44.5%) closely followed by adverse weather (41.9%).

ATM-RELATED OPERATIONAL EFFICIENCY (GATE-TO-GATE)

ATM-related flight gate-to-gate efficiency is measured by phase of flight (taxi-out, en-route, arrival/descent and taxi-in) with reference to a benchmark time or distance.

Taxi-out efficiency in the U.S. improved notably between 2008 and 2012, which reduced the observed gap between the U.S. and Europe. From 2012, the additional time in the taxi-out phase started to increase in the U.S. while in Europe it continued to improve until 2014 when it also started to increase again.

Between 2015 and 2017, additional taxi-out time increased in both systems but at a higher rate in the U.S. For the increase in additional taxi-out time in the U.S. from 2017 (+0.82 min per departure), almost half is linked to runway/taxiway construction projects at airports such as San Francisco and Los Angeles and increase in departure operations at Newark and Seattle. Overall, additional taxi-out time in 2017 was 2.5 minutes higher per departure than in Europe. This is largely driven by different flow control policies and the absence of scheduling caps at most U.S. airports.

While in Europe the inefficiencies in additional taxi-out time are more evenly spread among airports, in the U.S. half of taxi-out inefficiency is driven at eight airports (Chicago ORD, New York LGA, Dallas DFW, New York JFK, Los Angeles, Atlanta, Charlotte, and Newark). These airports have high contributions to system totals based due to both high averages and the large number of operations at the facility.

Both systems show a comparable level of flight “inefficiency” in the en-route phase of the actual trajectories (between a 40 NM radius around the departure airport and a 100 NM radius around the arrival airport). Between 2015 and 2017 the inefficiency in the en-route phase of the actual trajectories slightly decreased in Europe and increased in the U.S. The improvement in Europe is to some extent driven by the gradual implementation of Free Route Airspace which aims at removing the rigid route network in order to give airspace users more choices to file their flight plans.

The increase in the U.S. is attributable to flights arriving at Seattle from west coast airports (LAX & SFO) and flights arriving at New York JFK and Atlanta along with the presence of Special Use Airspace (SUA) at the coastal regions. More detailed studies are required to determine the impact of wind optimal routes on city pairs impacting en-route flight inefficiency. The results would identify if the inefficiency was because of flights following wind optimal paths.

Contrary to en-route flight efficiency, the U.S. showed a higher level of efficiency in the last 100 NM before landing. At system level, average additional ASMA time was 2.5 minutes per arrival in the U.S. in 2017 which was 0.3 minutes lower than in Europe.

Although at different levels, terminal area flight efficiency in the U.S. and in Europe remained relatively stable between 2015 and 2017. In Europe the result is significantly affected by London Heathrow airport which had an average additional time of 9.5 minutes per arrival which is almost twice as high as the second highest airport. In the U.S., efficiency levels in the terminal area are more homogenous.

Due to the large number of variables involved, the direct ATM contribution towards the additional time within the last 100 NM is difficult to determine. One of the main particularities of the U.S. air traffic management system is the ability to maximize airport capacity by taking action in the en-route phase of flight, such as in trail spacing. In Europe strategies can differ from airport to airport and the impact of the respective air traffic management systems on airport capacity utilization in the U.S. and in Europe was not quantified in this report, but would be a worthwhile subject for further study.

Complementary to the analysis of additional time within the last 100 nautical miles, a comparison of vertical flight efficiency in the arrival and departure phase between the U.S. and Europe provides a more complete picture on ANS-related constraints ranging from airspace and procedure design through tactical interventions by air traffic controllers, including arrangements between adjacent air traffic units. The analysis focused on the arrival phase of a flight in terms of the top-of-descent within a 200 NM radius around the arrival airport.

It is interesting to note that the average level distance flown per arrival in the U.S. is almost double the average distance flown level in Europe. Between 2015 and 2017, the U.S. showed an overall improvement of -2.6 miles per arrival at the 34 main airports with the highest improvement observed at Charlotte (CLT) airport. In Europe, average distance flown level increased by +1.5 miles per arrival with the highest increase being observed for Cologne (CGN) airport.

Both in the U.S. and Europe a significant share of the level flight is accrued below FL245. This is directly linked with the procedural airspace for final approach at the different airports. It follows that for this heavily procedurally characterized portion of the flight, a significant high level of inefficiencies in the vertical profile applies. This also describes the major challenge and opportunity for mitigating the inefficiency during this phase of the arrival. Improving the observed performance in terms of reducing the number of level segments requires advanced synchronization and separation of the air traffic. Such benefits can be expected from the implementation of extended arrival management operations (XMAN) that comprises the establishment of the arrival sequence much earlier, leading to speed adjustments 150-250 NM away from the arrival airport.

The observed level distance in climb is much below the level distance in descent and the results in the U.S. and in Europe are much closer together.

THEORETICAL MAXIMUM “BENEFIT POOL” ACTIONABLE BY ATM

As there are many trade-offs between flight phases, the aggregation of the observed results enables a high-level comparison of the theoretical maximum “benefit pool” actionable by ATM in both systems. For each flight phase, the theoretical “benefit pool” is computed in terms of additional time and fuel burn as the inefficiencies in the various flight phases (airborne versus ground) have a different impact on airspace users. For comparability reasons, the computation was based on the assumption that the same aircraft type performs a flight of 450 NM in the en-route phase in the U.S. and the European ATM system.

For the interpretation of the observed results, it is important to stress that the determined “benefit pool” is based on a theoretical optimum (averages compared to unimpeded times), which is, due to inherent necessary (safety) or desired (capacity) limitations, clearly not achievable at system level.

Overall, the relative distribution of the ATM-related inefficiencies associated with the different phases of flight is consistent with the differences in flow management strategies described throughout the report. In Europe, ATM-related departure delays (ATM/TMI) are much more frequently used for balancing demand with en-route and airport capacity than in the U.S., which leads to a notably higher share of traffic affected but with a lower average delay per delayed flight. Moreover the share of en-route-related TMIs in Europe is 51.6% while in the U.S. 82.8% of TMIs are airport-related during 2017.

Consequently, in Europe flights are three times more likely to be held at the gate or on the ground for en-route constraints than in the U.S, however, the delay per delayed flight is higher in the U.S (28 vs 36 minutes). The percentage of flights delayed at the departure gate or on the surface for arrival airport-related constraints is higher in Europe than in the U.S., however, the delay per delayed flight in the U.S. is more than twice as high as in Europe (31 vs 71 minutes).

Although in a context of increasing traffic, system-wide ATM performance deteriorated in the U.S. and in Europe between 2015 and 2017.

The degradation in Europe between 2015 and 2017 was mainly driven by an increase in ATFM delay in a limited number of en-route facilities combined with an increase in additional taxi time. In the U.S., traffic increased at a more moderate rate than in Europe but the level of ATM-related inefficiencies increased at a higher rate compared to Europe between 2015 and 2017. The increase in the U.S. is mainly related to a limited number of key airports which experienced higher levels of weather-related ATFM delays. Newark also saw schedule peak increases with the move from IATA Level 3 to IATA Level 2 and ATFM Delay increased when reduced capacity could not support the increase in demand. Runway/taxiway construction at certain airports such as San Francisco and Los Angeles along with increase in departure operations at Newark and Seattle contributed to the increase of additional time in the taxi-out phase from 2015-2017.

Overall it can be concluded that the two systems differ notably in the way TMIs are applied. In the U.S., TMIs are used less frequently, are mostly airport- and weather-related, and affect fewer flights, but when they are used the delay per delayed flight at system level is much higher than in Europe (30 vs 61 minutes).

