European Commission

EUROCONTROL

U.S. Department of Transportation
Federal Aviation Administration

2013 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

June 2014

This document is a joint publication of the Air Traffic Organization System Operations Services of the FAA and EUROCONTROL on behalf of the European Union in the interest of the exchange of information.

It is prepared for the first time in application of Annex 2 of the Memorandum of Cooperation NAT-I-9406 signed between the United States of America and the European Union on 12 February 2013 and managed by a joint EC-FAA Performance Analysis Review Committee (PARC). The report builds on the body of work developed since 2009 between the FAA and the Performance Review Commission of EUROCONTROL.

The objective is to make a factual high-level comparison of Air Traffic Management performance between the US 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.

Maurizio Castelletti
PARC Co-Chair, European Commission

David Chin
PARC Co-Chair, US, FAA

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

Final report – June 2014

ABSTRACT

This report is the 4th in a series of joint ATM operational performance comparisons between the US and Europe. 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 optimise 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 harmonised 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

Federal Aviation Administration Air Traffic Organization System Operations Services	Performance Analysis Office 800 Independence Ave., S.W. Washington, DC 20591 Tel: 202-527-2845 E-mail: john.gulding@faa.gov
European Commission	Directorate General for Mobility and Transport Directorate E - Aviation and international transport affairs Unit E2 - Single European Sky Tel. +32 2 291 915 E-mail: Maurizio.castelletti@ec.europa.eu
EUROCONTROL	Performance Review Unit 96 Rue de la Fusée, B-1130 Brussels, Belgium Tel: +32 2 729 3956, E-mail: pru@eurocontrol.int

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

This report comprises the first deliverable performed under Annex 2 of the Memorandum of Cooperation NAT-I-9406 signed between the United States of America and the European Union. It provides a comparative operational performance assessment between Europe and the US using Key Performance Indicators (KPIs) that have been harmonized by both groups. The ability to work with harmonized KPIs fosters a unique opportunity for both organizations to learn each other's strengths and identify opportunities for improvement across all phases of flight. The demonstrated use of common indicators also further supports ICAO goals on assessing the benefits of the global implementation of Aviation System Block Upgrades (ASBUs).

For most indicators, trends are provided from 2008-2013 with a focus on the change in performance from 2012-2013. The report begins by examining the commonalities and differences in the two systems in terms of fundamental air traffic management and external factors such as demand and weather that can have a large influence on the indicators year over year. Many of these external factors are quantified with related indicators provided for demand/capacity and weather. KPIs are then developed and compared using airline and ANSP data. These cover Predictability and Flight Efficiency. Predictability is calculated using airline data in the form of airline punctuality as well as time variability by phase of flight. ANSP indicators focus on ANSP imposed delay and efficiency of flight against an ideal benchmark distance or time. The report concludes with a summary of findings and recommendations for future work that will improve the understanding of ATM performance as well as influence improvements globally.

To make the most ideal comparison, US CONUS airspace as represented by its 20 CONUS centers is compared to European airspace as covered by 63 en route centers. The US area is about 10% smaller and handles approximately 57% more flight activity as measured by operations or flight hours. US airspace density is higher and airports tend to be larger and more complex. The US also operates with fewer airports applying schedule limitations. This may lead to more US facilities operating near their peak capacity. However, analysis of peak arrival throughput shows the US and Europe operating at similar levels. Each system has areas that are highly impacted by special use airspace (SUA) and these are highlighted in the report. For Europe, special use airspace permeates all regions and adds complexity in some of the most densely traveled areas of Europe. For the US, SUA is 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.

In reporting Air Traffic Flow Management (ATFM) imposed delay, Europe ascribes a greater percentage of delay to en route facilities while in the US the large majority is ascribed to constraints at the airport. In the US, when en route is the constraining facility it is most often due to thunderstorm activity. In Europe, en route delay is most often ascribed to volume or capacity. From 2012 to 2013, total European ATFM delay decreased by 20.6% while US ATFM delay increased by 25%. In Europe, 87% of the decrease is attributed to less impact from volume or capacity constraints while in the US, 91% of the increase is attributed to weather. Of the US weather-related ATFM delay increase, 62% was reported as due to thunderstorms, 22% due to winter ops while 16% was due to other causes. The report notes that 2012 appears to have been a historically good weather year for the US, and average ATFM delay has been largely on the decline since 2008.

The change in reported ATFM delay proved to be a leading indicator for the other KPIs tracked in this report. In general from 2012 to 2013, US performance declined while European performance improved. However overall, the US shows improvements over Europe in the airborne phase of flight with most delay pushed back to the departure airport. This ability to reduce airborne delay, even in the terminal arrival phase of flight, is largely attributed to more integrated traffic flow management.

In terms of airline reported indicators, both gate departure and gate arrival on-time percentages remained largely unchanged for Europe. However the US saw a decline in both arrival on-time (83.6% in 2012 vs. 80.7% in 2013) and gate departure on-time (82.9% in 2012 vs. 80.1% in 2013). Large airports in the US such as Atlanta (ATL) and Chicago (ORD) drove the decline in this indicator. The predictability of airline flight time as measured by travel time variability declined in the US while remaining fairly constant in Europe. This increase in variability was largely seen in the surface phase of flight, particularly in the departure gate-out phase. This confirms that most ATFM initiatives have flights absorbing delay on the ground with much of the delay even pushed back to the gate.

The report concludes with flight efficiency reported for the taxi-out, en route, arrival/descent and taxi-in phases of flight. In these areas, performance in the US either decreased or remained relatively unchanged while Europe improved or remained unchanged.

Europe continues to demonstrate less additional time in the taxi-out phase than in the US. This difference in additional time in the taxi-out phase between the US and Europe widened from 2012 to 2013 with average additional time in the US growing from an average of 4.9 minutes to 5.2 minutes. Large increases at Detroit (DTW), Minneapolis (MSP), New York (JFK), and Denver (DEN) influenced the change in this metric. European performance improved slightly with a drop in additional time from 4.0 to 3.9 additional minutes in this phase. The improvement in Europe was driven by reductions in taxi out time at London Gatwick (LGW), Dublin (DUB), Prague (PRG), and Frankfurt (FRA).

The US continues to show a lower level of inefficiency in the airborne phase of flight. This is seen across the three airborne indicators assessed which cover actual and flight plan trajectories in the en route phase as well as additional time spent in the Arrival Sequencing and Maneuvering Area (ASMA).

The en route indicators follow the KPI definitions called for in the European Performance Scheme which compare the actual flight trajectory length and the flight plan length to a great-circle based measure called the "achieved distance". With regards to the flight plan, European airlines file on average almost 5% greater than their achieved distance compared to 3.5% in the US. Causal reasons for this excess in filing distance are mostly likely linked to comparing the single provider system in the US to the multiple provider system in Europe. However the proliferation of SUA in the core operating areas of Europe may also contribute to the filing of excess distance. Similarly, much of the variability in this measure for the US can be linked to SUA as well.

For actual compared to achieved distance, the differences are more comparable. As a percentage, the total horizontal en route flight inefficiency for Europe was 2.91% compared to 2.71% in the US. Both measures taken together reveal that both in the US and Europe, airlines fly a shorter distance than they file. The gap between filed vs. flown, however, is much smaller in the US (0.73%) than in Europe (1.90%). The report notes that Europe has been on a downward (improving) trend for both the flight plan and actual flight efficiency indicators since 2011.

In the Arrival Sequencing and Maneuvering Area, which comprises the last 100 NM of flight, the additional time is higher on average in Europe (2.8 minutes) than in the US (2.5 minutes). The larger values in Europe are largely due to high additional minutes at London Heathrow (LHR), where holding is frequently used to maintain maximum throughput for the runways. From 2012 to 2013, both systems registered very small changes system-wide in this phase of flight. The nearly negligible changes in the airborne flight efficiency numbers compared to the much larger variation on the surface both at the gate and in the taxi-out phase confirm that the impact due to weather or other constraining events in the US is taken on the ground during the departure phase of flight.

The additional time in the taxi-in phase is slightly higher in the US than in Europe but remains relatively stable over time in both systems. From 2012 to 2013, there are no significant changes that can be reported.

The report concludes with a list of priority work items which will be performed under the US/European Union Memorandum of Cooperation. It is expected that this work will continue over the next two years with a fully updated benchmark report completed in 2016. In that time, the groups have agreed to focus on KPIs that address optimal traffic flow management and improve upon the trajectory indicators by developing KPIs for vertical inefficiency and the departure phase of flight.

1 INTRODUCTION

1.1 Background and objectives

The EUROCONTROL Performance Review Commission (PRC) and the US Air Traffic Organization[1] (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 through 2008 was completed in 2009 [Ref.1]. Subsequent benchmark reports comparing ATM performance in 2010, and 2012 have since been published [Ref.2].

This report represents the fourth in the series. For the first time however, it is prepared in application of Annex 2 of the Memorandum of Cooperation NAT-I-9406 signed between the United States of America and the European Union. Building on the well-established and commonly accepted elements of the previous studies, it now adds the dimension of the EU performance scheme set up and implemented since 2012 as a keystone of the Single European Sky initiative.

This document is therefore a joint publication of the Air Traffic Organization System Operations Services of the FAA and EUROCONTROL on behalf of the European Union in the interest of the exchange of information.

The goal of these studies is to understand differences between the two ATM systems in order to further optimise ATM performance and to identify best practices for the benefit of the overall air transport system.

The studies are 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 EUROCONTROL with a focus on comparability of indicators that identify areas where performance differs between Europe and the US. The consistent use of these indicators also allows both groups to track how performance has changed over time.

The report quantifies ATM performance in the form of Key Performance Indicators (KPIs) as well as the effect of external factors such as traffic levels and weather. The latter are referred to as related indicators and can be used to help explain trends in the more fundamental KPIs. The report also includes a qualitative comparison of the two ATM systems in which a single ANSP provider (FAA) is compared to a system that must coordinate among 37 different ANSPs over a similar geographic area.

Where possible, performance indicators were improved in order to consider new data flows and input received over the last two years. This report for example adds a new KPI related to the filed flight plan which is part of the EU performance scheme. The framework applied in this report will continue to be refined as more advanced methodologies are being developed and

1 The US 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.

initiatives are underway to better consider external factors that could influence ATM performance (i.e. differences in weather conditions, airline schedules, aerodrome capacity, etc.).

Historically, both groups have produced other benchmark comparisons including a 2003 report which compared economic performance (productivity and cost effectiveness) in selected US and European en route centers [Ref. 3]. This study measured economic performance in a homogenous way and identified systemic differences which would explain the significant higher level of unit costs observed in Europe. The methodology applied for the economic comparison at that time has been adopted by the International Civil Aviation Organization (ICAO) in the ICAO Manual on Air Navigation Economics [Ref. 4]. In 2013, FAA and EUROCONTROL collaborated on an assessment of cost-effectiveness indicators [Ref. 5] that examined cost trends using the EUROCONTROL ATM cost-effectiveness (ACE) [Ref. 6] and CANSO[2] reporting definitions [Ref. 7].

Since the 2009 report, there have been several publications that have referenced the original work. CANSO has made use of the phase-of-flight efficiency assessments for several guidance documents on methods for calculating environmental indicators [Ref.8]. In 2012, Airservices Australia [Ref.9] produced a comparable "Analysis of Australian ATM-Related Operational Performance" which utilised the EU and US work while extending it to other phases of flight. The Airservices work continues to advance performance assessment by linking observed performance to both changing demand and technology improvements in ATM.

The work from the joint US/ Europe comparison reports was introduced to ICAO at the Air Navigation Conference (AN-Conf/12) in November 2012. FAA and the European Commission, assisted by EUROCONTROL, are prepared to support ICAO efforts to update its guidance on performance measurement using the demonstrated implementation of common indicators utilised in these benchmarking studies.

1.2 European and FAA Performance Reporting

Both FAA and European ANSPs operate with their own reporting requirements. Some KPIs such as ATM attributable delay are common to both groups using calculations and underlying databases that are nearly identical. 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 Capacity Efficiency for official targets.

However, there is wide commonality in the underlying databases used which makes common KPIs possible for both groups. And where other indicators, such as additional time in the taxi-out phase do not have a status in terms of targets for official reporting, they are widely used at other levels including the cost-benefit analysis performed as part of program acquisition. The remainder of this section provides additional insight into the key performance reporting that is undertaken by both groups.

SINGLE EUROPEAN SKY PERFORMANCE SCHEME

A number of performance indicators in this report are used for target setting or monitoring purposes within the Single European Sky (SES) performance scheme [Ref.10, 11]. In the first reference period (RP1) from 2012-2014, EU-wide targets were set on cost-efficiency (not in the scope of this report), en route delay per flight, and horizontal flight efficiency [Ref.12].

[2] The Civil Air Navigation Services Organization.

The Performance Scheme (PS) is one of the key pillars of the Single European Sky (SES) aiming at achieving the objectives of the SES as detailed in Article 1 of the SES Framework Regulation (EC 549/2004):

1. to enhance current air traffic safety standards;
2. to contribute to the sustainable development of the air transport system; and,
3. to improve the overall performance of ATM and ANS for General Air Traffic (GAT) in Europe, with a view to meeting the requirements of all airspace users.

By setting EU-wide and local targets, as well as performance monitoring and corrective actions, the SES PS aims at driving performance improvements in European aviation - initially in the fields of safety, capacity, the environment and cost efficiency.

The PS is organised around fixed Reference Periods (RPs) for which performance targets are set both at EU-wide level and National/FAB level. These targets are legally binding for EU Member States and designed to encourage air navigation service providers (ANSPs) to be more efficient and responsive to traffic demand, while ensuring adequate safety levels.

The first reference period (RP1) runs for three years from 2012 to 2014. The 2nd reference period (RP2) will be from 2015-2019. EU-wide targets were also set recently for the second reference period [Ref.13]. They are not in the scope of this report.

FAA PERFORMANCE REPORTING

FAA formally reports Operational Performance under several frameworks. These cover management processes that incentivize pay-for-performance, indicators that support tactical management of the system, indicators reported to external stakeholders as well as indicators required by U.S. Congress.

The largest share of FAA pay-for-performance indicators are directly related to safety with many others related to successful program implementation. There are three operational indicators that track ATM efficiency including 1) capacity, 2) NAS attributable delay in terms of on-time performance and 3) operational availability which is an indicator of how equipment used to operate the system is maintained.

In addition, FAA/ATO management tracks capacity efficiency which is an indicator of how effective the system performs in accommodating demand given the capacity of the airport. The trajectories used in this calculation are further assessed for flight track efficiency using the indicators later reported in this report for terminal arrival efficiency. Recently, ATO has begun tracking indicators that track efficiency against the flight plan. This is related to a similar indicator in the EU performance scheme and is a new addition to joint EU/FAA benchmarking.

In 2013, FAA began reporting indicators to external stakeholders as part of its agency metrics harmonization. These include time in level flight as well as 4 indicators for the surface phase of flight. For this benchmarking report, the surface indicators are reported in the form of efficiency against a benchmark time using a KPI that has been harmonized with EUROCONTROL.

1.3 Harmonized 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 and are developed using the best available data from both the FAA-ATO and the PRU.

Key Performance Areas (KPAs) and Key Performance indicators (KPIs)

In its Manual on Global Performance of the Air Navigation System [Ref. 14], 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.

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 below summarizes the harmonized KPIs that are associated with the ICAO KPAs that are analysed for Europe and the US in this report. Many of these indicators are linked. For example the ability to manage demand against consistent capacity will result in improved flight efficiency. All flight efficiency indicators have a degree of variability and it is this indicator that is reported as the KPI for Predictability.

Table 1-1: US/Europe Harmonized Key Performance Indicators

Key Performance Area	Key Performance Indicator
Capacity	Declared Capacity
	Maximum Throughput
Efficiency	Airline Reported Delay Against Schedule
	Airline Reported Attributable Delay
	ATM Reported Attributable Delay
	Taxi-Out Additional Time
	Horizontal en route flight efficiency (flight plan and actual trajectory)
	Descent/Arrival Phase Additional Time
	Taxi-In Additional Time
Predictability	Airline Reported Punctuality
	Capacity Variability
	Phase of Flight Time Variability

In addition to the KPIs listed in Table 1-1, this report also provides a series of Related Indicators that help explain why a KPI improved or became worse over time. These related indicators do not fit the standard ICAO KPI 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: US/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
	Seat capacity on sched. flights
Weather	Operations by Met Condition
	Delay by Met Condition
System Characteristics	System size & structure

1.4 Data sources

The report examines several operational key performance indicators derived from comparable databases for both EUROCONTROL and the Federal Aviation Administration (FAA). There are five primary data sources for the analysis of ATM performance. These include 1) trajectory position data 2) databases that record ATFM imposed delay, 3) Key event times from airlines for reporting carriers, 4) METAR information for weather and 5) airline schedule data.

Data from air traffic management systems

Both US 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 US, flight position 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. This source provides the total IFR traffic picture and is 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 radar track sample points from actual flight trajectories. They also have built-in capabilities for tracking ATM-related ground delays by airport and en route reference location.

The data set also provides flight trajectories which are used for the calculation of flight efficiency in terms of planned routes and actual flown routing. The data set which includes data in the en route transitional phase and in the terminal areas allows for performance comparison throughout various phases of flight.

For the US, one minute updated radar data was used for flight efficiency calculations. For Europe, the quality of the surveillance data provided to the central ETFMS system of EUROCONTROL varied from one position per three minutes to several positions per minute. It is planned to improve the provision of surveillance data to the central ETFMS system to achieve an update rate of 30 seconds. Better data quality will improve the accuracy of the analysis and will facilitate the detection of areas for improvement for the benefit of the European network.

In the US, ATM delay by Causal Factor is recorded in the FAA OPSNET database. FAA requires facilities to report all delay greater than 15 minutes. In Europe, when an ATFM regulation is activated, the Computer Assisted Slot Allocation (CASA) system – a function within ETFMS – centrally extracts the planned flights that will enter the constraint airspace and allocates an Estimated Take-Off Time (ETOT) for each flight at the departure airport. The ATFM delay analysed in this report is the duration between the last take-off time requested by the aircraft operator and the take-off slot allocated by CASA following an ATFM regulation communicated by the Flow Management Position (FMP), in relation to an airport (airport delay) or sector (en route delay) location.

DATA FROM AIRLINES

The US 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.

In the US, most performance indicators are derived from the Aviation System Performance Metrics (ASPM) database which fuses detailed airline data with data from the traffic flow system. ASPM coverage in 2013 is approximately 94% of the IFR traffic at the main 34 airports with 87% of the total IFR traffic reported as scheduled operations.

Air carriers are required to report performance data if they have at least 1% of total domestic scheduled-service passenger revenues. In addition there are other carriers that report voluntarily. Airline reported performance data for scheduled flights at the main 34 airports represent only 68% of all IFR flights at these airports. The air carrier reported data cover non-stop scheduled-service flights between points within the United States (including territories). Data include what is referred to as OOOI (Out of the gate, On the runway, Off the runway, and Into the gate). OOOI data along with airline schedules allow for the calculation of gate delay, taxi times, en route times, and gate arrival time delay on a flight by flight basis. The US data contains cause codes for arrival delays over 15 minutes on a flight-by-flight basis. Delay cause categories include ATM system, Security, Airline, Extreme Weather, and Late Arrival (from previous leg).

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 year[3] within the European Union airspace are required to submit the data on a monthly basis according to Regulation (EU) No 691/2010 [Ref. 10]

In 2013, the CODA coverage was approximately 63% of total scheduled IFR flights and approximately 76% of flights at the 34 main airports. The data reported are similar to the US and include OOOI data, schedule information and causes of delay, according to the IATA delay codes. However the European data provides greater coverage (76% vs 68%) for the 34 main airports.

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

ADDITIONAL DATA ON CONDITIONS

Post-operational analyses have focused on causes of delay and a better understanding of real constraints. Additional data is needed for airport capacities, runway configurations, sector capacities, winds, visibility, and convective weather.

---

[3] Calculated as the average over the previous three years.

Both the US and Europe performance groups use detailed weather information known as METAR data. This data is highly standardised and provides information on ceiling, visibility, as well as a host of other meteorological information. The FAA-ATO is collecting this data at major airports and uses commercially available data to assess convective weather impacts at a high level.

Weather events such as high winds, freezing conditions, and low ceiling and visibility have a noticeable impact on aviation performance. This report provides an initial look at weather events and both organisations look to improve the quantification of meteorological conditions on overall system efficiency.

1.5 Report Scope

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 States plus those States outside the EU that are members of EUROCONTROL[4], excluding Oceanic areas, Georgia and the Canary Islands.

Unless otherwise indicated, "US" 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 (US CONUS).

Figure 1.1 shows the geographical scope with the US CONUS sub-divided into 20 Air Route Traffic Control Centers (ARTCCs) and the European area subdivided into 63 en route centres[5].

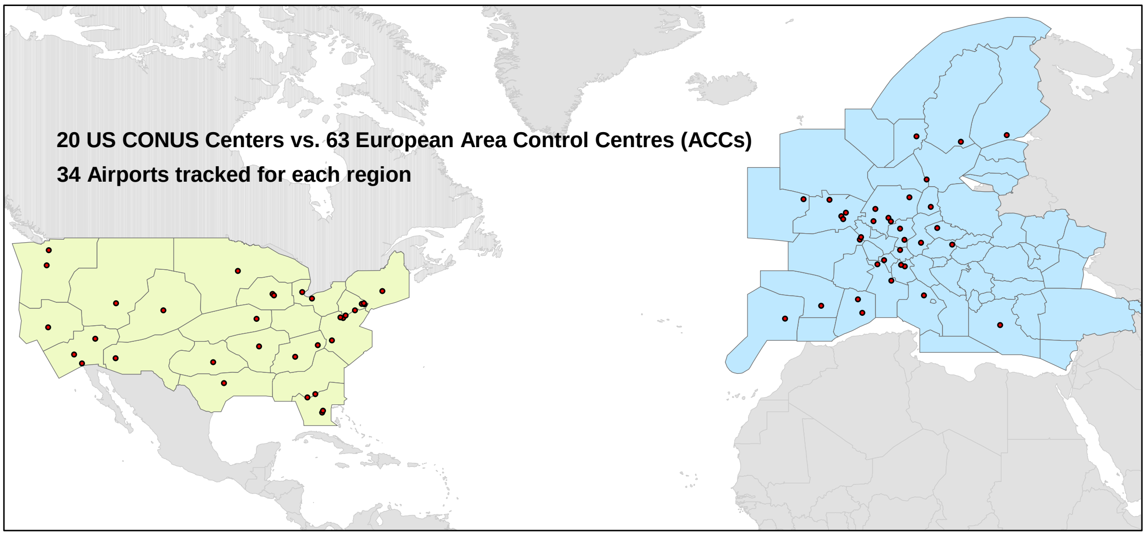


Figure 1.1: Geographical scope of the comparison in the report

Also depicted are the 34 main airports used for more detailed performance tracking. For the US, many of these high volume airports are located on the coasts or edges of the study region which creates a greater percentage of longer haul flights in the US, especially when only flights within the study region are considered. The fidelity of airborne trajectory performance indicators on these transcontinental flights may be affected by the influences of wind and adverse weather.

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

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

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. Therefore - unless stated otherwise - the detailed analyses of ATM-related operational performance by phase of flight in Chapter 5 are limited to flights to or from the main 34 airports for IFR traffic in both the US and in Europe. A detailed list of the airports included in this report can be found in Annex I.

TEMPORAL SCOPE

The operational analyses in this report were carried out for the calendar year 2013 and, where applicable, comparisons to previous years were made to track changes over time.

1.6 Organisation of this report

The report is organised in five 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 related 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 operational service quality as it relates to the airline schedule and the amount of delay attributable to the airlines.
- Chapter 5 provides a detailed comparison of the ATM-related KPIs focusing on ATFM delay and the efficiency of actual operations by phase of flight.
- Chapter 6 concludes with a summary of findings before Chapter 7 highlights areas for further analysis and potential improvements in data and methods for ATM performance assessment.

2 COMPARISON OF AIR TRAFFIC MANAGEMENT (ATM) IN THE US AND EUROPE

Broadly speaking, air traffic management (ATM) consists of Air Traffic Control (ATC), Airspace Management (ASM) and Air Traffic Flow Management (ATFM). Whereas ATC is more concerned with ensuring the safe separation between aircraft[6], the role of ATFM is to ensure safety by preventing overloads, and regulating demand according to available capacity. ATFM covers a longer time horizon (up to days before the day of operations).

This section provides essential background information on both the US and European ATM system that may be used to explain differences in the core KPIs. This section starts with the differences in the air traffic management in terms of physical geographic airspace, technology, and equipment. The roles and responsibilities that the respective ANSP takes in airspace management are also discussed. Finally, the section concludes with an overview of air traffic flow management techniques that are employed in different scenarios and stages of planning to manage capacity to demand imbalances in the two regions.

2.1 Organisation of ATM

While the US and the European system are operated with similar technology and operational concepts, there is a key difference. The US 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 is provided centrally by the Network Manager, the European system is much more fragmented and ANSPs are still largely organised by State boundaries.

Figure 2.1 shows the diversity of flight data processing (FDP) suppliers in use in Europe [Ref. 6].

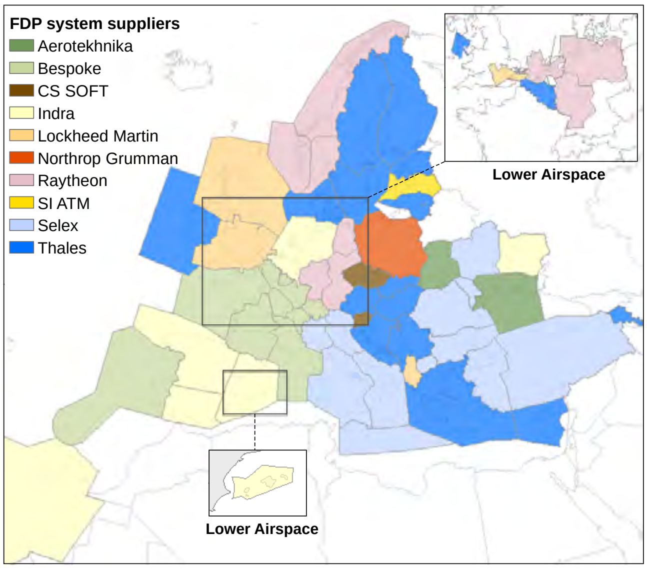


Figure 2.1: Flight data processing (FDP) systems supplier in Europe (2011)

In total, there are 37 different en route ANSPs of various geographical areas, each operating different systems under slightly different sets of rules and procedures. This makes it more difficult to implement effective inter-centre flow management or arrival management across national boundaries (e.g. sequencing traffic into major airports of other States) and may also affect the level of coordination in ATFM and ATC capacity.

Quite a number of adjacent ANSPs operate different FDP systems which can contribute to additional ATCO workload associated with the interface between the different systems with a possible negative impact on efficiency levels and costs.

---

6 According to ICAO Annex 11, ATC is a service provided for the purpose of (1) preventing collisions (a) between aircraft, and (b) on the manoeuvring area between aircraft and obstructions and (2) expediting and maintaining an orderly flow of air traffic.

2.2 Airspace management (ASM)

The controlled airspace is made up of a complex network of routes, waypoints, sectors and ATC units. Different from the US where the Federal Aviation Administration (FAA) is responsible for airspace management and route design, in the amalgamated European ATM system, airspace design remains the prerogative of the individual States.

2.2.1 Route networks

However, the design of airspace and related procedures are not carried out or implemented in isolation in Europe. Inefficiencies in the design and use of the air route network are considered to be a major causal factor of flight inefficiencies in Europe (see also Section 5.2.3) and a number of initiatives, coordinated by EUROCONTROL, aim at improving the design and use of the European route network.

For those States subject to Single European Sky legislation, the European Commission Regulation for ATM Network Functions [Ref. 15] requires the Network Manager to produce a European Route Network Improvement Plan as part of the Network Operations Plan to:

- ensure appropriate airspace design and utilisation developments to meet the European capacity and environment targets;
- develop and maintain a medium and a long term view of the evolution of the airspace structure and utilisation; and,
- ensure coordinated deployment of airspace design and utilisation improvement packages.

As already pointed out, the individual European States remain responsible for the detailed development, approval and establishment of the airspace structures for the airspace under their responsibility. Hence, the development of the European Route Network Improvement Plan relies on fully cooperative decision-making processes.

2.2.2 Special use airspace

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 whilst 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 meet the increasing needs of both sets of stakeholders, in terms of volume and time, close civil/military co-operation and co-ordination across all ATM-related activities is key.

Here also the situation is fundamentally different between the US and Europe. Different from the US, the individual States forming the European ATM system have all their individual military needs and requirements which need to be accommodated and which can make ATC operations and airspace management (ASM) more difficult.

The comparison of Special Use Airspace (SUA)[7] between the US and Europe (in Europe, SUA is mostly referred to as segregated airspace) in Figure 2.2 illustrates a significant difference in the

[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.

number and location of the special use airspace within the respective ATM systems[8].

Europe shows a larger number of Special Use Airspace (SUA). In order to meet the military requirements of the individual States, quite a number of SUA is located directly in the core area of Europe whereas in the US, SUA tends to be more located along the coastlines.

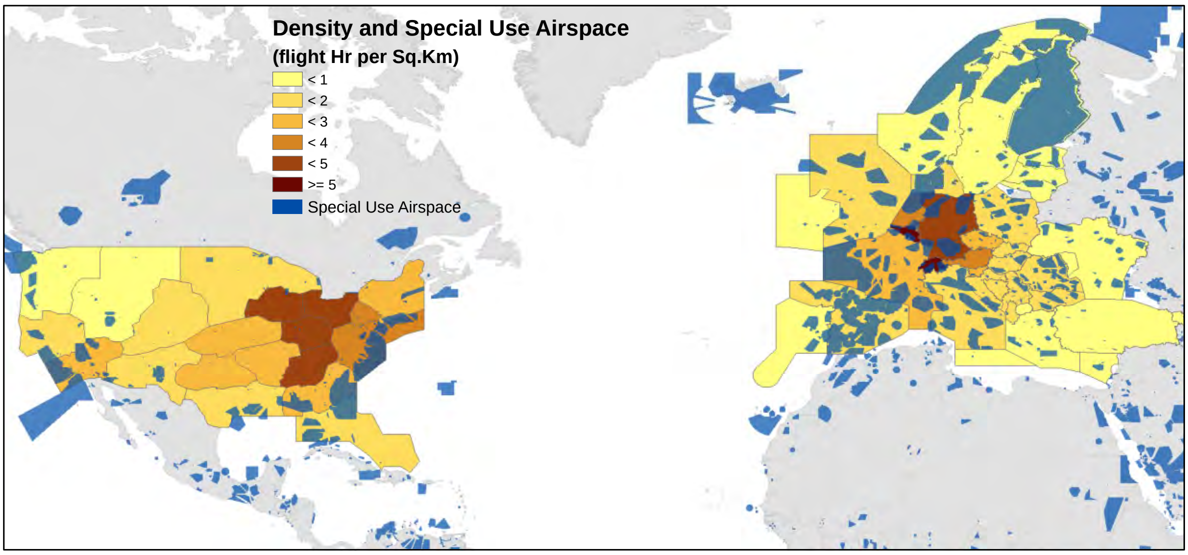


Figure 2.2: Comparison of Special Use Airspace (SUA)

A further difference between the US and Europe with potential implications for ATM performance is the organisation of the civil/military cooperation. In the US, the FAA headquarters is the final approval authority for all permanent and temporary SUA[9] and operations are organised according to a common set of rules.