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ANNEX I - LIST OF AIRPORTS INCLUDED IN THIS STUDY

Table I-1: Main 34 European airports included in the study (2017)

EUROPE	ICAO	IATA	COUNTRY	Avg. daily IFR departures in 2017	2017 vs. 2015	2017 vs. 2012
Amsterdam (AMS)	EHAM	AMS	NETHERLANDS	696	10.1%	17.5%
Paris (CDG)	LFPG	CDG	FRANCE	661	1.5%	-2.8%
London (LHR)	EGLL	LHR	UNITED KINGDOM	652	0.4%	0.4%
Frankfurt (FRA)	EDDF	FRA	GERMANY	651	1.6%	-1.1%
Munich (MUC)	EDDM	MUC	GERMANY	551	6.6%	1.9%
Madrid (MAD)	LEMD	MAD	SPAIN	531	5.7%	4.1%
Barcelona (BCN)	LEBL	BCN	SPAIN	443	12.0%	11.9%
Rome (FCO)	LIRF	FCO	ITALY	407	-5.6%	-5.0%
London (LGW)	EGKK	LGW	UNITED KINGDOM	392	6.8%	16.1%
Zurich (ZRH)	LSZH	ZRH	SWITZERLAND	361	2.2%	1.0%
Copenhagen (CPH)	EKCH	CPH	DENMARK	355	1.8%	7.0%
Oslo (OSL)	ENGM	OSL	NORWAY	344	4.0%	6.9%
Stockholm (ARN)	ESSA	ARN	SWEDEN	341	10.1%	18.8%
Vienna (VIE)	LOWW	VIE	AUSTRIA	329	-1.0%	-8.0%
Brussels (BRU)	EBBR	BRU	BELGIUM	319	-0.3%	7.1%
Paris (ORY)	LFPO	ORY	FRANCE	318	-0.9%	-0.6%
Dublin (DUB)	EIDW	DUB	IRELAND	305	13.1%	37.4%
Dusseldorf (DUS)	EDDL	DUS	GERMANY	303	5.5%	2.2%
Palma (PMI)	LEPA	PMI	SPAIN	286	17.1%	20.7%
Manchester (MAN)	EGCC	MAN	UNITED KINGDOM	279	17.7%	21.2%
Lisbon (LIS)	LPPT	LIS	PORTUGAL	278	22.5%	41.3%
Athens (ATH)	LGAV	ATH	GREECE	260	12.2%	27.3%
London (STN)	EGSS	STN	UNITED KINGDOM	258	12.3%	33.0%
Geneva (GVA)	LSGG	GVA	SWITZERLAND	252	1.2%	2.0%
Milan (MXP)	LIMC	MXP	ITALY	245	11.4%	2.4%
Helsinki (HEL)	EFHK	HEL	FINLAND	242	4.4%	3.0%
Berlin (TXL)	EDDT	TXL	GERMANY	235	-5.8%	2.0%
Hamburg (HAM)	EDDH	HAM	GERMANY	211	2.7%	7.1%
Prague (PRG)	LKPR	PRG	CZECH REPUBLIC	197	16.4%	12.8%
Nice (NCE)	LFMN	NCE	FRANCE	195	4.9%	0.5%
Cologne (CGN)	EDDK	CGN	GERMANY	190	10.3%	13.2%
Stuttgart (STR)	EDDS	STR	GERMANY	162	-1.0%	-1.4%
Milan (LIN)	LIML	LIN	ITALY	159	-0.7%	-1.5%
Lyon (LYS)	LFLY	LYS	FRANCE	154	3.6%	-5.7%
Average				340	5.2%	6.9%

Table I-2: Main 34 U.S. airports included in the study (2017)

USA	ICAO	IATA	COUNTRY	Avg. daily IFR departures in 2017	2017 vs. 2015	2017 vs. 2012
Atlanta (ATL)	KATL	ATL	United States	1200	0.3%	-4.7%
Chicago (ORD)	KORD	ORD	United States	1181	-0.5%	-1.1%
Dallas (DFW)	KDFW	DFW	United States	893	-4.1%	0.7%
Los Angeles (LAX)	KLAX	LAX	United States	946	7.6%	15.1%
Denver (DEN)	KDEN	DEN	United States	792	5.8%	-6.1%
Charlotte (CLT)	KCLT	CLT	United States	748	1.4%	0.2%
Houston (IAH)	KIAH	IAH	United States	613	-10.5%	-12.0%
New York (JFK)	KJFK	JFK	United States	610	1.5%	10.6%
Phoenix (PHX)	KPHX	PHX	United States	574	-3.6%	-6.3%
San Francisco (SFO)	KSFO	SFO	United States	620	6.9%	8.3%
Las Vegas (LAS)	KLAS	LAS	United States	587	3.3%	3.4%
Miami (MIA)	KMIA	MIA	United States	559	-1.2%	5.7%
Philadelphia (PHL)	KPHL	PHL	United States	502	-10.8%	-16.8%
Newark (EWR)	KEWR	EWR	United States	592	5.9%	5.1%
Minneapolis (MSP)	KMSP	MSP	United States	567	2.8%	-2.1%
Detroit (DTW)	KDTW	DTW	United States	540	4.2%	-7.6%
Seattle (SEA)	KSEA	SEA	United States	567	9.8%	35.2%
Boston (BOS)	KBOS	BOS	United States	548	6.5%	13.9%
New York (LGA)	KLGA	LGA	United States	496	-0.3%	-1.7%
Orlando (MCO)	KMCO	MCO	United States	460	7.5%	10.8%
Washington (IAD)	KIAD	IAD	United States	401	0.0%	-12.8%
Washington (DCA)	KDCA	DCA	United States	404	1.2%	3.2%
Salt Lake City (SLC)	KSLC	SLC	United States	407	5.0%	3.3%
Ft. Lauderdale (FLL)	KFLL	FLL	United States	407	11.6%	20.3%
Chicago (MDW)	KMDW	MDW	United States	332	0.7%	1.7%
Baltimore (BWI)	KBWI	BWI	United States	353	8.4%	-1.8%
Memphis (MEM)	KMEM	MEM	United States	301	1.9%	-17.9%
Dallas Love (DAL)	KDAL	DAL	United States	299	3.8%	30.8%
Portland (PDX)	KPDX	PDX	United States	307	9.2%	10.0%
San Diego (SAN)	KSAN	SAN	United States	283	7.4%	12.8%
Houston (HOU)	IHOU	HOU	United States	255	0.2%	4.3%
Tampa (TPA)	KTPA	TPA	United States	258	2.2%	4.5%
St. Louis (STL)	KSTL	STL	United States	264	5.3%	1.8%
Nashville (BNA)	KBNA	BNA	United States	266	10.4%	18.7%
Average				533	2.1%	1.9%

ANNEX II - DEMAND CAPACITY BALANCING

In order to minimize the effects of ATM system constraints, the U.S. and Europe use a comparable methodology to balance demand and capacity⁵¹. This is accomplished through the application of an “ATFM planning and management” process, which is a collaborative, interactive capacity and airspace planning process, where airport operators, ANSPs, Airspace Users (AUs), military authorities, and other stakeholders work together to improve the performance of the ATM system.

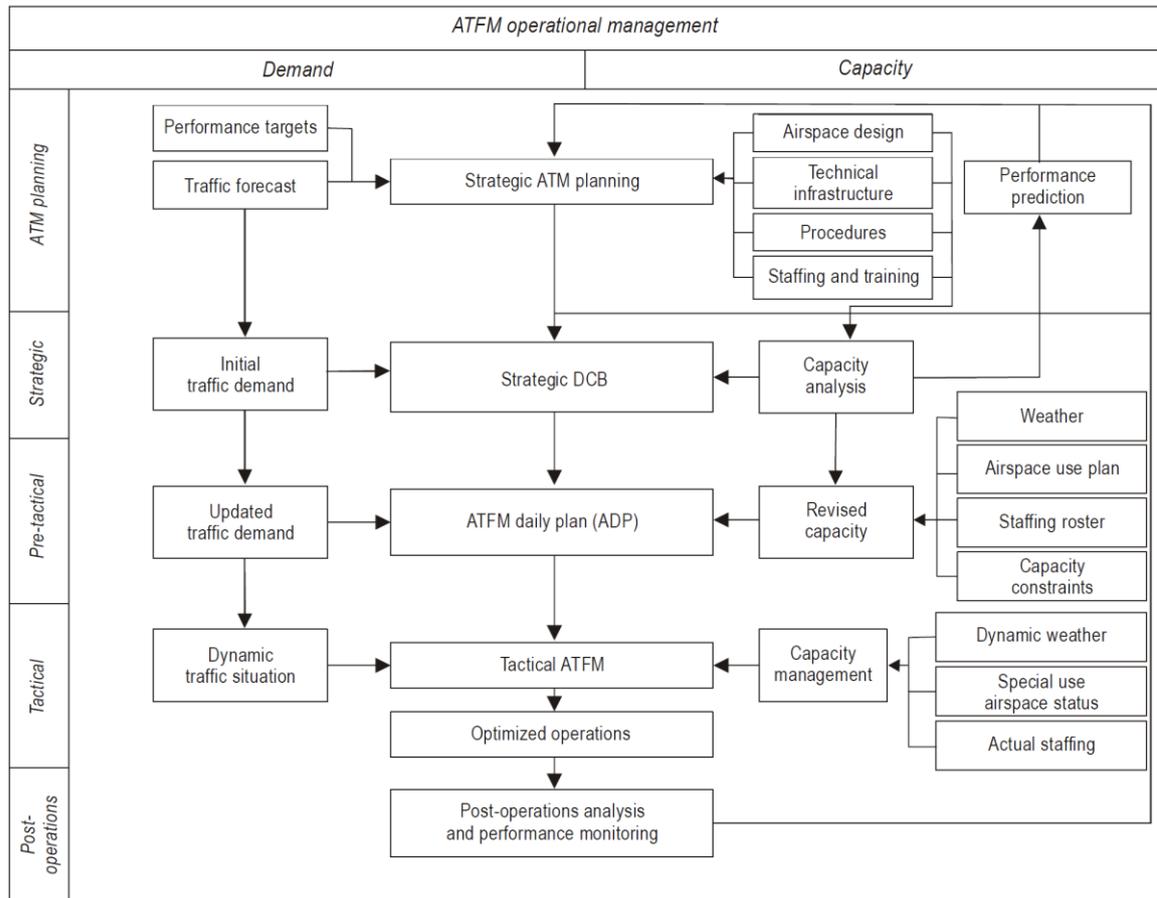


Figure II-0-1: Generic ATFM process (ICAO Doc 9971)

This CDM process allows AUs to optimize their participation in the ATM system while mitigating the impact of constraints on airspace and airport capacity. It also allows for the full realization of the benefits of improved integration of airspace design, ASM and ATFM.