In Europe, civil/military cooperation arrangements may differ across States [Ref. 16].

Since 1996, EUROCONTROL States have been applying the FUA concept to meet the requirements of both civil and military airspace users, and this was formalised as part of SES legislation, applicable to the EU member States, in EU Regulation 2150/2005 [Ref. 17].

The Flexible Use of Airspace (FUA) Concept

With the application of the Flexible Use of Airspace Concept (FUA), airspace is no longer designated as "civil" or "military" airspace, but considered as one continuum and allocated according to user requirements.

The implementation of the FUA concept is applicable at three separate, but dependent levels: Level 1, at strategic level within the State/ FAB; Level 2, at pre-tactical level; and Level 3, at tactical level.

More detailed comparison on the utilisation and coordination of SUA will improve the understanding of the impact of ATM civil/military arrangements on ATM performance in Europe and the US. A potential indicator for comparison between the US and Europe would be the share of flights that would enter shared civil/military airspace if great circle or more direct routes were used.

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

9 FAA Order JO 7400.2J – Part 5 Chapter 21, http://www.faa.gov/air_traffic/publications/atpubs/AIR/air2101.html

2.3 Air traffic flow management (ATFM)

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

ATFM procedures are typically applied when a mismatch between demand and en route or airport capacity is anticipated. The ATFM measures encompass a wide range of techniques aimed at resolving a mismatch between capacity and demand which may originate from temporary excess demand or reduced capacity, as illustrated in Figure 2.3. Typical reasons for capacity reductions are directional winds, severe weather conditions, staffing issues, or equipment failure.

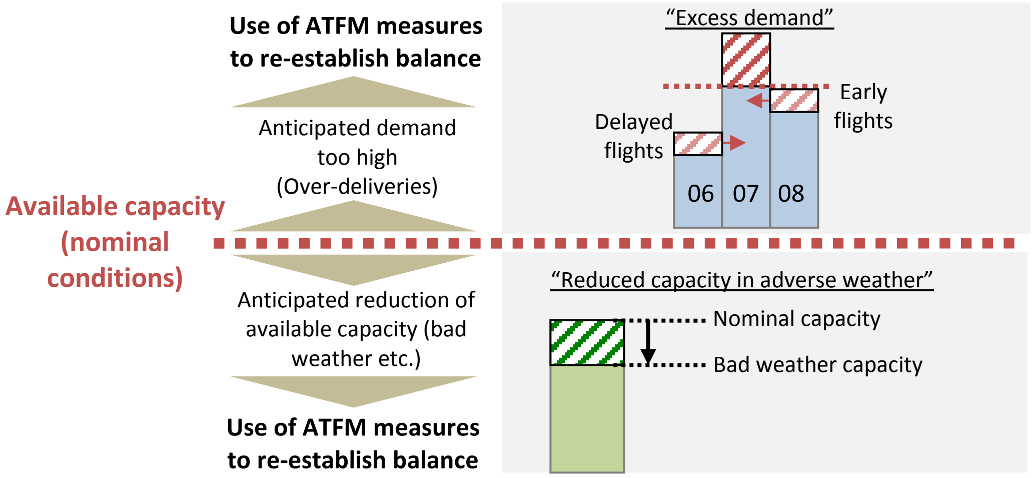


Figure 2.3: Imbalance between demand and capacity

When a mismatch between demand and capacity is anticipated, some decisions have to be taken in order to maintain safe and orderly operations. The actions taken (strategic vs. tactical) and the ATFM measures applied depend on (1) the time the imbalance is known before it is envisaged to take place, (2) the severity of the capacity shortfall, and (3) the level of uncertainty (accuracy of weather or traffic forecast) associated with the anticipated imbalance. In fact, the accuracy of the *forecast* of these events is as crucial as the duration and frequency of these events.

The key issue is the length of time that elapses between the time a decision is taken and the time when the indicator is implemented. Different ATFM strategies or processes are based on a particular situation. As events evolve, from forecast to actual, different flow measures are applied, as appropriate.

Broadly speaking, capacity can be balanced with demand by (1) restricting the level of demand already in the strategic phase (before the operation takes place) and (2) by applying tactical air traffic flow and capacity management (ATFCM) measures on the day of operations.

The European and the US ATM systems differ notably in the timing (when) and the phase of flight (where) ATFM measures are applied. In Europe, a lot of emphasis is put on strategic planning with airport demand measures being applied already months in advance through strategic agreements on airport capacities and airport slots.

In the US, the emphasis is on the tactical traffic management in the gate to gate phase in order to maximise system and airport throughput under prevailing conditions on the day of operations. Very few airports in the US have schedule limitations.

2.3.1 ATFM Facility organization

Both the US and Europe have established system-wide, centralised traffic management facilities to ensure that traffic flows do not exceed what can be safely handled by ATC units, while trying to optimise the use of available capacity. Table 2-1 provides an overview of the key players involved and the most common ATFM techniques applied [Ref.18].

Table 2-1: Organisation of ATFM (Overview)

	Flight phase	Local ATC units	US	Europe	ATFM measures	Network (ATFM) US	Network (ATFM) Europe
Strategic	Origin Airport				Airport scheduling (departure slot)		
Tactical	Taxi-out	Ground control	*Airports with ATC services: 514*	*Airports with ATC services: 425*	Dep. restrictions (ground holding)	Air traffic Control System Command Center (ATCSCC) located in Warrenton, Virginia.	Eurocontrol Network Operations Centre (NOC), located in Brussels, Belgium (formerly - CFMU)..
	Take-off	Tower control					
	En route	En route Area Control	*Air Route Traffic Control Center (ARTCC): 20 US CONUS*	*Area Control Centre (ACC): 63*	Routing, sequencing, speed control, holding		
	Approach	Terminal control	*Terminal Radar Approach Control (TRACONs): 163*	*Approach control units (APPs): 260*	Airborne holding (circular, linear), vectoring		
	Landing	Tower					
	Taxi-in	Ground					
Strategic	Destination Airport				Airport scheduling (Arrival slot)		

Overall, it can be noted that the European ATM system is an amalgamation of a large number of individual ANSPs whereas the US system is operated by a single ANSP. There are 20 Air Route Traffic Control Centres (ARTCC) in the US CONUS compared to 63 ACCs in Europe. Figure 2.4 below depicts the size of the 20 US ARTCCs compared to the 20 largest ACCs in Europe.

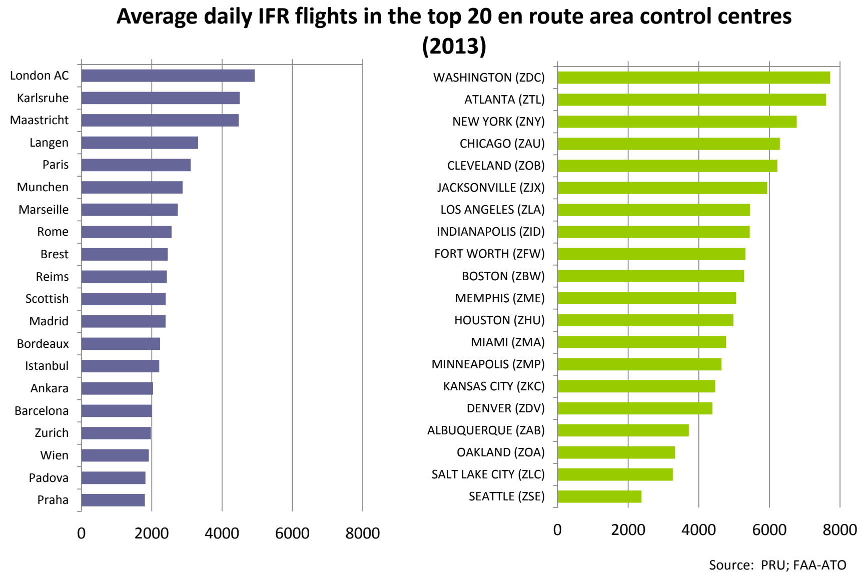


Figure 2.4: Comparison of en route area control centres

A key difference between the two systems is the role of the network ATFM function. The fact that the ATM system in the US is operated by a single provider puts the Air Traffic Control Command Centre (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 US. Terminal Radar Approach Control (TRACON) units work through the overlying ARTCC which coordinate directly with the central Air Traffic Control System Command Centre (ATCSCC) in Virginia. The ATCSCC has final approval authority for all national traffic management initiatives in the US and is also responsible for resolving inter-facility issues.

In Europe, the Network Operations Centre (NOC) in Brussels monitors the traffic situation and proposes flow measures but the final approval remains 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 NOC to implement flow measures.

Over the past years, the role of the network function in Europe was strengthened by the Single European Sky (SES) II legislation. This evolution foresees a more proactive role in Air Traffic Flow Management, ATC capacity enhancement, route development and the support to the deployment of technological improvements across the ATM network for the European Network Manager.

Whereas the decisions on the implementation of flow management measures are usually taken by ATM units, there has been a paradigm change on both sides of the Atlantic to more and more involve airlines and airports in the decision making. The development of collaborative decision making (CDM) allows all members of the ATM community to participate in ATM decisions affecting them.

2.3.2 Airport Scheduling (Strategic phase)

The two ATM systems differ in terms of scheduling of operations at airports. In Europe, there is a stronger emphasis on strategic planning. Traffic at major airports is usually regulated (in terms of volume and concentration) in the strategic phase through the airport capacity declaration process, and the subsequent allocation of airport landing and departure slots to aircraft operators months before the actual day of operation.

Airports are usually designated as ‘coordinated’ when the airport capacity is insufficient to fulfil airlines’ demand during peak hours. The subsequent airport scheduling process aims at matching airline demand with airport capacity several months before the actual day of operations to avoid frequent and significant excess of demand on the day of operations. This is the case for 31 of the 34 European airports analysed in this report which are coordinated (IATA Level 3) [10].

The declared airport capacity[11] takes account of airport infrastructure limitations and environmental constraints and is decided by the coordination committee[12] and/or by the respective States themselves. It represents an agreed compromise between the maximisation of airport infrastructure utilisation and the quality of service considered as locally acceptable. This

---

10 Full definitions of airport scheduling status can be found in the latest edition of the IATA World Scheduling Guidelines.

11 The airport capacity declaration is a local process and can vary by airport. There is no harmonised method to declare an airport’s capacity in Europe.

12 The responsibility to set up a coordination committee lies with the respective State.

trade-off is usually agreed between the airport managing body, the airlines, and the local ATC provider during the airport capacity declaration process. The so called "coordination parameters" can vary by time of day and for arrivals and departures.

Depending on the economic value of the airport slot for aircraft operators, at some airports a higher level of "planned" delay is accepted by airlines as a trade to get access to the airport. For instance, the current agreed average stack holding time at London Heathrow airport is set at ten minutes through an agreement between the airlines, airports and NATS (service provider).

In the US, airline scheduling is unrestricted at most airports. Demand levels are self-controlled by airlines and adapted depending on the expected cost of delays and the expected value of operating additional flights. Increased delays can lead to both changes in block times as well as number of operations scheduled. The operations are based on real time capacity forecasts provided by local ATC. The airport capacity is determined by taking the runways in use, weather conditions, staffing, and navigational aid (NAVAID) limitations into consideration.

The few schedule constrained airports in the US are typically served by a wide range of (international) carriers and are located in high density areas in the US core airspace. In the US, schedule constraints exist only at New York LaGuardia (LGA), New York (JFK), Newark (EWR), and Washington National (DCA).

The European airport capacity declaration process requires a strategic trade-off between the locally acceptable service level and the utilisation of scarce airport capacity six months before the day of operations. However, airport capacity on the day of operations can vary quite significantly as it is influenced by a number of factors which are difficult to predict months in advance. Hence, a declared airport capacity close to Instrument Meteorological Conditions (IMC) can support overall stability of operations but there is a risk that resources might be underutilised for considerable periods.

With more emphasis on the tactical phase, the US system seems to be geared towards maximising airport throughput according to the available capacity on the day of operations. The approach is supported by the en route function and the ATFM flexibility discussed in the next section.

The more dynamic approach in the US helps to maximise the use of scarce runway capacity on the day of operations and provides more flexibility to airlines. However, it is more susceptible to service disruptions (such as weather) which potentially result in major delays and cancellations when there is a mismatch between scheduled demand and available capacity at airports.

2.3.3 Traffic flow management initiatives (Tactical Phase)

The following sections provide a brief overview on the main ATFM measures applied in the US and Europe. For the US, there are a variety of measures that seek to avoid ground holding. The NAS playbook offers a set of pre-validated routes for a variety of weather scenarios to re-route aircraft around affected areas. The validated scenarios have been developed over years and applied successfully for the overall benefit of the entire system. During periods of convective activity or significant system constraints, local ATC units are called upon to accept traffic that is not normally routed through their area. Hence, capacity constrained en route sectors can often be bypassed by selecting an alternative route. However, convective weather in the summer is quite severe and widespread in the US and may require ground holds and continent wide re-routing of entire traffic flows.

Departure restrictions (ground holding)

Aircraft that are expected during a period of capacity shortfall en route or at the destination airport are held on the ground at their various origin airports. Flights are assigned take-off times which in turn regulate their arrival time at the impacted airspace or airport. Ground holdings are implemented to ensure the arrival demand stays at a manageable level to avoid extensive holding and to prevent aircraft from having to divert to other airports. A sophisticated system usually assigns "ATFM slots" to aircraft based on the available capacity and flight arrival times and adds delay in sequential order until demand equals capacity. Each flight needs to plan to taxi in a manner consistent with meeting the allocated ATFM slot. Most of these delays are taken at the gate but some occur also during the taxi phase.

In the US, ground holding is usually implemented through a ground delay program (GDP) which is put into effect for cases when demand exceeds capacity for a sustained period of time. In the US it is mostly used in the airport context when capacity has been reduced because of weather such as low ceilings, thunderstorms or wind, and other ATFM measures are not considered to be sufficient. The Air Traffic Control System Command Centre (ATCSCC) applies Estimated Departure Clearance Times (EDCT) to delay flights prior to departure. Aircraft must depart within +/- 5 minutes of their EDCT to be in compliance with the GDP. The GDP incorporates flexibility for the airlines. Specifically, in order to meet their schedule objectives, airlines may substitute/swap their allotted position at the destination airport with another aircraft thus modifying their current EDCT at the source airport. EDCT times are based on the scheduled arrival at the constrained airport and their estimated airborne flight time. A ground stop (GS) is a more extreme form of ground holding whereby all departures bound for a constrained airport are temporarily postponed. Similar to a GDP, aircraft can be delayed on the ground with EDCTs due to capacity limitations in the airspace. This most likely occurs due to thunderstorms/convective weather and can be very specific to the direction of flight. These programs are called Airspace Flow Programs (AFP) and are more practical than running multiple GDPs when a large geographical area is affected.

In addition to EDCT/GS initiatives, the FAA has instituted a Traffic Management Initiative (TMI) called the Severe Weather Avoidance Program or SWAP which is largely utilized with ATFM delay charged to New York Center (ZNY) [Ref.19]. It is a specialized program for a coordinated response to when multiple convective cells or clusters of thunderstorms force a closure of jet routes that service traffic into the most congested airspace in the US. One key element to the success of this program is the ability to forecast thunderstorm activity so that both airlines and FAA can minimize impact [Ref.20]. While previous versions of this report only considered EDCT/GS delay, this version includes all TMI initiatives with the most prominent addition being the SWAP events. Note that EDCT/GS delay comprises 80% of all reported TMI delay.

In Europe, ground holding is also commonly used to avoid the overloading of en route sectors and airports. When traffic demand is anticipated to exceed the available capacity in en route sectors or at airports, local ATC units may call for "ATFM regulations." Aircraft subject to ATFM regulations are regulated at the departure airport according to "ATFM slots" allocated by the Eurocontrol Network Operations Centre (NOC) in Brussels. The ATFM delay of a given flight is attributed to the most constraining ATC unit, either en route (en route ATFM delay) or airport (airport ATFM delay). Different from the US, the departure window is wider in Europe and ATFM regulated aircraft must depart within -5/+10 minutes of their assigned ATFM slot to be in compliance.

Differences in ATM can be seen in the way ATFM delay is charged to ANSP facilities. Figure 2.5 below shows that as a percentage of total ATFM delay, the en route facilities in Europe report a higher number of constraints (mainly due to volume or capacity) than the US. The US on the other hand is much more impacted by airport related ATFM delays (predominantly due to severe weather) and it can be shown that for many of the KPIs, US trends track with severe weather. A more detailed assessment of the differences in ATFM delay by facility and impacting condition can be found in Section 5.2.1. Section 3.3.2 looks at the specific impacting condition of weather on airport charged ATFM delay as weather is considered a primary related factor in explaining changes in operational performance.

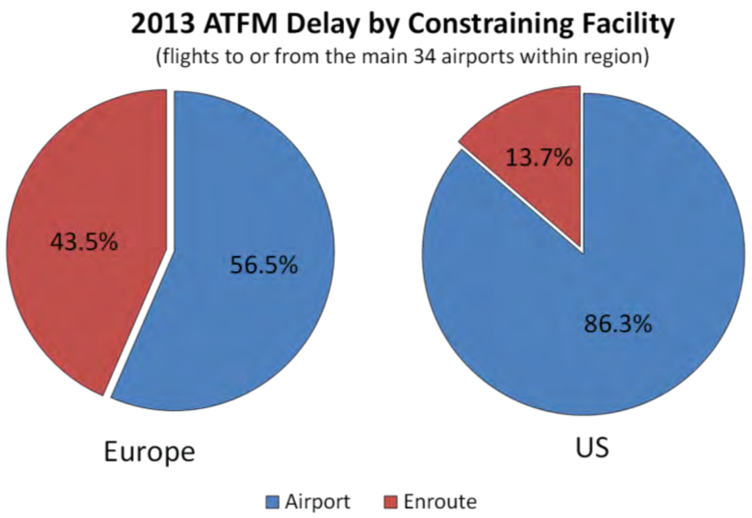


Figure 2.5: Comparison of ATFM delay by constraining facility

The US appears to have less en route capacity restrictions and constraints which enable the US ATM system to absorb a considerable amount of time through speed control and vectoring in en route airspace to achieve the metering required by terminal control units. In general, the regions in the US with the most en route constraints correspond to the most "dense" airspace shown in Figure 3.3.

The difference appears to be linked to the fragmentation of service provision and the number and location of special use airspace in Europe (see Figure 2.2) which limits the level of flexibility to manage traffic flows in the en route airspace.

Although recently there have been local initiatives, due to the fact that ATM is still largely organised by State boundaries in Europe, tactical re-routing through adjacent airspace and spacing of aircraft across national boundaries (e.g. sequencing traffic into major airports of other States) is still very limited in Europe.

Instead, departure restrictions at the various origin airports are used as the primary means of ATFM for handling en route capacity constraints. In the US, the ATM system appears to be more flexible to tactically adjust to capacity and demand variations on the day of operations. Departure restrictions are only used as a last resort when all other ATFM measures are considered to be insufficient (see also Table 5-1 on 66).

EN ROUTE FLOW MANAGEMENT (AIRBORNE)

Sequencing programmes are designed to achieve specified spacing between aircraft using distance (miles) or time (minutes). The most commonly known is called miles in trail (MIT). It describes the number of miles required between aircraft departing an airport, over a fix, at an altitude, through a sector, or on a specific air route. MIT is used to apportion traffic into a manageable flow, as well as to provide space for additional traffic (merging or departing) to enter the flow. When aircraft are in a non-radar environment (i.e. transatlantic flights), the exact intra aircraft distance is difficult to determine and Minutes in Trail are used instead.

MIT restrictions are widely used in the US where the responsibility for maintaining a traffic flow at or below the restricted level can be propagated back upstream, in some cases even leading to restrictions at the departure airport. Hence, ultimately MIT restrictions can also affect aircraft on the ground. If an aircraft is about to take-off from an airport to join a traffic flow on which a MIT restriction is active, the aircraft needs a specific clearance for take-off. The aircraft is only released by ATC when it is possible to enter into the sequenced flow. En route-caused MIT restrictions are small compared to airport driven flow restrictions in the US. The measures have a considerable effect on the workload of ATCOs by optimising the use of the available spacing in terms of MIT and, where necessary, modify up-stream constraints thus contributing significantly to reduce the complexity of the traffic sequences. The US is transitioning away from distance based MIT to time based metering (TBM) due to gained spacing efficiencies. Time based metering allows individual flights to be spaced as needed as compared to spacing all flights with standard distance based miles in trail.

There is currently no or very limited en route spacing or metering in Europe. When sequencing tools and procedures are developed locally, their application traditionally stopped at the State boundary.

Speed control can also be used to adjust transit times. Aircraft are slowed down or sped up in order to adjust the time at which the aircraft arrive in a specific airspace (Required Time of Arrival – RTA concept) or at an airport. The latter uses Cross-Border Arrival management (XMAN), which is currently under development in Europe. Early 2014 trials have started to cut the amount of time aircraft circle in holding stacks at London Heathrow Airport: if delays in the Heathrow holding stacks begin to build, air traffic controllers in the Netherlands, France, Scotland and Ireland will be asked to slow down aircraft up to 350 miles away from London to help minimise delays on arrival [Ref. 21]

Arrival flow management (airborne)

In both the US and the European system, the terminal area around a congested airport is used to absorb delay and ensure that aircraft are available to maximise the use of scarce runway capacity. Traffic management Initiatives (TMIs) generally recognise that maximising the airport throughput is paramount.

With Time Based Metering (TBM) systems in US control facilities, delay absorption in the terminal area is focused on keeping pressure on the runways without overloading the terminal area. Combined with MIT initiatives, delays can be propagated further upstream at more fuel efficient altitudes, if necessary. However, holding is more manageable at lower altitudes where aircraft can hold with a smaller radius to their holding pattern.

Altitude has different effects on the fuel burn, depending on the airframe/engine combination. Generally speaking, the closer the hold altitude to the optimum flight level (FL200 to FL350 depending on aircraft type) the lower the fuel flow. Although varying by aircraft type, there appear to be significant potential savings if the increase in cruise time can be used to reducing the time in holding patterns at lower altitude.

ATM-related inefficiencies per flight phase are analysed in more detail in the comparison of operational performance in Section 5.2.4 of this report.

3 EXTERNAL FACTORS AFFECTING KEY PERFORMANCE INDICATORS

This chapter describes and quantifies the effects of some of the key external factors that affect the primary Key Performance Indicators. These related indicators focus on changing traffic levels, airport capacity, and weather in the US and Europe. In addition to external factors, the way the ATM system is managed with the US having a single provider compared to the European system of disjoint ANSPs can also influence the resulting KPIs. These differences in the ATM system are addressed in more detail in Chapter 2.

3.1 Traffic characteristics in the US and in Europe

This section provides some key air traffic characteristics of the ATM system in the US and in Europe. The purpose is to provide some background information and to ensure comparability of traffic samples. As shown in Table 3-1, the total surface of continental airspace analysed in the report is similar for Europe and the US. However, the US controls approximately 57% more flights operating under Instrumental Flight Rules (IFR) [13] with less Air Traffic Controllers (ATCOs)[14] and fewer en route and terminal facilities.

Table 3-1: US/Europe ATM key system figures at a glance (2013)

Calendar Year 2013	Europe[15]	USA[16]	US vs. Europe
Geographic Area (million km^2)	11.5	10.4	≈ -10%
Nr. of civil en route Air Navigation Service Providers	37	1	
Number of Air Traffic Controllers (ATCOs in Ops.)	17 200	13 400[17]	≈ -22%
Number of OJT/developmental ATCOs	1 000	1 740	≈ +74%
Total ATCOs in OPS plus OJT/developmental	18 200	15 140	≈ -17%
Total staff	58 000	35 500	≈ -39%
Controlled flights (IFR) (million)	9.6	15.1	≈ +57%
Flight hours controlled (million)	14.3	22.4	≈ +57%
Relative density (flight hours per km^2)	1.2	2.2	≈ x1.7
Share of flights to or from top 34 airports	67%	66%	
Share of General Aviation	3.9%	21%	
Average length of flight (within respective airspace)	551 NM	515 NM	≈ -7%
Number of en route centres	63	20	-43
Number of APP units (Europe) and terminal facilities (US)	260	163	-97
Number of airports with ATC services	425	516[18]	+91
Of which are slot controlled	> 90	4 [19]	
Source	EUROCONTROL	FAA/ATO	

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

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

15 EUROCONTROL States plus Estonia, excluding Oceanic areas, Georgia and Canary Islands. European staff numbers and facility count refer to 2011 which is the latest year available.

16 Area, flight hours and centre count refers to CONUS only.

17 This value reflects the CANSO reporting definition of a fully trained ATCO in OPS <u>and includes supervisors</u>. It is different than the total controller count from the FAA controller workforce plan which does not include supervisors. The number of ATCOs in OPS does not include 1375 controllers reported for contract towers.

18 Total of 516 facilities of which 264 are FAA staffed and 252 Federal contract towers.

19 LGA, JFK, EWR, and DCA.

The method of reporting controller counts has changed over the assessment period as both groups learn more about the different classifications and how best to make the comparison. 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 US tends to operate with some 22% less full time ATCOs than Europe in 2013.

For the ATM system, Europe is more fragmented and operates with more physical facilities than the US. The European study region comprises 37 ANSPs (and a similar number of different regulators) and 63 Area Control Centres (ACC). In contrast, the US has one ANSP and 20 Air Route Traffic Control Centres (ARTCC). The US has 163 Terminal Radar Approach Control Facilities (TRACONs) and Combined Facilities servicing a number of airports each, compared to Europe’s 260 Approach control units (APPs). Some TRACONs in the US are so large in terms of size of airspace and service provided that they could be compared to some of the lower airspace ACCs in Europe.

Another notable difference illustrated in Table 3-1 is the low number of airports with schedule or slot limitations in the US compared to Europe, where most of the airports are regulated.

Notwithstanding the large number of airports in the US and Europe, only a relatively small number of airports account for the main share of traffic. The main 34 airports account for 67% and 66% of the controlled flights in Europe and the US, respectively.

3.1.1 AIR TRAFFIC GROWTH

Figure 3.1 depicts the evolution of IFR traffic in the US and in Europe between 1999 and 2013.

There is a notable decoupling in 2004 when the traffic in Europe continued to grow while US traffic started to decline.

Whereas traffic in Europe grew by almost 17% between 1999 and 2013, the traffic in the US declined by 12% during the same period.

The effect of the economic crisis starting in 2008 is clearly visible on both sides of the Atlantic.

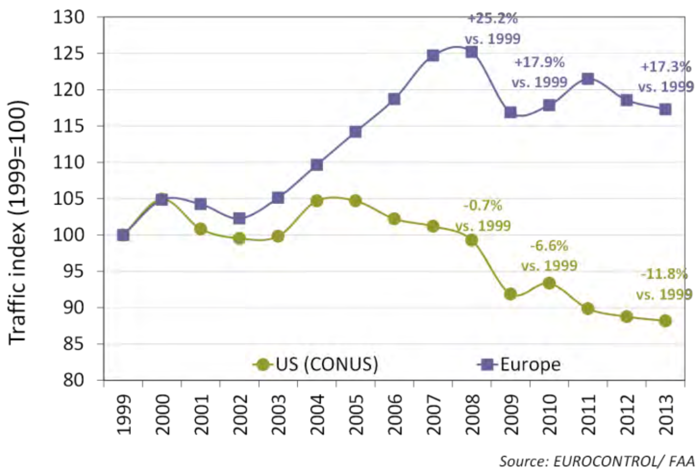


Figure 3.1: Evolution of IFR traffic in the US and in Europe

However, the system level averages mask contrasted growth rates within the US and Europe as illustrated in the map in Figure 3.2.

In Europe, much of the air traffic growth was driven by strong growth in the emerging markets in the East. The highest decrease compared to 2008 levels was observed in Ireland, Spain and the United Kingdom.

The US is a more homogenous and mature market which shows a different behaviour. Compared to 2008, traffic levels in the US declined in all centres, with a strong decline on the entire West coast. The traffic growth at the main airports in the US and Europe is shown in Figure 3.10 and Figure 3.11 on page 38 respectively.

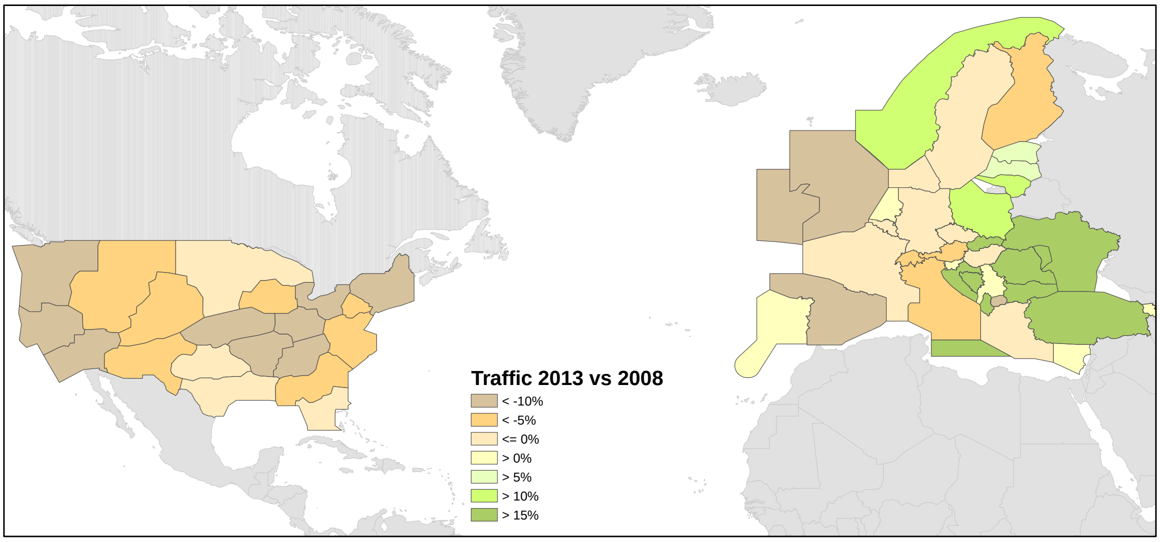


Figure 3.2: Evolution of IFR traffic in the US and in Europe (2013 vs. 2008)

3.1.2 Air Traffic Density

Figure 3.3 shows the traffic density in US and European en route centres measured in annual flight hours per square kilometre for all altitudes in 2013. For Europe, the map is shown at State level because the display by en route centre would hide the centres in lower airspace.