⁵¹ In line with the guidance in ICAO Doc 9971 (Manual on Collaborative Air Traffic Flow Management).

The process contains a number of equally important phases:

- ATM planning
- ATFM execution
 - Strategic ATFM
 - Pre-tactical ATFM
 - Tactical ATFM
 - Fine-tuning of traffic flows by ATC (shown in Figure II-0-1 as Optimized operations)
 - TMIs that have an impact on traffic prior to take-off
 - TMIs acting on airborne traffic
- Post-operations analysis.

ATFM PLANNING

In order to optimize ATM system performance in the ATM planning phase, available capacity is established and then compared to the forecasted demand and to the established performance targets. Measures taken in this step include:

- reviewing airspace design (route structure and ATS sectors) and airspace utilization policies to look for potential capacity improvements;
- reviewing the technical infrastructure to assess the possibility of improving capacity. This is typically accomplished by upgrading various ATM support tools or enabling navigation, communications or surveillance infrastructure;
- reviewing and updating ATM procedures induced by changes to airspace design and technical infrastructure;
- reviewing staffing practices to evaluate the potential for matching staffing resources with workload and the eventual need for adjustments in staffing levels; and
- reviewing the training that has been developed and delivered to ATFM stakeholders.

Such an analysis quantifies the magnitude of any possible imbalance between demand and capacity. Mitigating actions may then be identified to correct that imbalance. However, before they are implemented, it is very important to:

- establish an accurate picture of the expected traffic demand through the collection, collation, and analysis of air traffic data, bearing in mind that it is useful to:
 - monitor airports and airspaces in order to quantify excessive demand and significant changes in forecast demand and ATM system performance targets;
 - obtain demand data from different sources such as:
 - comparison of recent traffic history (e.g. comparing the same day of the previous week or comparing seasonal high-demand periods);
 - traffic trends provided by national authorities, user organizations (e.g. International Air Transport Association (IATA)); and
 - other related information (e.g. air shows, major sports events, large-scale military manoeuvres); and
- take into account the complexity and cost of these measures in order to ensure optimum performance, not only from a capacity point of view but also from an economic (and cost-effectiveness) perspective.

The next phase is built on declared ATC capacity. It aims at facilitating the delivery of optimal ATM services.

Table II-1: Planning layer

U.S.	Europe
<p>The FAA publishes a variety of plans that take a multi-year view on the evolution of the NAS. This includes for example:</p> <ul style="list-style-type: none"> • Aerospace forecasts • Terminal area forecast • Airport capacity profiles • Air Traffic Controller Workforce Plan • National Airspace System Capital Investment Plan 	<p>The European ATM Network Operations Plan represents a view, at any moment in time, of the expected demand on the ATM Network at a particular time in the future and the resources available across the network, together with a set of agreed actions to accommodate this demand, to mitigate known constraints and to optimize ATM Network performance.</p> <p>The time-frame of the Network Operations Plan is medium to short-term, moving into pre-tactical planning. However, this document is strategically focused, listing the medium to short-term activities that contribute to the safe provision of additional capacity and improved flight efficiency at European ATM network level.</p> <p>The Plan is developed through the formal Cooperative Decision Making (CDM) Process established between the Network Manager and its operational stakeholders and is a consolidation of all network and local capacity plans to provide an outlook of the expected network performance for the next five year period by comparing the expected benefit from planned capacity enhancement initiatives with the requirements at network and local level, as determined by the Single European Sky Performance Framework.</p> <p>The objectives of the NOP are:</p> <ul style="list-style-type: none"> • to ensure coordinated planning, execution, assessment and reporting of all measures agreed at operational level; • to be used as a tool in the execution of the network management functions, under the governance of the Network Management Board and the Network Directors of Operations; • to assist Network Manager stakeholders, mainly ANSPs, in carrying out agreed activities towards enhancing and/or optimizing performance; • to provide references for the monitoring and reporting as a part of Network Management activities; and, • to ensure formal commitment of all operational stakeholders towards the implementation of the agreed measures. <p>The document identifies potential bottlenecks and gives early indications to the European Commission, Network Manager, States, ANSPs, Airports and Aircraft Operators for the need to plan better use of existing resources or, if required, to plan for additional resources, on network interactions and on the need to implement improvements coordinated at Network level.</p>

STRATEGIC ATFM

The ATFM strategic phase encompasses measures taken more than one day prior to the day of operation. Much of this work is accomplished two months or more in advance.

This phase applies the outcomes of the ATM planning activities and takes advantage of the increased dialogue between AUs and capacity providers, such as ANSPs and airports, in order to analyze airspace, airport and ATS restrictions, seasonal meteorological condition changes and significant meteorological phenomena. It also seeks to identify, as soon as possible, any discrepancies between demand and capacity in order to jointly define possible solutions which would have the least impact on traffic flows. These solutions may be adjusted according to the demand foreseen in this phase.

The strategic phase includes:

- a continuous data collection and interpretation process that involves a systematic and regular review of procedures and measures;
- a process to review available capacity; and,
- a series of steps to be taken if imbalances are identified. They should aim at maximizing and optimizing the available capacity in order to cope with projected demand and, consequently, at achieving performance targets.

The main output of this phase is the creation of a plan, composed of a list of hypotheses and resulting capacity forecasts and contingency measures. Some elements of the plan will be disseminated in aeronautical information publications. Planners will use them to resolve anticipated congestion in problematic areas. This will, in turn, enhance ATFM as a whole as solutions to potential issues are disseminated well in advance.

Scheduling at airports is not really part of ATFM, but it is a strategic demand capacity balancing activity with a time horizon of several months, and is therefore included in the table below.



Airport coordination levels

IATA has defined three levels:

- A non-coordinated airport (Level 1) is one where the capacities of all the systems at the airport are adequate to meet the demands of users.
- A schedules facilitated airport (Level 2) is one where there is potential for congestion at some periods of the day, week or scheduling period, which is amenable to resolution by voluntary cooperation between airlines and where a schedules facilitator has been appointed to facilitate the operations of airlines conducting services or intending to conduct services at that airport.
- A coordinated airport (Level 3) is one where the expansion of capacity, in the short term, is highly improbable and congestion is at such a high level that:
 - the demand for airport infrastructure exceeds the coordination parameters during the relevant period;
 - attempts to resolve problems through voluntary schedule changes have failed;
 - airlines must have been allocated slots before they can operate at that airport.