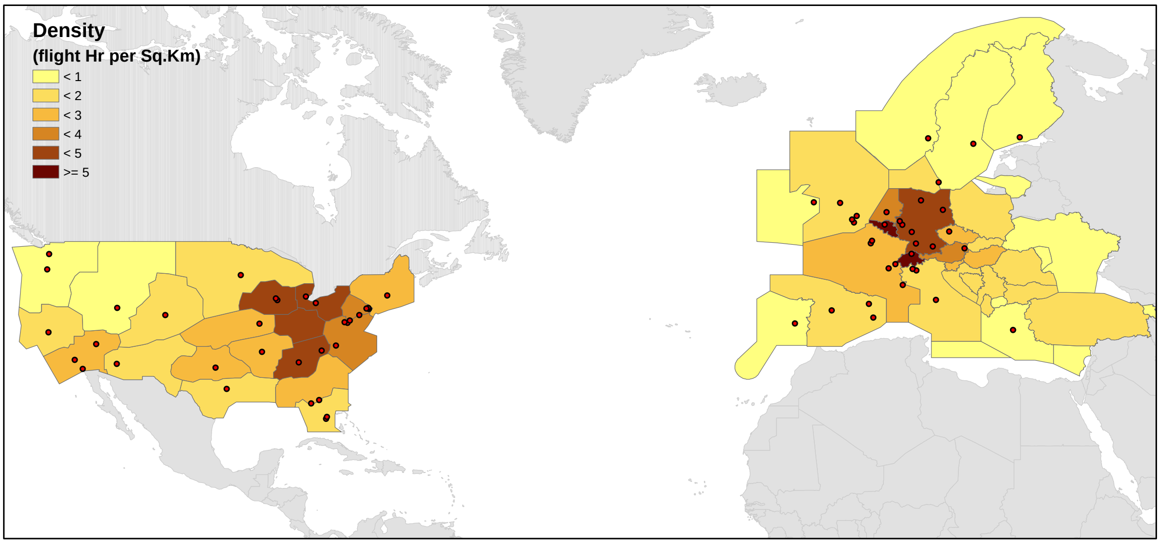


Figure 3.3: Traffic density in US and European en route centres (2013)

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

Similarly in the US, the centrally located centres 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 centre with the highest density in the US.

3.1.3 AVERAGE FLIGHT LENGTH

Table 3-2 provides a more detailed breakdown of IFR traffic for the US and Europe in 2013. 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.

By far the largest share of total IFR traffic in both systems is due to traffic within the respective region. In the US this share is 84.5% which is notably higher than in Europe with 78.1%. Consequently the share of flights to or originating from outside the respective region is higher in Europe.

Table 3-2: Breakdown of IFR traffic (2013)

ALL IFR TRAFFIC	EUROPE (2013)			US CONUS (2013)		
	N	% of total	Avg. dist. (NM)	N	% of total	Avg. dist. (NM)
Within region	7.5 M	78.1%	471 NM	12.7 M	84.5%	515 NM
To/from outside region	1.9 M	19.8%	895 NM	2.0 M	13.5%	514 NM
Overflights	0.2 M	2.0%	628 NM	0.3 M	2.0%	499 NM
Total IFR traffic	9.6 M	100%	551 NM	15.1 M	100%	515 NM

Traffic to/from main 34 airports	EUROPE (2013)			US CONUS (2013)		
	N	% of total	Avg. dist. (NM)	N	% of total	Avg. dist. (NM)
Within region	4.9 M	80.3%	480 NM	8.3 M	83.9%	607 NM
To/from outside region	1.2 M	19.7%	984 NM	1.6 M	16.1%	543 NM
Total	6.1 M	100%	563 NM	9.9 M	100%	597 NM

When all IFR flights including overflights are taken into account, the average flight length is longer in Europe (551 NM) compared to the US (515 NM).

However, this changes when only "domestic" flights within the respective regions are considered. For example, en route efficiency indicators shown later in Section 5.2.3 use "within region" traffic to or from the main 34 airports (lower part of Table 3-2).

For this population, the average flight length is much higher in the US (607 NM) compared to Europe (480 NM). This is due mainly to the large amount of transcontinental traffic in the US system. This gap would narrow considerably if outside region traffic were included (597 NM) US vs. (563 NM) Europe.

For the US, a significant amount of "Outside Region" traffic have a coastal airport as a final destination or traverse a significant distance through Canada before entering US 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 US.

Although average flight length in the US showed a decrease between 2007 and 2009, both systems show a notable increase in average flight length over time which is an interesting observation for the more detailed evaluation of ATM related operational service quality in Chapter 4.4.

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 underutilised during off-peak times but scarce at peak times. Different types of variability require different types of management practices to ensure that ATM can operate efficiently in the face of variable demand.

Figure 3.4 compares the seasonal variability (relative difference in traffic levels with respect to the yearly averages) and the "within week" variability.

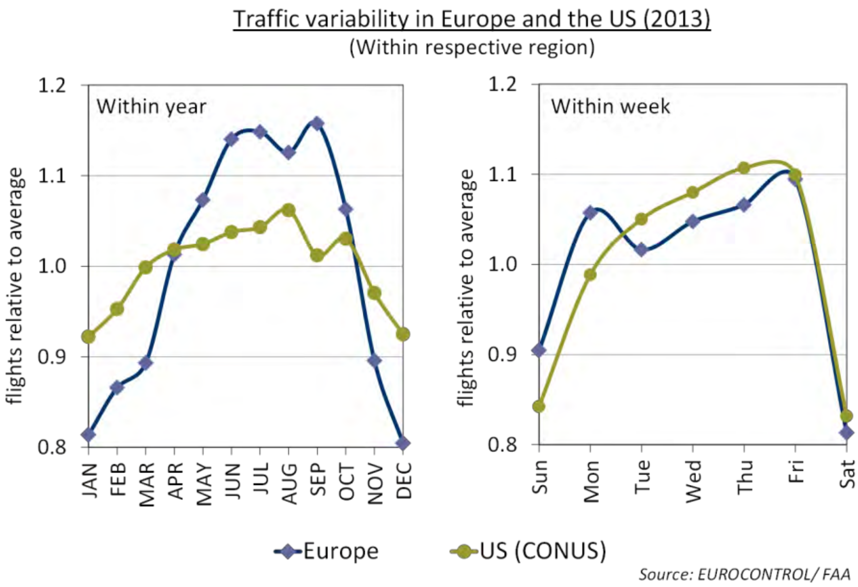


Figure 3.4: Seasonal traffic variability in the US and Europe (system level)

Whereas weekly traffic profiles in Europe and the US are similar (lowest level of traffic during weekends), the seasonal variation is higher in Europe. European traffic shows a clear peak during the summer months. Compared to average, traffic in Europe is in summer about 15% higher whereas in the US the seasonal variation is more moderate.

Figure 3.5 shows the seasonal traffic variability in the US and in Europe for 2013. In Europe, a very high level of seasonal variation is observed for the holiday destinations in South Eastern Europe where a comparatively low number of flights in winter contrast sharply with high demand in summer.

In the US, the overall seasonality is skewed by the high summer traffic in northern en route centres (Boston and Minneapolis) offsetting the high winter traffic of southern centres (Miami and Jacksonville) (see Figure 3.5)

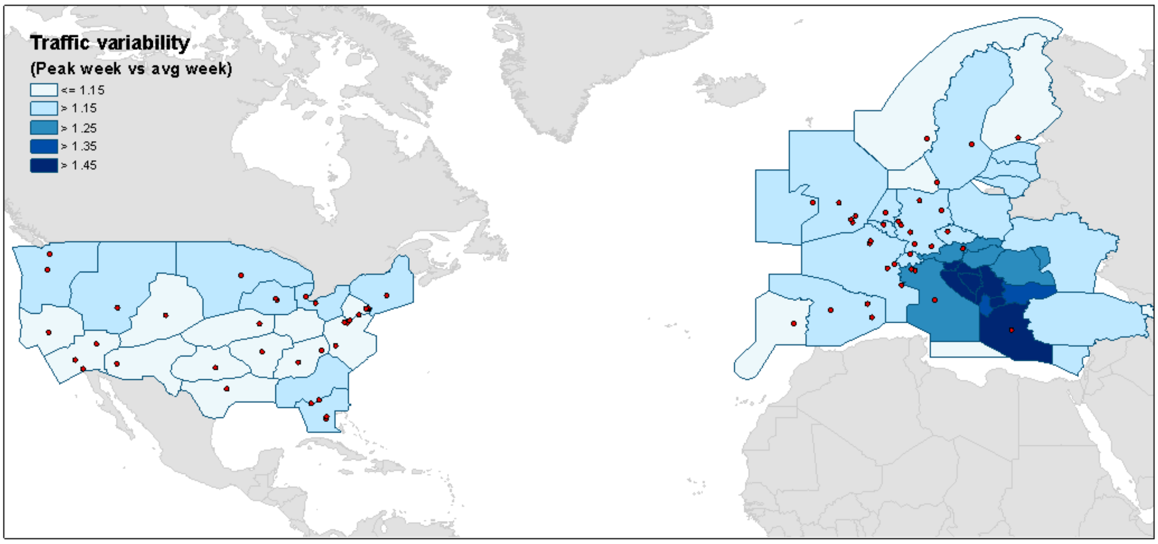


Figure 3.5: Seasonal traffic variability in US and European en route centres (2013)

3.1.5 TRAFFIC MIX

A notable difference between the US and Europe is the share of general aviation which accounts for 21% and 3.9% of total traffic in 2013, respectively (see Table 3-1 on page 28). This is confirmed by the distribution of physical aircraft classes in Figure 3.6 which shows a large share of smaller aircraft in the US for all IFR traffic (left side of Figure 3.6).

The samples are more comparable when only flights to and from the 34 main airports are analysed as this removes a large share of the smaller piston and turboprop aircraft (general aviation traffic), particularly in the US.

In order to improve comparability of data sets, the more detailed analyses in Chapters 4 and 4.4 are limited to controlled IFR flights either originating from or arriving to the main 34 US and European airports (see Annex I). Traffic to or from the main 34 airports in 2013 represents some 67% of all IFR flights in Europe and 66% in the US.

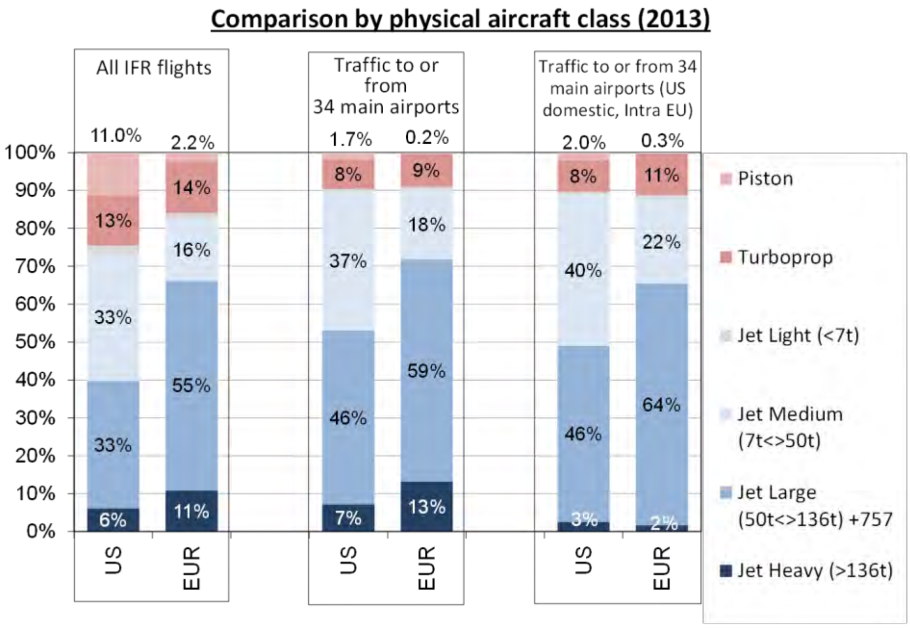


Figure 3.6: Comparison by physical aircraft class (2013)

Figure 3.7 shows the evolution of the number of average seats per scheduled flight in the US and in Europe, based on data for passenger aircraft. For 2013, the average number of seats per scheduled flight is 33% 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 2005 and 2013, the number of seats per aircraft declined in the US between 2008 and 2010. However, recent US trends since 2010 point to an increase in aircraft gauge. Figure 3.7 indicates the potential for growing US passengers with relatively flat or modest growth in operations.

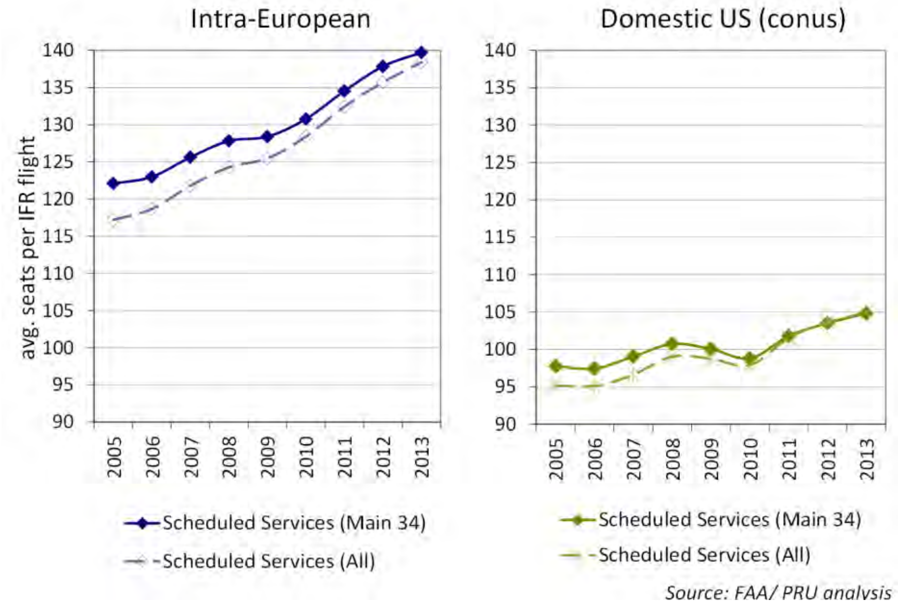


Figure 3.7: Average seats per scheduled flight (2005-2013)

The large 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. 22]. For example, it can be observed that for similar flight segment lengths such as Munich (MUC) to Hamburg (HAM) and San Francisco (SFO) to Los Angeles (LAX), an increasing number of European low cost carriers are utilising a high density one-class seat layout compared to a standard two-class configuration preferred by US carriers. Additionally, since only a few US airports are slot restricted, this enables airlines to increase the frequency of service (with smaller aircraft) to win market share and to attract high yield business travellers. Further analysis and research will improve the understanding of the factors driving the differing trends between the US and Europe and the subsequent effect on performance.