Table II-2: Strategic scheduling and ATFM solutions

U.S.	Europe
<p><u>Scheduling at airports</u></p> <p>With regard to airline scheduling, only one airport is slot coordinated (IATA level 3) in the U.S.: JFK. Six airports are schedules facilitated (IATA level 2): EWR, LAX, MCO, ORD, SEA, & SFO.</p> <p>For DCA and LGA, schedule restrictions are in effect based on Federal and local regulations.</p> <p>STMPs (Special Traffic Management Programs) may be put in place. These are reservation programs implemented to regulate arrivals and/or departures at airports that are in areas hosting special events such as the Masters Golf Tournament, Indianapolis 500, Denver Ski Country. STMP reservations provide a long-range planning capability for such events.</p>	<p><u>Scheduling at airports</u></p> <p>In Europe, approximately 100 airports are slot coordinated (IATA level 3).</p> <p>Approximately 70 are schedules facilitated (IATA level 2).</p>
<p><u>North American Route Program (NRP)</u></p> <p>The North American Route Program (NRP) specifies provisions for flight planning at flight level 290 (FL290) and above, within the conterminous U.S. and Canada.</p> <p>It enables flexible route planning for aircraft operating at FL290 and above, without reference to the ATS route network, from a point 200 nautical miles (NM) from their point of departure to a point 200 NM from their destination. Additional flexibility is available by utilizing specified Departure Procedures (DP) and Standard Terminal Arrival Routes (STAR) that have been identified within 200 NM of the airport(s).</p> <p>Beyond 200 NM from point of departure or destination, operators must ensure that the route of flight contains no less than one waypoint or NAVAID, per each ARTCC that a direct route segment traverses and these waypoints or NAVAIDs must be located within 200 NM of the preceding ARTCC's boundary. Additional route description fixes for each turning point in the route must be defined.</p> <p>Operators must ensure that the route of flight avoids active restricted areas and prohibited areas by at least 3 NM unless permission has been obtained from the using agency to operate in that airspace and the appropriate air traffic control facility is advised.</p> <p>The ARTCCs must avoid issuing route and/or altitude changes for aircraft which display the remarks "NRP" except when due to strategic, meteorological or other dynamic conditions. They must coordinate with ATCSCC before implementing any reroute to NRP flights beyond 200 NM from point of departure or destination. The ATCSCC has the authority to suspend and/or modify NRP operations for specific geographical areas or airports. Suspensions may be</p>	<p><u>Free Route Airspace (FRA)</u></p> <p>In Europe FRA is a specified airspace within which users may freely plan a route between a defined entry point and a defined exit point. Subject to airspace availability, the route can be planned directly from one to the other or via intermediate (published or unpublished) way points, without reference to the ATS route network. Within this airspace, flights remain subject to air traffic control.</p> <p>Free route operations can be:</p> <ul style="list-style-type: none"> • Time limited (e.g. at night) – this is usually a transitional step that facilitates early implementation and allows field evaluation of the FRA while minimizing the safety risks. • Structurally or geographically limited (e.g. restricting entry or exit points for certain traffic flows, applicable within CTAs or upper airspace only) – this is done in complex airspaces where full implementation could have a negative impact on capacity. • Implemented in a Functional Airspace Block (FAB) environment – a further stage in the implementation of FRA. The operators should treat the FAB as one large FIR. • Within SES airspace – this is the ultimate goal of FRA deployment in Europe. <p><u>Route Availability Document (RAD)</u></p> <p>The RAD is a common reference document containing the policies, procedures and description for route and traffic orientation. It also includes route network and Free Route Airspace (FRA) utilization rules and availability.</p> <p>The RAD is also an Air Traffic Flow and Capacity Management (ATFCM) tool that is designed as a sole-</p>

<p>implemented for severe weather reroutes, special events, or as traffic/equipment conditions warrant.</p> <p><u>Pre-defined routes</u></p> <p>Pre-planned rerouting options are contained in the National Playbook. It is a collection of Severe Weather Avoidance Plan (SWAP) routes that have been pre-validated and coordinated with impacted ARTCCs. They have been designed to mitigate the potential adverse impact to the FAA and users during periods of severe weather or other events that affect coordination of routes. These events include, but are not limited to, convective weather, military operations, communications, and other situations.</p> <p>Other examples of predefined routes include:</p> <ul style="list-style-type: none"> • Coded Departure Routes (CDR). These are a combination of coded air traffic routings and refined coordination procedures. • Preferred routes: routes that have been published by ATC to inform users of the “normal” traffic flows between airports. They were developed to increase system efficiency and capacity by having balanced traffic flows among high-density airports, as well as de-conflicting traffic flows where possible. <p><u>Altitude segregation</u></p> <p>Altitude segregation measures are predefined in U.S. facilities through capping and tunneling plans:</p> <ul style="list-style-type: none"> • Capping: indicates that aircraft will be cleared to an altitude lower than their requested altitude until they are clear of a particular airspace. Capping may apply to the initial segment of the flight or for the entire flight. • Tunneling: descending traffic prior to the normal descent point at an arrival airport to keep aircraft clear of an airspace situation on the route of flight. It is used to avoid conflicting flows of traffic and holding patterns. <p><u>Severe Weather Avoidance Plan (SWAP)</u></p> <p>A SWAP is a formalized program that is developed for areas susceptible to disruption in air traffic flows caused by thunderstorms.</p> <p>This is mainly used for the Northeast, to balance throughput of arrivals and departures at the New York City-area airports for those days that convective weather is forecast.</p> <p>There a three-tier system is used, based upon the severity of the weather as well as the location of the convective activity:</p> <ul style="list-style-type: none"> • SWAP Level 1: Weather is expected to be 100 miles or more from N90 (NY TRACON) airspace 	<p>source flight-planning document, which integrates both structural and ATFCM requirements, geographically and vertically.</p> <p>The content of the RAD is agreed between the Network Manager and the Operational Stakeholders through an appropriate cooperative decision making (CDM) process.</p> <p>Each State ensures that the RAD is compatible with their AIP with regard to the airspace organization inside the relevant FIR/UIR.</p> <p>EUROCONTROL is responsible for preparing of a common RAD reference document, collating, coordinating, validating and publishing it, following the CDM process as described above.</p> <p><u>Scenarios</u></p> <p>Scenarios are the European means by which the best possible airspace organization combined with the best ATFCM measures can be implemented to meet airspace demand and to take into account traffic flows, airport and ATC capabilities.</p> <p>A scenario is a coherent set of measures combining airspace organization, route flow restrictions, sector configuration plan, capacity plan, rerouting plan and/or regulation plan. Each scenario is accompanied by its particular modus operandi for use of the network in relation with the ATC sector configuration, the route and airspace availability, special events, etc.</p> <p>Scenarios are characterized by:</p> <ul style="list-style-type: none"> • the traffic origin • the traffic destination • the scenario type(s) • the On-load Areas • the Off-load Areas • suggested alternative routes <p>There are four types of scenario:</p> <ul style="list-style-type: none"> • Level capping scenarios (FL): carried out by means of level restrictions or through dynamic routeing restrictions (RAD restrictions, EURO restrictions). • Rerouteing scenarios (RR): diversion of flows to off-load traffic from certain areas. • Alternative routeing scenarios (AR): alternative routes which are exceptionally made available to off-load traffic from certain areas, implemented by regulations with a low rate. • EU Restrictions: airspace restrictions that affect the flight planning phase based on route or airspace closures. <p><u>Event management</u></p>
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<p>and/or there is minor impact expected to ZNY (NY Center) arrival/departure gates, and to over flight routes. This level of SWAP provides for developing some basic structure, route expectations, and planning capability. The objective is to manage expectations and complexity early. Customers should begin filing appropriate route solutions and managing their flights in response to the actions taken or planned.</p> <ul style="list-style-type: none"> • SWAP Level 2: Weather is expected to be between 50-100 miles from N90 airspace and/or there is moderate impact expected to ZNY arrival/departure gates, and possibly to over flight routes. This level of SWAP provides for increasing structure and reducing holding, diversions, and other serious complexity issues. The objective is to prioritize airspace availability, reduce airborne inventory, and manage surface congestion issues. All initiatives in SWAP Level 1 are included. • SWAP Level 3: Weather is expected to be within 50 miles from N90 airspace and/or there is moderate or greater impact expected to ZNY arrival/departure gates, and possibly to over flight routes. This level of SWAP provides real-time constraint, route and volume management. The focus of this stage is to prioritize traffic that requires more expeditious handling, and that requires a much higher priority than other traffic sharing the same airspace. The objective is to reduce diversions, holding, surface delays and taxi-back situations. All initiatives in SWAP Level 1 and 2 are included. 	<p>Event management is used to resolve potential capacity/demand imbalances caused by seasonal or significant events, by applying ATFCM solutions. These solutions are a set of ATFCM measures, including routing scenarios, to deliver optimum network performance; they take the constraints of both AOs and ANSPs into consideration. ATFCM events are:</p> <ul style="list-style-type: none"> • Seasonal events happen every year at the same time and impact on the ATFCM network in a relatively predictable way. Examples of seasonal events include: the South-West Axis flows, the North-East Axis flows, the ski season traffic flows etc. • Significant events are those that generate a strong traffic demand in a relatively small area, generating local congestion. Examples of significant events are: the Olympic Games, the Football World Cup Finals, or Summits of Heads of States. • Military events refer primarily to military exercises. They are coordinated with the national AMC (Airspace Management Cells) and addressed through specific scenarios. <p>The general process consists of preparing scenarios under the Network Manager Operations Centre's (NMOC) supervision, in coordination with FMPs from the ACCs concerned, and the operations staff from the airlines involved.</p> <p><u>Axis management</u></p> <p>The above mentioned seasonal events are dealt with through the axis management process.</p> <p>This is a CDM process which starts in advance and has as an output ATFCM Measures (e.g., re-routings, FL capping or alternative routings) that would be further consolidated and applied on the day of operations.</p> <p>This output is discussed and agreed through dedicated CDM conferences (either via a meeting or an e-conference) and there is a monitoring process to fine-tune the event management as well.</p>
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PRE-TACTICAL ATFM

The ATFM pre-tactical phase encompasses measures taken one day prior to operations.

During this phase, the traffic demand for the day is analysed and compared to the predicted available capacity. The plan, developed during the strategic phase, is adapted and adjusted accordingly.