3.2 Airport operations and changes in airport capacity

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.

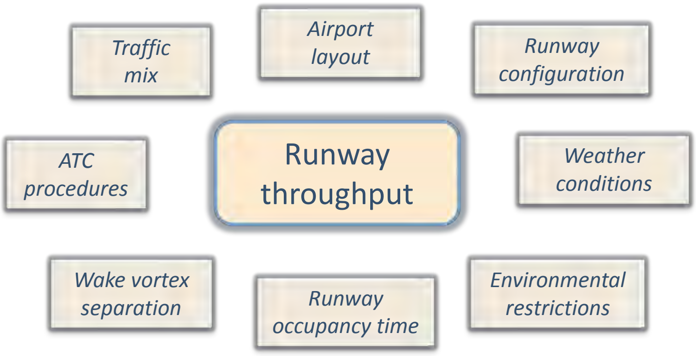


Figure 3.8: Factors affecting runway throughput

The runway throughput is directly related to the time needed to accommodate each flight safely. The separation requirements in segregated mode[20] 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 optimise 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 operations[21], throughput is driven by inter arrival spacings into which departures are interleaved. Here the required spacing between departures and arrivals virtually eliminates wake vortex and radar separation requirements on final approach.

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

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

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

regulations. In the early morning, night noise curfews might even result in considerable arrival holding with a negative impact on fuel burn and thence CO_2 emissions.

More work is required to better understand the differences in the impact of environmental constraints on ATM performance in Europe and the US (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 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 independent[22]), the mode of operation (mixed[23] or segregated[24]), and geographical layout (intersecting runways, crossing taxiways).

Figure 3.9 shows the airport layouts of Boston Logan (BOS) and Chicago Midway (MDW) in the US and Amsterdam Schiphol (AMS) in Europe which all have multiple runway systems.

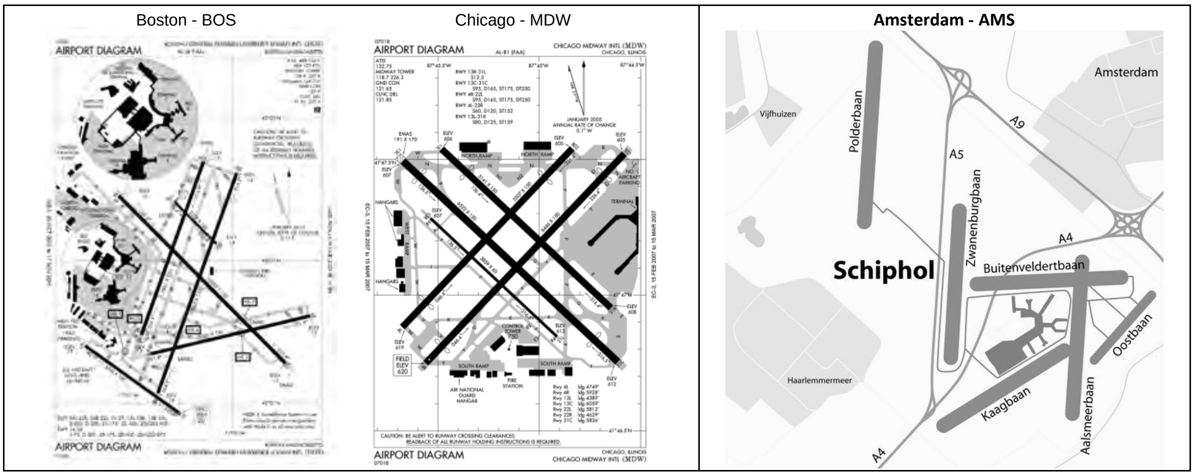


Figure 3.9: Airport layouts (BOS, MDW, AMS)

22 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

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

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

Although those airports technically have a large number of runways, operational data shows that the applied configurations restrict the type of operations and runways to be used at any one time.

For this reason, the number of runways used for the comparison of operations at the 34 main airports in the US 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

In previous versions (2008 and 2010) of the report the number of existing physical runways was used for the computation of the indicators in Table 3-3.

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

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. The number of physical runways might be higher.

Table 3-3: Comparison of operations at the 34 main airports in the US and Europe

Main 34 airports	Europe		US		US vs. Europe
	2013	vs. 2008	2013	vs. 2008	
Avg. number of annual IFR movements per airport ('000)	228	-10.8%	380	-7.1%	67%
Avg. number of annual passengers per airport (million)	25.4	3.9%	33.2	3.6%	31%
Passengers per IFR movement	111	16.5%	87	11.6%	-22%
Average number of runways per airport	2.0	-4.2%	3.4	10.2%	69%
Annual IFR movements per runway ('000)	114	-6.9%	112	-15.7%	-1%
Annual passengers per runway (million)	12.7	8.5%	9.8	-6.0%	-23%

There were several airport development projects in the US between 2008 and 2013. These included 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 reveals that the average number of IFR movements (+67%) and the number of annual passengers per airport (+31%) are significantly higher in the US than in Europe. Consistent with Figure 3.6 and Figure 3.7, the number of passengers per movement is much lower (-22%) in the US due to the US on average utilizing a larger share of smaller aircraft and offering fewer seats per scheduled flight.

Figure 3.10 shows the average number of daily IFR departures at the 34 main European and US airports. The average number of IFR departures per airport (523) is considerably higher (68%) in the US, compared to 312 average daily departures at the 34 main airports in Europe in 2013[25].

25 The analysis relates only to IFR flights. Some airports - especially in the US - have a significant share of additional VFR traffic which has not been considered in the analysis.

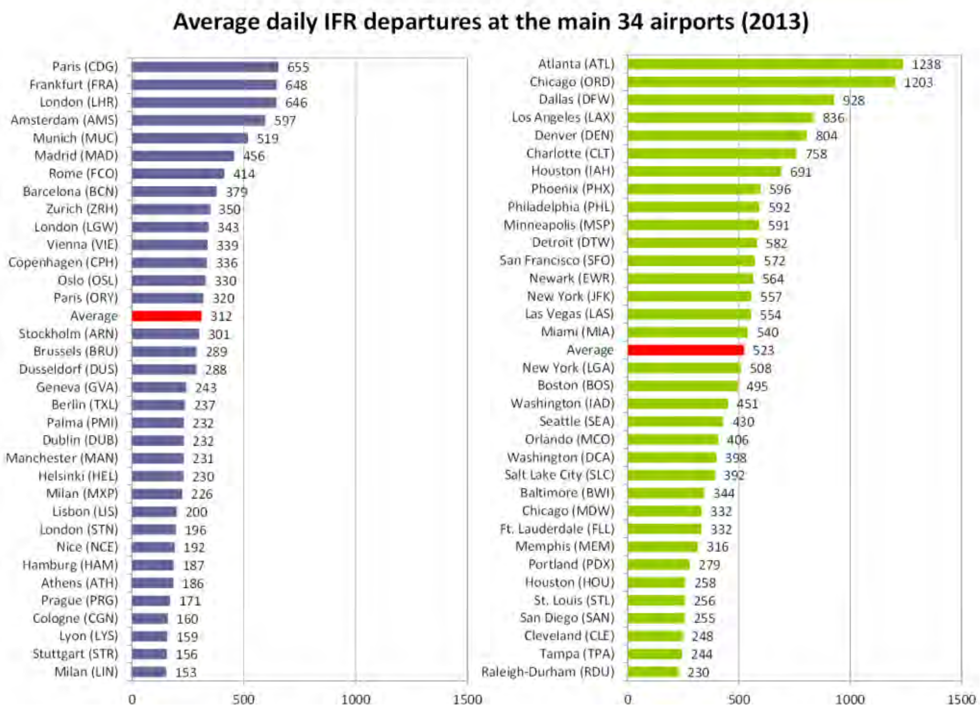


Figure 3.10: Operations at the main 34 airports (2013)

Figure 3.11 shows the change in IFR departures by airport compared to 2012. In the US, the airports with the highest decrease in departures between 2012 and 2013 are Memphis (-51), Denver (-40), and Atlanta (-21). The airports showing a growth in departures compared to 2012 include Houston (HOU) (+41), Boston (+14) and Los Angeles (+14).

In Europe, the airports with the highest decrease in terms of departures were Madrid (-54), Paris (-25), and Munich (-21). The airports showing an increase in departures compared to 2012 include Stockholm (+14) and Dublin (+10).

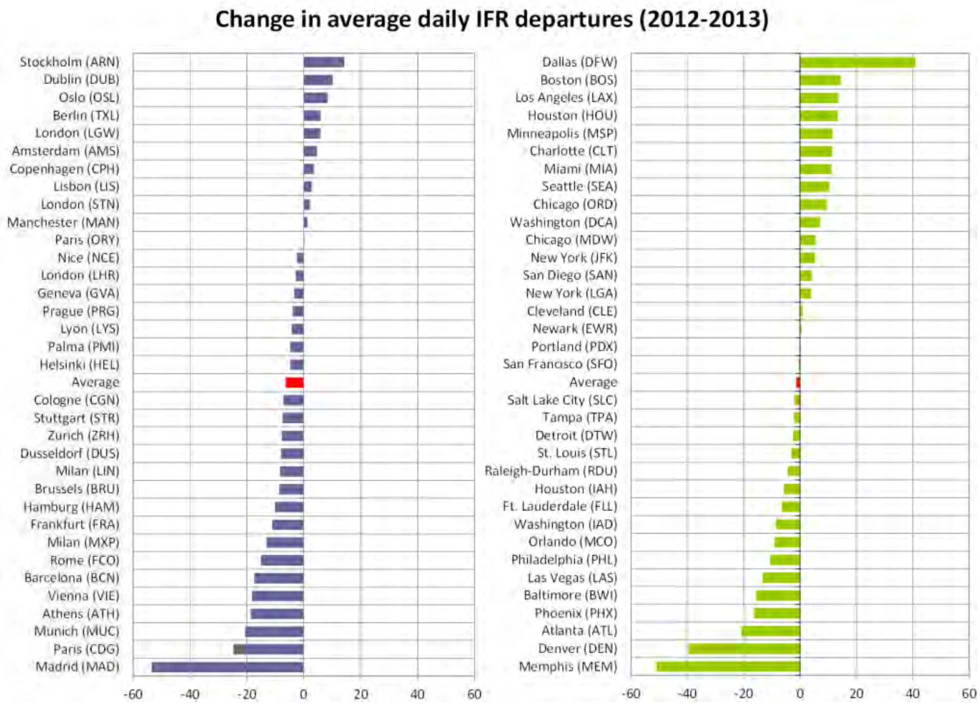


Figure 3.11: Change in operations at the main 34 airports (2012-2013)

The difference in IFR departures and the drop in traffic as measured by IFR departures fit well with the overall operations as reported in Table 3-3. The ATM performance measurements used throughout this report will make use of radar and operator reporting databases available to both FAA and EUROCONTROL. The IFR flights shown in Figure 3.10 are the basis for the majority of the trends and analysis presented in this report.

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 US, 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 3.12 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.

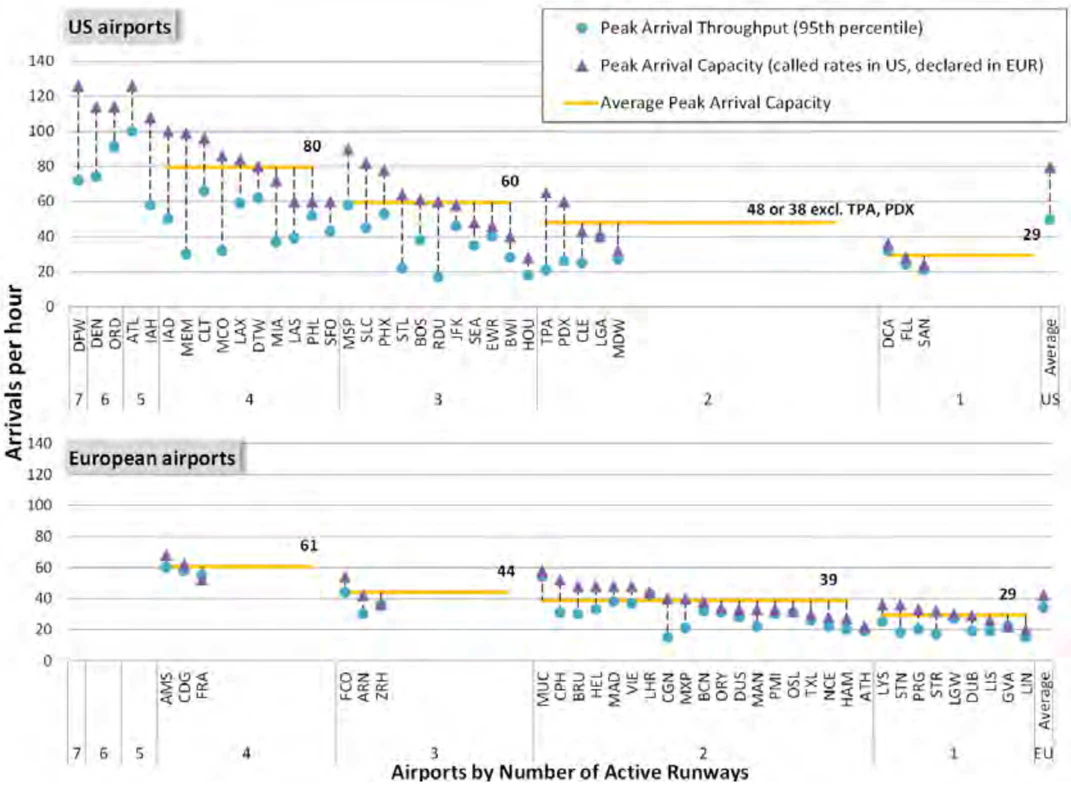


Figure 3.12: Actual airport throughput vs. declared capacity (2013)

The figure depicts the peak arrival capacity (peak called arrival rates for US 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 categorised 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 recognised 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 shown below.

In the US and Europe, airports with one and even two active runways are more comparable in terms of peak arrival capacity for the two regions. For the US, the two active runway case average value (48) is influenced by the ability to operate in mixed mode with independent runways for Tampa (TPA) and Portland (PDX). Otherwise the grouping is more comparable (38 vs. 39).

For airports with three or more active runways, the peak arrival capacity at US airports is on average notably higher than at European airports. The majority of US airports have three or more active runways whereas in Europe, most of the airports have one or two active runways.

Despite normalising 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. In general, the US airports with high value arrival capacity rates in the same class 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 US 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, PHL) 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 US 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 US airports based on runway layout, runway dependency, and mixed and single mode operations. Another difficulty is that throughput is highly sensitive to demand. High demand drives high throughput and vice-versa. It is difficult to properly assess throughput as demand levels are lower on both sides of the Atlantic with some airports having larger demand drops than others. Lastly, 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.

Capacity and throughput indicators may be refined in the future as performance databases contain more information on runway use and the degree to which ATM is able to provide independent operations to runways.

3.2.3 CAPACITY VARIATION AT US AIRPORTS

Many of the differences in performance appear to be attributable to the effects of capacity variation between most favourable and least favourable conditions. Also, many of the improvements at the system level observed over time track with an overall decrease in demand.