The main objective of the pre-tactical phase is to optimize capacity through an effective organization of resources (e.g. sector configuration management, use of alternate flight procedures).

The work methodology is based on a CDM process established between the stakeholders (e.g. FMU, airspace managers, AUs).

The tasks to be performed during this phase may include the following:

- determine the capacity available in the various areas, based on the particular situation that day;
- determine or estimate the demand;
- study the airspace or the flows expected to be affected and the airports expected to be saturated, calculating the acceptance rates to be applied according to system capacity;
- conduct a comparative demand/capacity analysis;
- prepare a summary of ATFM measures to be proposed and submit them to the ATFM community for collaborative analysis and discussion; and,
- at an agreed-upon number of hours before operations, conduct a last review consultation involving the affected ATS units and the relevant stakeholders, in order to fine-tune and determine which ATFM measures should be published through the corresponding ATFM messaging system.

The final result of this phase is the ATFM Daily Plan (ADP), which describes the necessary capacity resources and, if needed, the measures to manage the traffic. This activity is based on hypotheses developed in the strategic phase and refined to the expected situation. It should be noted that the time limits of the pre-tactical phase may vary, as they depend on forecast precision, the nature of operations within the airspace and the capabilities of the various stakeholders.

The ADP is developed collaboratively and aims at optimizing the efficiency of the ATM system and balancing demand and capacity. The objective is to develop strategic and tactical outlooks for a given airspace volume or airport that can be used by stakeholders as a planning forecast.

The ADP covers, as a minimum, a 24-hour period. The plan may however cover a shorter period, provided mechanisms are in place to update the plan regularly.

The operational intentions of AUs should be consistent with the ADP (developed during the strategic phase and adjusted during the pre-tactical phase).

Once the process has been completed, the agreed measures, including the ATFM measures, are disseminated using an ATFM message, which may be distributed using the various aeronautical communications networks or any other suitable means of communication, such as internet and email.

Table II-3: Pre-tactical planning

U.S.	Europe
<p><u>Operations Plan (OP)</u></p> <p>The FAA ATCSCC Operations Plan represents a view of the NAS performance, constraints, and risks that are accurate at the time it is published.</p> <p>The time-frame of the Operations Plan (Ops Plan) is pre-tactical/tactical. The development of the Ops Plan begins in the pre-tactical phase on the day before by a group called the PERTI/Advanced Planning team. An advanced planning webinar is held with stakeholders at 2:30pm Eastern Time. An update to the plan is developed by 5:00pm Eastern Time and emailed to stakeholders. These advanced plans contain FAA’s best forecast of weather impacts and special events that will constrain operations as well as the anticipated FAA mitigation through TMIs such as Ground Delay Programs and Re-Routes.</p> <p>An initial Operations Plan is published by FAA ATCSCC Advisory no later than 6:00 a.m. Eastern Time. The ATCSCC host a series of Planning Webinars (PWs) with FAA facilities (ARTCCs, Large TRACONS, and large ATCTs), with flight operators, and other stakeholders on the day of operation. The first PW is conducted at 7:15 am Eastern Time and every 2 hours thereafter until 9:15 pm Eastern Time.</p> <p>The ATCSCC has a designated Planner position that is staffed by a supervisor - National Traffic Management Officer (NTMO) at the ATCSCC. The Planner is responsible for developing, collaborating, conducting the PW and for publishing the Operations Plan by Advisory immediately following the PW. An operations agenda web-page is available to all stakeholders for submitting proposed constraints and mitigations between the PWs. The Planner is responsible for managing that web-page.</p> <p>The Operations Plan has the following sections:</p> <ul style="list-style-type: none"> • Terminal (airport) and En-route constraints • Plain language description of the Ops Plan • Actual and anticipated Traffic Management Initiatives (TMIs), such as Ground Delay Programs (GDPs), Airspace Flow Programs (AFPs), Ground Stops (GS) • Actual and Planned Routes (sometimes referred to as reroutes) are published. Actual TMIs and routes include a valid time while anticipated TMIs and routes include both a projected valid time and a qualifying description of the confidence that it may be needed. The qualifiers are: <ul style="list-style-type: none"> ○ Possible – indicates that an initiative may be needed if the constraint develops as forecast; timing is broad and confidence is low; ○ Probable – indicates that a TMI is very likely and confidence is high; timing is less certain; and, ○ Expected – indicates there is high confidence the TMI will be implemented when the projected time is reached. ○ 	<p><u>ATFCM Daily Plan (ADP)</u></p> <p>The ADP is a proposed set of tactical ATFCM measures (TMIs) prepared pre-tactically and agreed between all partners concerned to optimize the European Network. It covers a 24-hour period (the day prior to the day of operation) for each day.</p> <p>Normally the ADP starts as a draft on D-2 and it is finalized and promulgated on D-1 by means of the ATFCM Notification Message (ANM) and the ATFCM Information Message (AIM) Network News. During tactical operations the ADP is further modified according to the developments of the day.</p> <p><u>Airspace Use Plan (AUP)</u></p> <p>Agencies responsible for airspace activities submit their requests for the allocation of airspace or routes – Temporary Segregated Areas (TSAs) or Conditional Routes (CDRs) – to the appropriate national AMC (Airspace Management Cell).</p> <p>After the AMC has received, evaluated and de-conflicted the airspace requests, the notification of the airspace allocation is published in advance in a daily AUP.</p> <ul style="list-style-type: none"> • The Airspace Use Plan activates Conditional Routes and allocates Temporary Segregated Areas and Cross-Border Areas for specific periods of time. • If necessary, changes to the pre-tactical airspace allocation can be made by AMCs through the publication of an Updated Airspace Use Plan. This UUP notifies the changes to the airspace allocation on the actual day of operations. The process of update of airspace use requests is very dynamic. • The AUP and the UUP are published nationally and internationally in a harmonized format.

TACTICAL ATFM

During the ATFM tactical phase, measures are adopted on the day of the operation. Traffic flows and capacities are managed in real time. The ADP is amended taking due account of any event likely to affect it.

The tactical phase aims at ensuring that:

- the measures taken during the strategic and pre-tactical phases actually address the demand/capacity imbalances;
- the measures applied are absolutely necessary and that unnecessary measures be avoided;
- capacity is maximized without jeopardizing safety; and
- the measures are applied taking due account of equity and overall system optimization.

During this phase, any opportunity to mitigate disturbances will be used. The need to adjust the original ADP may result from staffing problems, significant meteorological phenomena, crises and special events, unexpected opportunities or limitations related to ground or air infrastructure, more precise flight plan data, the revision of capacity values, etc.

The provision of accurate information is of paramount importance in this phase, since the aim is to mitigate the impact of any event using short-term forecasts. Various solutions will be applied, depending on whether the aircraft are already airborne or about to depart.

Proactive planning and tactical management require the use of all information available. It is of vital importance to continuously assess the impact of ATFM measures and to adjust them, in a collaborative manner, using the information received from the various stakeholders.

Table II-4: Tactical ATFM

U.S.	Europe
<p><u>Managing airport constraints</u></p> <p>Airport TMIs in the U.S. are designed to manage inbound traffic flows (arrivals):</p> <p>Ground Delay Program (GDP): GDPs will normally be implemented at airports where capacity has been reduced because of weather—such as low ceilings, thunderstorms or wind—or when demand exceeds capacity for a sustained period.</p> <p>GDPs are implemented to ensure the arrival demand at an airport is kept at a manageable level to preclude extensive holding and to prevent aircraft from having to divert to other airports. They are also used in support of Severe Weather Avoidance Plan (SWAP).</p> <p>A ground stop (GS) is a procedure requiring aircraft that meet specific criteria to remain on the ground. Ground Stops are implemented for a number of reasons. The most common reasons are:</p> <ul style="list-style-type: none"> • To control air traffic volume to airports when the projected traffic demand is expected to exceed the airport’s acceptance rate for a short period of time. • To temporarily stop traffic allowing for the 	<p><u>Managing airport constraints</u></p> <p>Europe uses ATFM regulations to manage airport traffic flows. Airport ATFM regulations can apply:</p> <ul style="list-style-type: none"> • To a single aerodrome (AD) or to a set of aerodromes (AZ). This is called the Reference Location (RL). • For the AD or AZ: to all or just to a subset of the traffic; i.e. to arrivals only, departures only, or both (called ‘global’). This is called the traffic volume (TV). In most cases only arrival regulations are used. <p>Airport ATFM regulations with a non-zero rate are the equivalent of a GDP.</p> <p>Airport ATFM regulations with a zero rate are the equivalent of a GS.</p> <p>In some cases, an airport ATFM regulation starts off with a zero rate, which is later increased to accept a limited amount of traffic. This is the equivalent of a combined GS+GDP.</p>