The analysis in this section is a first attempt to better understand and quantify these differences using readily available airport capacity and throughput indicators in each system.

Changes in capacity can in part be tied to changes in demand, weather, and airport infrastructure. For the study period from 2012 to 2013, most US airports report a decrease in airport arrival rate which tracks with an overall decrease in traffic.

In Figure 3.13, the average hourly arrival ATC acceptance rates for the 34 main US airports between 6AM-10PM local time are shown with the percent change in arrival capacity compared to 2012 (top of Figure 3.13).

Memphis (MEM), Denver (DEN), and Baltimore (BWI) experienced the greatest decline in traffic from 2012 to 2013, but these airports do not all reflect decreases in average arrival rates called by ATC for the facility. For example, Baltimore (BWI) saw an increase in average arrival capacity in 2013 compared to 2012 due to lower average capacities in 2012 as a result of runway closures and reconstruction projects. Many of these changes must be viewed in conjunction with external factors such as weather and airport infrastructure projects which may impact the called rate at these airports.

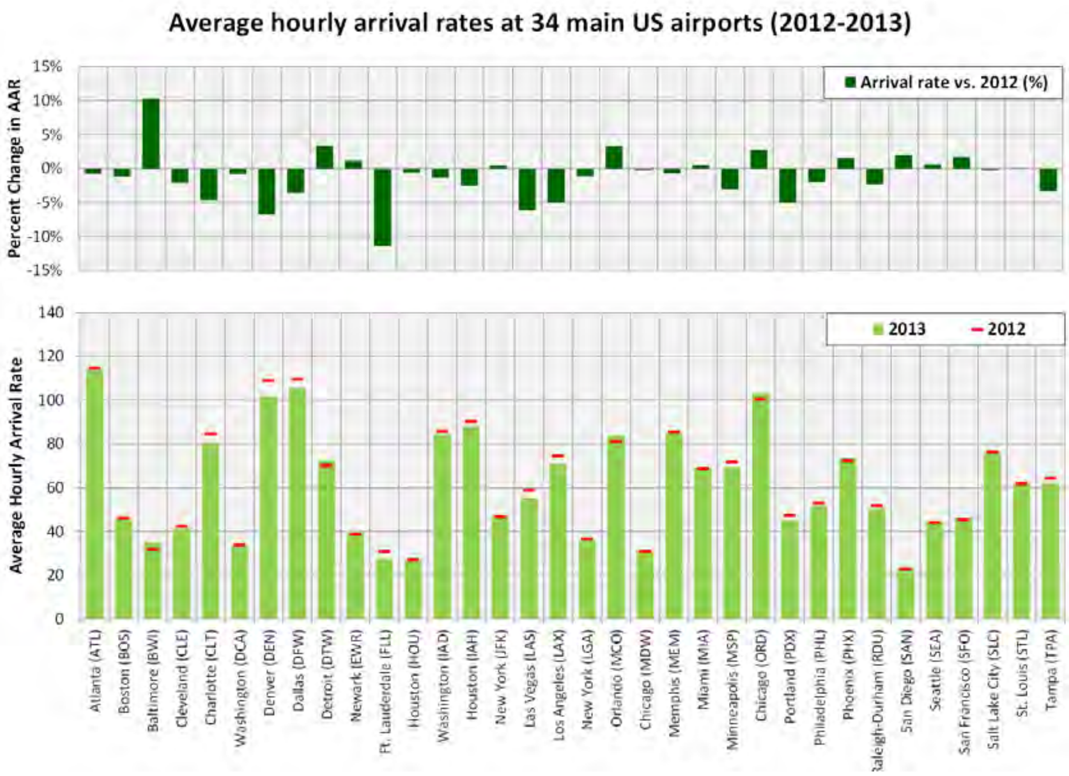


Figure 3.13: Average hourly arrival rates at 34 main US airports (2012-2013)

The period from 2012 to 2013 saw several airport development projects resulting in changes to capacity at US airports. These include a new runway at Chicago O'Hare (ORD) and a runway expansion project at Fort Lauderdale (FLL). However, the addition of a new eighth runway at

Chicago O'Hare (ORD), which opened in October 2013, resulted in only minor increases in average hourly arrival rates for 2013.

Capacity at airports can be tied to demand at the facility and also be impacted by external factors, such as weather conditions. It is also the case that not all capacity variation and performance changes can be explained by meteorological conditions as facilities may operate at low capacity rates during good weather due to other events such as temporary runway maintenance or dependencies with traffic flow of nearby airports.

For this reason, it is more straightforward to assess capacity variation using a percentile method that does not depend on a link to all the causal reasons described above. Figure 3.14 combines the various elements (volume, capacity reduction, and frequency) which drive performance at US airports using percentiles. In the previous section, peak capacity and throughput values were presented. In the following section, the focus is 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 left side of the chart shows the percent capacity variation (arrival & departure) between the 85^{th} and 15^{th} percentile capacities for the most critical US airports in 2013.

Using New York (LGA) as an example, Figure 3.14 would indicate that *at least 15%* of the time there is *at least a 20%* reduction in capacity from the target ideal value represented by the 85^{th} percentile. Frequency of time (15%) and magnitude of capacity reduction (20%) may actually be higher depending on the individual airport's distribution of capacity values. Alternatively, this can be interpreted as 70% of the time (85%-15%), LGA experienced a capacity reduction of *up to 20%.*

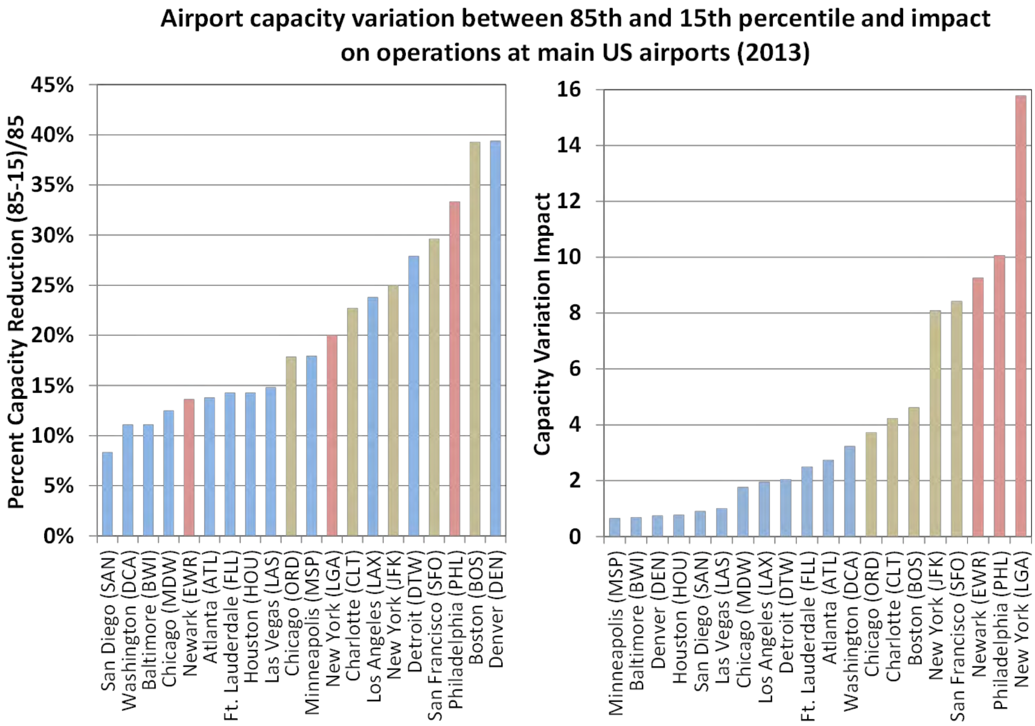


Figure 3.14: Capacity variation (85th-15th percentile) and impact on operations at US airports

Using percentiles to explain variability allows for a consistent comparison of the complete and more complex capacity distributions unique to each facility using two standard percentile values. Denver (DEN), Boston (BOS), Philadelphia (PHL), and San Francisco (SFO) report the largest percent reduction in capacity from the 85^{th} to 15^{th} percentile.

The right side of Figure 3.14 shows a composite indicator of capacity variation impact. It is a measure of the percent capacity reduction shown on the left weighted by the number of hours per day when demand at the airport is at 80% or higher of its called capacity. Airports with high demand relative to capacity are more likely to have performance affected by capacity changes that may occur due to adverse weather or other capacity constraining events. By this indicator, the New York airports (LGA, EWR, JFK), San Francisco (SFO), and Philadelphia (PHL) are the airports which are impacted the most by changes in capacity when also considering demand.

Although a percentile method was used to characterise 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 [Ref. 23]. 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. This will encompass the use of new and enhanced technology as foreseen in NextGen and SESAR.

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 3.15, movement rates depend on visibility conditions. Runway throughput can drop significantly when Low Visibility Procedures (LVP)[26] need to be applied.

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

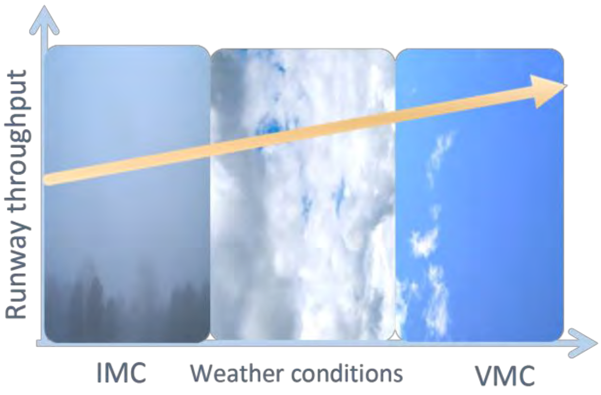


Figure 3.15: Impact of visibility conditions on runway throughput

In Europe, runway capacity declaration is usually based on separation requirements for "average" weather conditions. If actual conditions are better than considered in the capacity declaration process, a runway throughput higher than declared can be achieved.

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 capacity declaration process at European airports arguably results in schedule limitations closer to IMC capacity while in the US, where demand levels are controlled by airlines and capacity is managed more tactically, the ATM system appears to be more flexible to gear throughput according to prevailing conditions and thus potentially operate closer to VMC capacity when possible [Ref. 24].

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. Tracking these values over time may provide an indication of how weather may influence system performance over time.

Despite a number of local initiatives, the ability to consistently quantify the impact of weather on air traffic in Europe is not as developed as is in the US (convective weather forecast, WITI Metric, etc.). For this reason and the fact that weather may change during the flight time from origin to destination airport, the analysis in Section 3.3.2 is limited to comparing only ATFM

[26] 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.

delay attributed to weather causes at US and European arrival airports. Section 3.3.1 provides an assessment of weather in the two regions using general criteria for ceiling and visibility.

3.3.1 Measuring weather conditions

Both US and European performance groups use detailed weather observation reports known as METAR[27] and both groups have developed procedures for assessing weather's impact on aviation performance [Ref. 25 and 26]. 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 2012 and 2010 benchmark report as a practical way of comparing weather changes over time and weather differences between facilities.

Precise definitions differ between the US and Europe but for the analysis in the next section, a cloud ceiling of less than 1000 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.

27 METAR is also known as Meteorological Terminal Aviation Routine Weather Report or Meteorological Aerodrome Report.

Figure 3.16 shows the percent of time spent in visual, marginal, and instrument conditions in Europe and the US at system level from 2012 to 2013 between 6AM-10PM local time.

In 2013, approximately 84.4% of the year at the main 34 US airports was spent in VMC with 9.7% occurring in marginal and 5.9% in instrument conditions. Overall, US airports experienced a slightly worse weather year in 2013 compared to 2012 in terms of frequency of IMC (+1.1%).

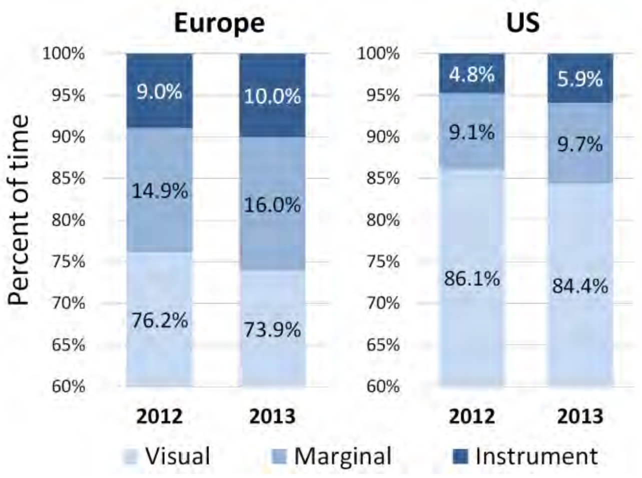


Figure 3.16: Overview of weather conditions in the US and Europe (2012-2013)

In general, weather in Europe at system level is less favourable than the US. The main 34 European airport spend on average 73.9% of the time in VMC, 16% in marginal, and 10% in instrument. At system level, weather conditions in Europe also got worse in 2013 compared to 2012 with a 2.3% reduction in VMC and a 1% increase in IMC.

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 3.17). The European airports located in the subtropical Mediterranean region including Palma (PMI), Athens (ATH), Nice (NCE), Barcelona (BCN), and Madrid (MAD) are the airports with the highest percentage of the VMC.

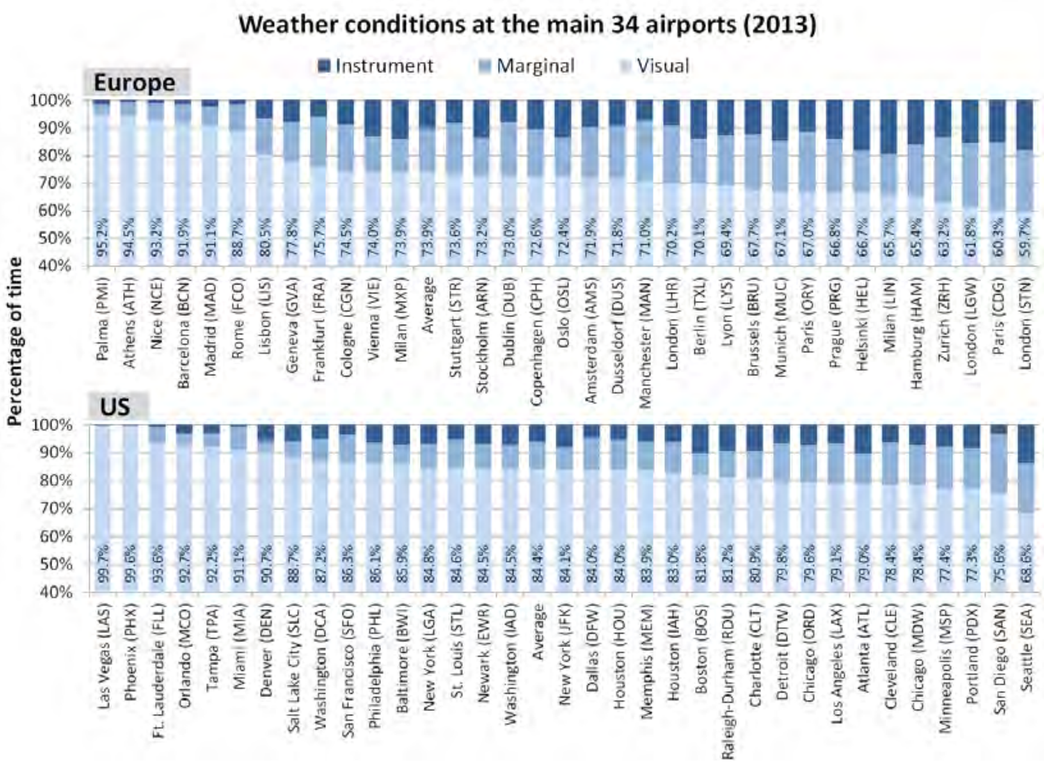


Figure 3.17: Percent of time by meteorological condition at the main 34 airports (2013)

In the US, 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 3.18 shows how the increase in instrument conditions is broken down by airport in Europe (+1%) and the US (+1.1%). In terms of performance, the observed capacity gap, traffic volume, and frequency of IMC drive overall system performance.