<p>implementation of a longer-term solution, such as a Ground Delay Program.</p> <ul style="list-style-type: none"> • The affected airport's acceptance rate has been reduced to zero. <p>A facility may initiate a local GS when the facilities impacted are wholly contained within the facility's area of responsibility and conditions are not expected to last more than 30 minutes. Local GSs must not be extended without prior approval of the ATCSCC.</p> <p>The ATCSCC may implement a national GS upon receipt of information that an immediate constraint is needed to manage a condition, after less restrictive TMIs have been evaluated.</p> <p>Not all inbound traffic is affected by a GDP or GS. The scope (departure scope) indicates which traffic is included in the TMI. Traffic departing from airports under the jurisdiction of the listed facilities will be subjected to the TMI. The scope can be distance based or tier based, e.g. the local ARTCC, the First Tier ARTCCs (neighbors), or the Second Tier ARTCCs (neighbors of neighbors).</p>	
<p><u>Managing airspace constraints</u></p> <p>A Departure Stop is similar to a GS. It assigns a departure stop for a specific NAS element other than a destination airport, such as an airway, fix, departure gate, or sector.</p> <p>An Airspace Flow Program (AFP) is a delay TMI with parameters similar to that of a GDP. The major difference between the two types of initiatives is that AFPs control the flow of aircraft into or through a volume of airspace versus controlling the flow of aircraft to a particular airport. The volume of airspace used is often one-dimensional (i.e. a border). All of these volumes are referred to as Flow Constrained Areas (FCA).</p> <p>Flow Evaluation Areas (FEA) are developed on an ad hoc basis. Just like FCAs, they are three-dimensional volumes of airspace, along with flight filters and a time interval, used to identify flights. They may be drawn graphically, around weather, or they may be based on a NAS element. They are used to evaluate demand on a resource. FEAs and FCAs are different because an Evaluation Area is just under study while a Constrained Area requires action to address a particular situation.</p> <p>FEA/FCAs provide reroutes using the Create Reroute capability and are published through a reroute advisory with an optional flight list attached. Stakeholders can monitor FEA/FCAs through reroute monitor in traffic situation display (TSD), web situation display (WSD) or collaborative constraint situation display (CCSD).</p>	<p><u>Managing airspace constraints</u></p> <p>Europe uses ATFM regulations to manage en-route traffic flows. En-route ATFM regulations can apply:</p> <ul style="list-style-type: none"> • To an airspace volume (AS) or to a special point (SP). This is called the Reference Location (RL). • To all or just to a subset of the traffic crossing the RL. This is called a traffic volume (TV). <p>En-route ATFM regulations can either take the form of</p> <ul style="list-style-type: none"> • A delay TMI. Those are comparable to AFPs. • A TMI for rerouting purposes, not generating delay (normally part of a scenario see above): <ul style="list-style-type: none"> ○ Level capping (FL): implemented by a zero-rate regulation with vertical restriction ○ Required rerouting (RR): implemented by a zero-rate regulation ○ Alternative routing (AR): implemented by a regulation with a low rate through airspace normally not accessible to the traffic flow. <p>In Europe the Network Manager has – in collaboration with aircraft operators – put in place a process called the Flight Efficiency Initiative (FEI). It is based on voluntary participation by aircraft operators and aims at offering them the most efficient routes on the day of operation. It entails scrutinizing their flight plans and seeing if there is not a quicker or more cost-effective way for their aircraft to fly.</p> <p>The FEI operates on the basis of a dynamic route generator and an automatically maintained catalogue of routes flown in the past. The routes are evaluated on the basis of subjective cost criteria provided by the airline operators, such as:</p>

<p>The Required Reroutes (RR) TMI is often applied in conjunction with delay programs to move flows around en-route constraints. The impact of the reroute is dependent on how it is implemented and what type of delay program it is interacting with. Required reroutes are issued by Departure (ETD), Arrival (ETA) or FCA entry time.</p> <p>CTOP (Collaborative Trajectory Options Program) is a new type of TMI, which automatically assigns delay and/or reroutes around one or more FCA-based airspace constraints in order to balance demand with available capacity. The unique feature of CTOP is that it allows for user preferences in route selection. Under a CTOP initiative, operators submit alternative routes of their choice around or away from a constraint, thus providing additional options for air traffic controllers to expedite flights away from congested airspace. Flights that have submitted a trajectory option set (TOS) could be exempt from ground delays or in-flight reroutes associated with such constraints.</p> <p>ICR (Integrated Collaborative Rerouting) is a process that builds on the FCA technology. The ICR process requires that a constraint be identified early. ICR allows airspace users to take action with their trajectory preferences in response to an identified system constraint. They have an opportunity to consider the area of concern and provide EI (Early Intent) messages that communicate their decisions in response to the constraint. At the expiration of the EI window, traffic managers can analyze the customer responses and decide if the actions taken have resolved the issue or decide if recommended routes, required routes, airspace flow programs, or other Traffic Management Initiatives (TMI) will be necessary to further reduce demand.</p>	<ul style="list-style-type: none"> • flying time costs, • fuel costs and • the cost of air traffic flow and capacity management (ATFCM) delays. <p>The FEI is based on a re-routing process that can take place on the day of operations up to two hours before the flight. It takes place in two phases:</p> <ul style="list-style-type: none"> • First phase: AOs and computerized flight plan service providers (CFSPs) can use an NM tool to compare their flight plans with the best filed flight plan accepted by the NM for a given city pair • Second phase: Re-routing proposals from the NM to AOs <p>The FEI also contributes to a strategic and continuous improvement of the airlines' route catalogues.</p>
<p><u>Slot substitution (subbing)</u></p> <p>The substitution process provides a way for airspace users, henceforth referred to as users, to manage their flights during a GDP, GS or AFP. Users can, for example, swap slots between a high priority flight and a less important flight, reducing the delay on one at the cost of increasing the delay for another. Users may only sub for their own flights; there is no trading or bartering for slots.</p>	<p><u>Slot swapping</u></p> <p>In Europe the ETFMS slot swapping functionality is used to swap flights requested by AOs or FMPs. Additionally it may be used to improve another flight if an aircraft operator requests a slot extension (i.e. instead of forcing the flight).</p> <p>AOs shall only request swaps concerning flights for which they are the responsible operator or where there is a formal agreement between both AOs to swap flights. For regulated flights departing from an A-CDM, AOs shall request the swap via the FMP / TWR.</p> <p>FMPs may request swaps for two flights of the same AO or, during critical events at airports, also between any different AOs.</p>

In the tactical phase Europe also uses STAM, Short Term ATFCM Measures, such as minor ground delays, flight level capping and minor re-routings applied to a limited number of flights, both airborne and pre-departure. STAM application allows reducing the complexity and/or demand of anticipated/identified traffic peaks and to prevent or limit the penalization that would result from the implementation of standard ATFCM measures.

Europe is also taking its first steps in Target Time Operations, by including the Target Time Over in the ATFM Slot Allocation Messages. At present, this is provided to create operational awareness of the planned time at the congestion point. Further developments are planned to use Target Time Over to optimize ATFM delivery.

FINE-TUNING OF TRAFFIC FLOWS BY ATC

After ATFM measures are taken, traffic flows are further fine-tuned by ATC.

A distinction can be made between TMIs that have an impact on traffic prior to take-off, and those acting on airborne traffic.

TMIs that have an impact on traffic prior to take-off

These are sequencing and metering measures that are used by ATC to fine-tune the traffic flow and that may have a delay impact on traffic prior to take-off.

The resulting cleared-for-take-off time (Call For Release Time – CFR) may be different from the slot time (EDCT/CTOT) produced by ATFM. Normally this adjustment falls within the ATFM tolerance window:

- In the U.S. this called the EDCT Window: -5/+5min;
- In Europe it is the STW (Slot Tolerance Window): -5/+10min during normal conditions and during adverse conditions up to 15/+30min.

In specific cases sequencing and metering may create additional delay beyond the ATFM tolerance window.

In the U.S. the CFR Window (Call For Release Window) for ATOT is -2/+1min around the assigned CFR time.

In Europe, for flights without an ATFM slot there is a DTW (Departure Tolerance Window) for ATOT of -15/+15min around the ETOT during normal conditions, during adverse conditions possibly extended to -15/+30min.

The TMIs in this category include:

- CFR (Call for Release)⁵² (U.S.)
- DSP (Departure Spacing) (U.S.)
- ESP (En-route Spacing)
- ASP (Arrival Spacing)
- Metering (en-route metering)
- MDI (Minimum Departure Interval) (Europe)
- MIT (Miles In Trail)
- MINIT (Minutes In Trail)

⁵² Also known as Approval Request (APREQ).

TMIs acting on airborne traffic

This TMI category comprises longitudinal (sequencing and metering), lateral (load balancing) and vertical (level off) tactical measures that are used by ATC after take-off with the objective to fine-tune the traffic flow.

- TBM (Time Based Metering) not propagating to the departure airport (U.S.)
 - TBFM Speed Advisories (U.S.) / XMAN (Cross-border Arrival Management) speed advisories (Europe)
- AH (Airborne Holding)
 - Planned Holding
 - Unplanned Holding
- Vectoring
- Tactical level offs
- Point Merge (Europe)
- Fix Balancing

POST-OPERATIONS ANALYSIS

The final step in the ATFM planning and management process is the post-operations analysis phase.

During this phase, an analytical process is carried out to measure, investigate and report on operational processes and activities. This process is the cornerstone of the development of best practices and/or lessons learned that will further improve the operational processes and activities. It covers all ATFM domains and all the external units relevant to an ATFM service.

While most of the post-operations analysis process may be carried out within the ATFM unit, close coordination and collaboration with ATFM stakeholders will yield better and more reliable results.

Post-operations analysis is accomplished by evaluating the ADP and its results. Reported issues and operational statistics are evaluated and analyzed in order to learn from experience and to make appropriate adjustments and improvements in the future.

Post-operations analysis includes analysis of items such as anticipated and unanticipated events, ATFM measures and delays, the use of predefined scenarios, flight planning and airspace data issues. They compare the anticipated outcome (where assessed) with the actual measured outcome, generally in terms of delay and route extension, while taking into account performance targets.

All stakeholders within the ATFM service can provide feedback, preferably in a standardized electronic format, enabling the information to be used in the post-operations analysis in an automated manner.

Post-operations analysis is used to:

- identify operational trends or opportunities for improvement;
- further investigate the cause and effect relationship of ATFM measures to assist in the selection and development of future actions and strategies;
- gather additional information with the goal of optimizing ATM system efficiency in general or for on-going events;
- perform analysis of specific areas of interest, such as irregular operations, special events, or the use of re-route proposals; and
- make recommendations on how to optimize ATM system performance and to minimize the negative impact of ATFM measures on operations.

It is important to ensure that the relevant ATFM stakeholders are made aware of the results. The following processes support this:

- collection and assessment of data including comparison with targets;
- broad review and further information gathering at a daily briefing;
- weekly operations management meetings to assess results and recommend procedural, training and system changes where necessary to improve performance; and
- periodic operations review meetings with stakeholders.

Table II-5: Post-Ops

U.S.	Europe
<p>There are different levels of post operations analysis:</p> <ul style="list-style-type: none"> • At 8:30 am Eastern time the ATCSCC conducts a post-ops review for ATCSCC management and staff. • At 10:00 am Eastern Time there is a National System review (NSR) post-ops telcon that includes flight operators and FAA Deputy Director System Operations and ATCSCC QC. • At 10:30 am Eastern Time, the Deputy Chief Operating Officer at FAA HQ conducts a post-ops review that includes safety, security, system operations (ATFM), and other significant events from the prior day's operation. <p>A NAS-AERO product that is an interactive web product is used in the briefings and is published widely within FAA. NAS performance, delay, airborne holding, diversions, TMI, and other NAS performance data is available. There are many national, regional, and facility level products that are created for post-ops review, including video replays.</p> <p>Traffic Management Reviews (TMRs) may be conducted on significantly positive NAS performance results as well as on poor results. The TMR is a very detailed review of a particular event or constraint and may take several days to perform.</p>	<p>The Network Manager provides traffic and delay forecasts and analysis to support the global performance of the European aviation network. The Network Manager:</p> <ul style="list-style-type: none"> • continuously assesses the performance of the network functions and has established pan-network processes of monitoring, analyzing and reporting on all network operational performance aspects; • recommends measures and/or takes the actions needed to ensure the network performance; • compares these performances against the objectives established in the network Strategy Plan (NSP), Network Operations Plan (NOP) & Performance Plans identifying gaps and proposing remedial actions. <p>This way NM provides a consolidated and coordinated approach to all planning & operational activities of the network.</p> <p><u>Playbook</u></p> <p>The playbook is a tool that combines historical data (5 years and the last 4 weeks) to indicate the risk of delay occurring in a particular area of the Network.</p> <p>A daily delay target is allocated globally for en-route and airports and individually for ACCs and airports based on the relevant en-route and airport annual targets.</p> <p>An advanced playbook is produced at D-6 to facilitate planning; this forms the template for production of the D+1 playbook which contains actual delay data from the day of operation for comparison and further post operations analysis.</p> <p>The Post Operations team is responsible for the production of the en-route ATC Capacity and Staffing and Airport playbooks.</p>

ANNEX III - GLOSSARY

A-CDM	Airport Collaborative Decision Making
AAR	Airport Arrival Acceptance Rate
ACC	Area Control Centre. That part of ATC that is concerned with en-route traffic coming from or going to adjacent centers or APP. It is a unit established to provide air traffic control service to controlled flights in control areas under its jurisdiction.
Achieved distance	The portion of the Great Circle distance between two airports that corresponds to a given portion of a flight trajectory. This can be computed for the actual trajectory as well as for the flight-plan trajectory. Regardless of the shape of the trajectory (and the actual or flight-planned distance), the achieved distance of the entire flight is equal to the Great Circle distance between the two airports.
ACI	Airports Council International (http://www.aci-europe.org/)
AD	Aerodrome
ADP	ATFM Daily Plan
ADR	Airport Departure Rate
AFP	Airspace Flow Program (U.S.)
AIG	Accident and Incident Investigation (ICAO)
AIM	ATFCM Information Message (Europe)
AIP	Aeronautical Information Publication, sets out procedures used by pilots and air traffic controllers
AIS	Aeronautical Information Service
AMC	Airspace Management Cell (Europe)
ANM	ATFCM Notification Message (Europe)
ANS	Air Navigation Service. A generic term describing the totality of services provided in order to ensure the safety, regularity and efficiency of air navigation and the appropriate functioning of the air navigation system.
ANSP	Air Navigation Services Provider
AO	Aircraft Operator
APP	Approach Control Unit
AR	Alternative routing scenario (Europe)
ARTCC	Air Route Traffic Control Center, the equivalent of an ACC in Europe.
ASBU	Aviation System Block Upgrade (ICAO)
ASM	Airspace Management
ASMA	Arrival Sequencing and Metering Area
ASP	Arrival Spacing (U.S.)
ASPM	FAA Aviation System Performance Metrics
ATC	Air Traffic Control. A service operated by the appropriate authority to promote the safe, orderly and expeditious flow of air traffic.
ATCO	Air Traffic Control Officer
ATCSCC	U.S. Air Traffic Control System Command Centre
ATCT	Air Traffic Control Tower (U.S.)
ATFCM	Air Traffic Flow and Capacity Management
ATFM	Air Traffic Flow Management. ATFM is established to support ATC in ensuring an optimum flow of traffic to, from, through or within defined areas during times when demand exceeds, or is expected to exceed, the available capacity of the ATC system, including relevant aerodromes.
ATFM delay (CFMU)	The duration between the last take-off time requested by the aircraft operator and the take-off slot given by the CFMU.
ATFM Regulation	When traffic demand is anticipated to exceed the declared capacity in en-route control centers or at the departure/arrival airport, ATC units may call for "ATFM regulations."
ATM	Air Traffic Management. A system consisting of a ground part and an air part, both of which are needed to ensure the safe and efficient movement of aircraft during all phases of operation. The airborne part of ATM consists of the functional capability which interacts with the ground part to attain the general objectives of ATM. The ground part of ATM comprises the functions of Air Traffic Services (ATS), Airspace Management (ASM) and Air Traffic Flow Management (ATFM). Air traffic services are the primary components of ATM.
ATO	Air Traffic Organization (FAA)
ATS	Air Traffic Service. A generic term meaning variously, flight information service, alerting

	service, air traffic advisory service, air traffic control service.
AU	Airspace User
AUP	Airspace Use Plan (Europe)
AZ	Aerodrome Zone (Europe)
Bad weather	For the purpose of this report, “bad weather” is defined as any weather condition (e.g. strong wind, low visibility, snow) which causes a significant drop in the available airport capacity.
BTS	Bureau of Transportation Statistics (U.S.)
CAA	Civil Aviation Authority
CANSO	Civil Air Navigation Services Organisation (http://www.canso.org)
CBA	Cross-Border Area (Europe)
CCF	Combined Control Facility (U.S.): An air traffic control facility that provides approach control services for one or more airports as well as en-route air traffic control (center control) for a large area of airspace. Some may provide tower services along with approach control and en-route services. Also includes Combined Center Radar Approach (CERAP) facilities.
CDA	Continuous Descent Approach
CDM	Collaborative Decision Making
CDR	Conditional Route (Europe)
CDR	Coded Departure Route (U.S.)
CFMU	See NMOC
CFR	Call For Release Time (U.S.)
CM	Capacity Management
CO ₂	Carbon dioxide
CODA	EUROCONTROL Central Office for Delay Analysis
CONUS	see U.S. CONUS
CTA	Control Area
CTOP	Collaborative Trajectory Options Program
CTOT	Calculated take-off Time
DCB	Demand Capacity Balancing
DP	Departure Procedure
DSP	Departure Spacing (U.S.)
DTW	Departure Tolerance Window (Europe)
EC	European Commission
ECAC	European Civil Aviation Conference.
EDA	European Defence Agency (EU)
EDCT	Estimate Departure Clearance Time. EDCT is a long-term Ground Delay Programme (GDP), in which the Command Centre (ATCSCC) selects certain flights heading to a capacity limited destination airport and assigns an EDCT to each flight, with a 15 minute time window.
EI	Early Intent (U.S.)
ESP	En-route Spacing (U.S.)
ETA	Estimated Time of Arrival
ETD	Estimated Time of Departure
ETFMS	Enhanced Tactical Flow Management System (Europe)
EU	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxemburg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and United Kingdom. All these 28 States are also Members of the ECAC.
EUROCONTROL	The European Organisation for the Safety of Air Navigation. It comprises Member States and the Agency.
EUROCONTROL Member States (2015)	Albania, Armenia, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Moldova, Monaco, Montenegro, The Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, The former Yugoslav Republic of Macedonia, Turkey, Ukraine and United Kingdom of Great Britain and Northern Ireland
FAA	U.S. Federal Aviation Administration
FAA-ATO	U.S. Federal Aviation Administration - Air Traffic Organization
FAB	Functional Airspace Block (Europe)

FCA	Flow Constrained Area (U.S.)
FDP	Flight data processing
FEA	Flow Evaluation Area (U.S.)
FEI	Flight Efficiency Initiative (Europe)
FIR	Flight Information Region. An airspace of defined dimensions within which flight information service and alerting service are provided.
FL	Flight Level. Altitude above sea level in 100-foot units measured according to a standard atmosphere. Strictly speaking a flight level is an indication of pressure, not of altitude. Only above the transition level are flight levels used to indicate altitude; below the transition level, feet are used.
FL	Level capping scenario (Europe)
FMP	Flow Management Position (Europe). The FMP's role is, in partnership with the NM, to act in such a manner so as to provide the most effective ATFCM service to ATC and AOs. Each FMP area of responsibility is normally limited to the area for which the parent ACC is responsible including the area(s) of responsibility of associated Air Traffic Services (ATS) units as defined in the NM Agreement. However, depending on the internal organization within a State, some FMPs may cover the area of responsibility of several ACCs, either for all ATFCM phases or only for part of them. All FMPs within the NM area have equal status. The size of individual FMPs will vary according to the demands and complexities of the area served.
FMS	Flight Management System
FMU	Flow Management Unit
FRA	Free Route Airspace (Europe)
FUA	Flexible Use of Airspace Level 1 Strategic Airspace Management Level 2 Pre-tactical Airspace Management Level 3 Tactical Airspace Management
GANP	Global Air Navigation Plan (ICAO)
GAT	General Air Traffic. Encompasses all flights conducted in accordance with the rules and procedures of ICAO. The report uses the same classification of GAT IFR traffic as STATFOR: 1. Business aviation: All IFR movements by aircraft types in the list of business aircraft types (see STATFOR Business Aviation Report, May 2006, for the list); 2. Military IFR: ICAO Flight type = 'M', plus all flights by operators or aircraft types for which 70%+ of 2003 flights were 'M'; 3. Cargo: All movements by operators with fleets consisting of 65% or more all-freight airframes 4. Low-cost: See STATFOR Document 150 for list. 5. Traditional Scheduled: ICAO Flight Type = 'S', e.g. flag carriers. 6. Charter: ICAO Flight Type = 'N', e.g. charter plus air taxi not included in (1)
GDP	Ground Delay Program (U.S.)
General Aviation	All flights classified as "G" (general aviation) in the flight plan submitted to the appropriate authorities.
GS	Ground Stop (U.S.)
IATA	International Air Transport Association (www.iata.org)
ICAO	International Civil Aviation Organization
ICR	Integrated Collaborative Rerouting (U.S.)
IFR	Instrument Flight Rules. Properly equipped aircraft with properly qualified flight crews are allowed to fly under bad-weather conditions following instrument flight rules.
ILS	Instrument landing System; a lateral and vertical beam aligned with the runway centreline in order to guide aircraft in a straight line approach to the runway threshold for landing.
IMC	Instrument Meteorological Conditions
KPA	Key Performance Area
KPI	Key Performance Indicator
M	Million
MDI	Minimum Departure Interval
MET	Meteorological Services for Air Navigation
MIL	Military flights
MINIT	Minutes In Trail
MIT	Miles in Trail

MTOW	Maximum Take-off Weight
NAS	National Airspace System
NextGen	The Next Generation Air Transportation System (NextGen) is the name given to a new National Airspace System due for implementation across the United States in stages between 2012 and 2025.
NM	Nautical mile (1.852 km)
NMOC	Eurocontrol Network Management Operations Centre located in Brussels (formerly CFMU)
NOP	Network Operations Plan (Europe)
NRP	North American Route Program (U.S. – Canada)
NSP	Network Strategy Plan (Europe)
NSR	National System Review (U.S.)
OEP	Operational Evolution Partnership (a list of 35 U.S. airports that was compiled in 2000, based on lists from the FAA and Congress and a study that identified the most congested airports in the U.S.).
OJT	On the Job Training
OP	Operations Plan (U.S.)
OPS	Operational Services
OPSNET	The Operations Network is the official source of NAS air traffic operations and delay data. The data is used to analyze the performance of the FAA's air traffic control facilities.
PBFA	DoD Policy Board on Federal Aviation (U.S.)
Percentile	A percentile is the value of a variable below which a certain per cent of observations fall. For example, the 80th percentile is the value below which 80 per cent of the observations may be found.
PPS	Purchasing power standard
PRC	Performance Review Commission
Primary Delay	A delay other than reactionary
PRU	Performance Review Unit
Punctuality	On-time performance with respect to published departure and arrival times
PW	Planning Webinar (U.S.)
RAD	Route availability document
Reactionary delay	Delay caused by late arrival of aircraft or crew from previous journeys
RL	Reference Location (Europe)
RR	Rerouting scenario (Europe)
RR	Required Reroutes TMI (U.S.)
RTCA	Radio Technical Commission for Aeronautics, Inc.
Separation minima	The minimum required distance between aircraft. Vertically usually 1,000 ft below flight level 290, 2,000 ft. above flight level 290. Horizontally, depending on the radar, 3 NM or more. In the absence of radar, horizontal separation is achieved through time separation (e.g. 15 minutes between passing a certain navigation point).
SES	Single European Sky (EU) http://ec.europa.eu/transport/modes/air/single_european_sky/index_en.htm
SESAR	The Single European Sky implementation programme
Slot (ATFM)	A take-off time window assigned to an IFR flight for ATFM purposes
SP	Special Point (Europe)
STAM	Short Term ATFCM Measure (Europe)
STAR	Standard Terminal Arrival Route
STATFOR	EUROCONTROL Statistics & Forecasts Service
STMP	Special Traffic Management Program (U.S.)
STW	Slot Tolerance Window (Europe)
SUA	Special Use Airspace
Summer period	May to October inclusive
SWAP	Severe Weather Avoidance Plan (U.S.)
Taxi-in	The time from touch-down to arrival block time.
Taxi-out	The time from off-block to take-off, including eventual holding before take-off.
TBFM	Time Based Flow Management (U.S.)
TBM	Time Based Metering (U.S.)
TFMS	Traffic Flow Management System (U.S.)
TMA	Terminal Manoeuvring Area

TMI	Traffic Management Initiative
TMR	Traffic Management Review (U.S.)
TMS	Traffic Management System
TMU	Traffic Management Unit (U.S.). TMUs use TFMS workstations to participate in traffic flow management. They are located at Air Route Traffic Control Centers (ARTCCs), Terminal Radar Approach Control (TRACON) facilities and large/stand-alone Airport Traffic Control Towers (ATCTs).
TOS	Trajectory Option Set (U.S.)
TRACON	Terminal Radar Approach Control
TSA	Temporary Segregated Area (Europe)
TSD	Traffic Situation Display (U.S.)
TV	Traffic Volume (Europe)
TWR	Tower
UAC	Upper Airspace Area Control Centre
UIR	Upper Information Region
U.S.	United States of America
U.S. CONUS	The 48 contiguous States located on the North American continent south of the border with Canada, plus the District of Columbia, excluding Alaska, Hawaii and oceanic areas
UUP	Updated Airspace Use Plan (Europe)
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
XMAN	Cross-border Arrival Management / Extended Arrival Management (Europe)

ANNEX IV - REFERENCES

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