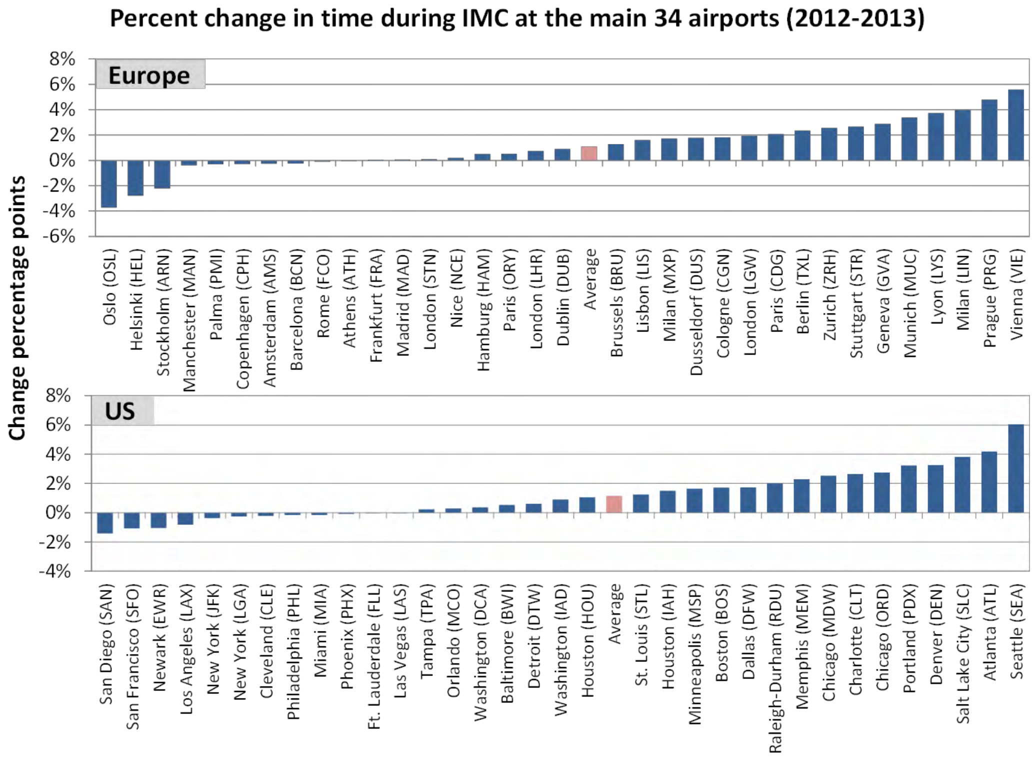


Figure 3.18: Percent change in time during IMC at the main 34 airports (2012-2013)

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. ATFM restrictions are only issued when capacity shortages occur. 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.

3.3.2 Weather-related airport ATFM delays at the main 34 airports

As weather is a major factor influencing runway throughput and airport capacity, airports typically issue ATFM restrictions to address capacity to demand imbalances when adverse weather occurs. Using comparable data sources in the US and Europe, this section provides a preliminary analysis of the specific types of weather-related causes for ATFM delays at the arrival airport. A more detailed analysis of ATFM delay for all causal factors is provided in Section 5.2.1.

Figure 3.19 shows the average airport arrival ATFM delay by causal factor at system level for the main 34 airports between 2008 and 2013.

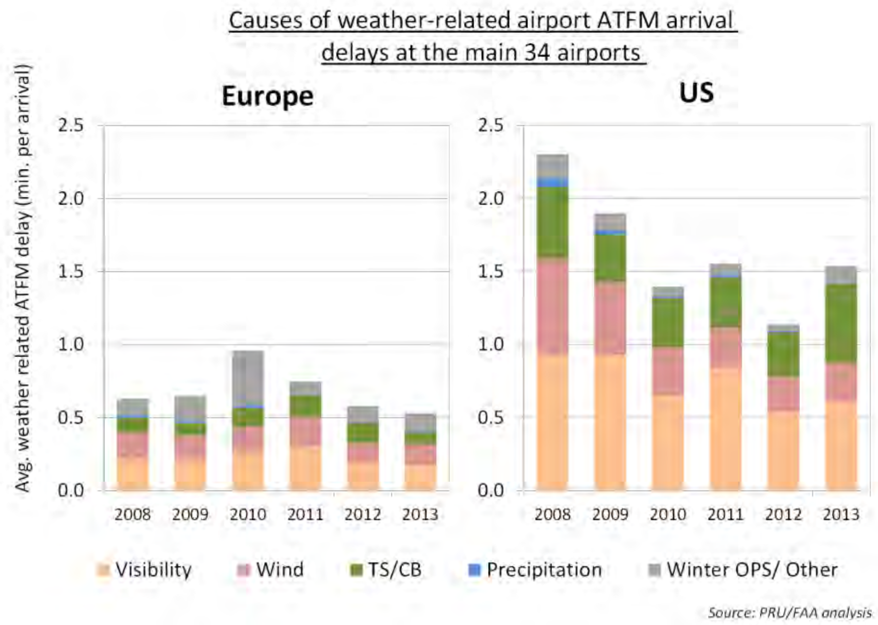


Figure 3.19: Causes of weather-related airport ATFM delays (2008-2013)

In Europe, ATFM airport regulations due to visibility are the main driver of delay, followed by wind, winter operations and thunderstorms. A notable exception is observed for 2010 where winter operations were the main cause for weather related airport ATFM regulations. The severe weather conditions in Europe in 2010 had a notable impact on punctuality as shown later in Figure 4.8 on page 58. Despite a slight increase in winter operations and wind related delays in 2013, average weather related airport ATFM delays at the 34 main European airports are at the lowest level in 2013.

Similarly in the US, the primary driver for ATFM delays is visibility, however, the impact of thunderstorms and severe weather are also very prominent. The increase in average weather-related airport ATFM delays in the US from 2012 to 2013 may be linked to a decrease in on-time punctuality shown later in Figure 4.1.

Overall, relatively higher ATFM delays per arrival are observed in the US compared to Europe when weather-related restrictions are present. This may be due to European capacities being set more conservatively to allow for unforeseeable events whereas the US operates by calling a higher capacity by presuming ideal operating conditions.

Figure 3.20 provides a breakdown of weather-related ATFM delay by arrival airport and by cause in 2013. 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).

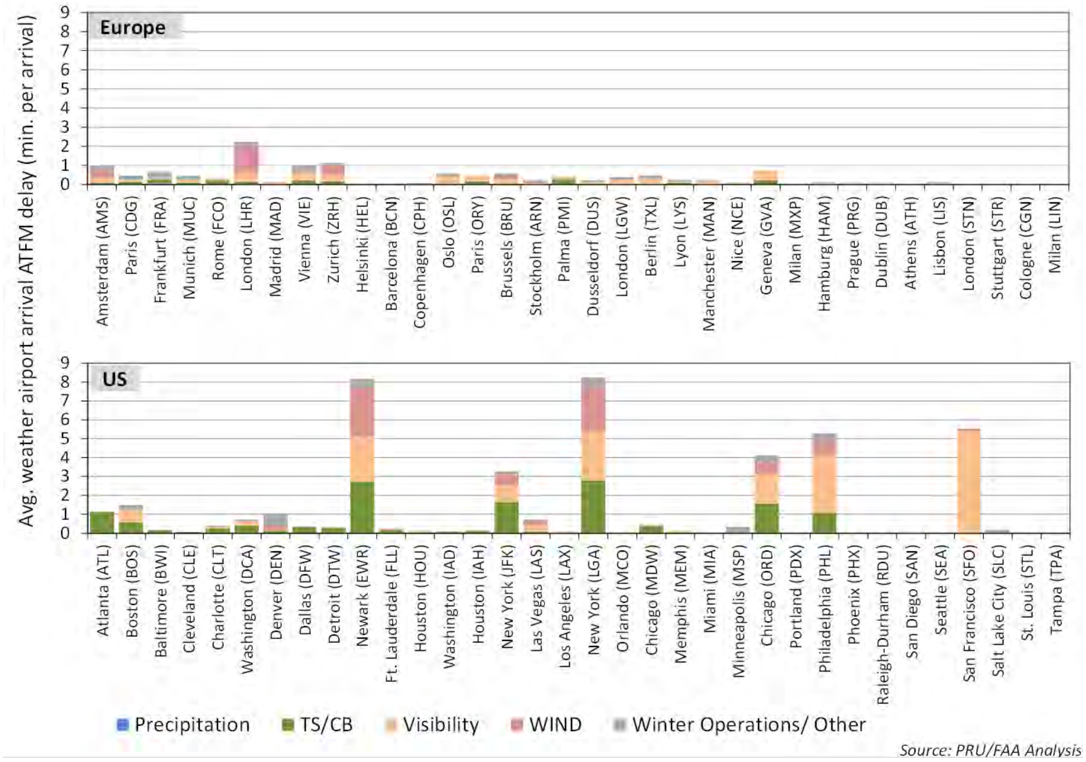


Figure 3.20: Airport charged weather-related ATFM delays by destination airport (2013)

As can be seen from the figure, a few notable US 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 very high average ATFM weather-related delays, specifically due to thunderstorms and severe weather. For this reason, the New York area has implemented a severe weather avoidance plan (SWAP) to handle aircraft reroutes and departure clearances during thunderstorm events. However, the frequency and wide-spread nature of convective weather still result in a large number of arrival and departure delays at airports in or near the affected region. On the west coast, fog and low visibility are the most impactful weather cause for ATFM delays at San Francisco (SFO).

In Europe, London Heathrow (LHR) shows by far the highest impact of weather on operations in 2013, followed by Zurich (ZRH), Geneva (GVA), Vienna (VIE), and Amsterdam (AMS). The average weather-related airport arrival ATFM delays at London (LHR) were mainly related to wind and visibility.

4 COMPARISON OF AIRLINE-RELATED OPERATIONAL SERVICE QUALITY

This chapter compares US and European performance using Key Performance Indicators as provided by the airlines. Also included are KPIs that use an airline schedule time as the reference for assessing performance. This would contrast with similar KPIs that utilize the filed time as the reference for benchmarking. 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.

This section starts with a high level evaluation of the number of delayed flights compared to airline schedules, which is often used as a proxy for the "service quality" provided. This KPI is reported by the US Department of Transportation [Ref. 27] and in Europe by the Central Office for Delay Analysis (CODA) [Ref. 28]. It 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 analysing the information reported by airlines in order to get a first estimate of the ATM-related[28] contribution towards overall air transport performance. Chapter 4.4 presents ATM delay as reported by the ANSP.

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.

4.1 On-time performance

Figure 4.1 compares the industry-standard indicators for punctuality, i.e. arrivals or departures delayed by more than 15 minutes versus schedule. 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).

With the exception of 2010 and 2013, the overall patterns are similar in the US and in Europe.

Punctuality/ On-time performance

The percentage of flights delayed by more than 15 minutes compared to published airline schedule (i.e. Punctuality) is the most commonly used industry standard for punctuality.
There are many factors contributing to the on-time performance of a flight. Punctuality is the "end product" of complex interactions between airlines, airport operators, and ANSPs, from the planning and scheduling phases up to the day of operation. For this reason, network effects have a strong impact on air transport performance.

While public focus is on delayed flights, it should be pointed out that, from an operational viewpoint, flights arriving more than 15 minutes ahead of schedule may have a similar negative effect on the utilisation of resources (i.e. TMA capacity, en route capacity, gate availability, etc.) as delayed flights.

For the US, on-time performance decreased from 2012-2013 for both arrival on-time (83.6% vs. 80.7%) and gate departure (82.9% to 80.1%). Large facilities in the US such as Atlanta (ATL) and Chicago (ORD) largely drove this indicator.

Historically, between 2003 and 2007, on-time performance degraded in the US and in Europe. It is interesting to note that during the same time, traffic in Europe increased substantially but

28 "ATM-related" in this report means that ATM has a significant influence on the operations.

remained similar at system level in the US (compare Figure 3.1).

The observed service degradation in the US during that time was due to an increase of traffic for already congested airports (New York airports and Philadelphia) which resulted in an increase in the number of delayed flights at those airports[29].

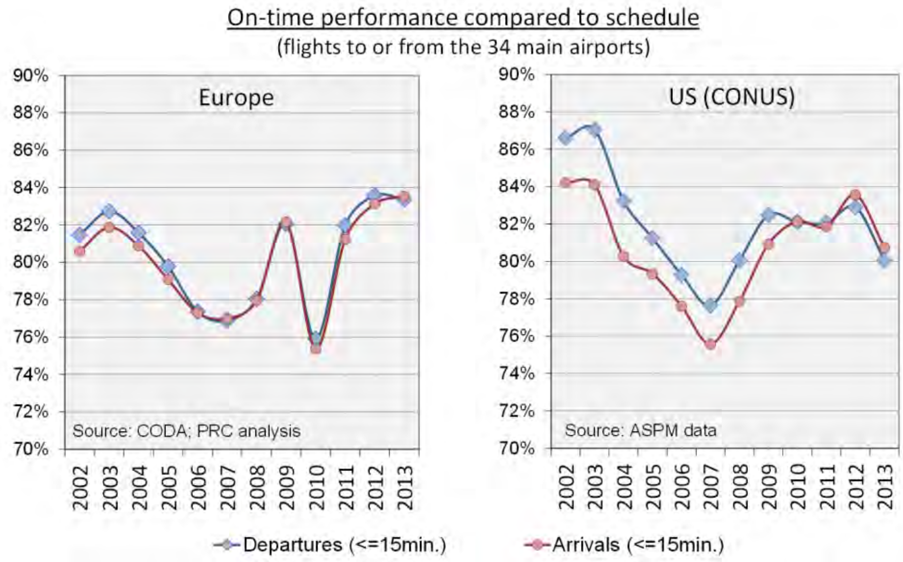


Figure 4.1: On-time performance (2002-2013)

From 2004 to 2009, the level of arrival punctuality was similar in the US and in Europe. This changed radically in 2010 when punctuality degraded dramatically in Europe but continued to improve in the US. This performance improvement needs to be seen in the context of decreasing traffic as a result of the global financial and economic crisis starting in 2008.

In 2010, punctuality in Europe was the worst recorded since 2001, although traffic was still below 2008 levels. The main factors for this deterioration were a large number of industrial actions and higher than usual weather-related delays (snow, freezing conditions) during the winter seasons of 2009 and 2010. 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.

From 2010 to 2012, punctuality in Europe has improved again and continued to improve in the US. However in 2013, whereas punctuality in Europe remained largely unchanged, punctuality in the US saw a sharp decline which may be due to unfavourable weather in 2013 compared to previous years.

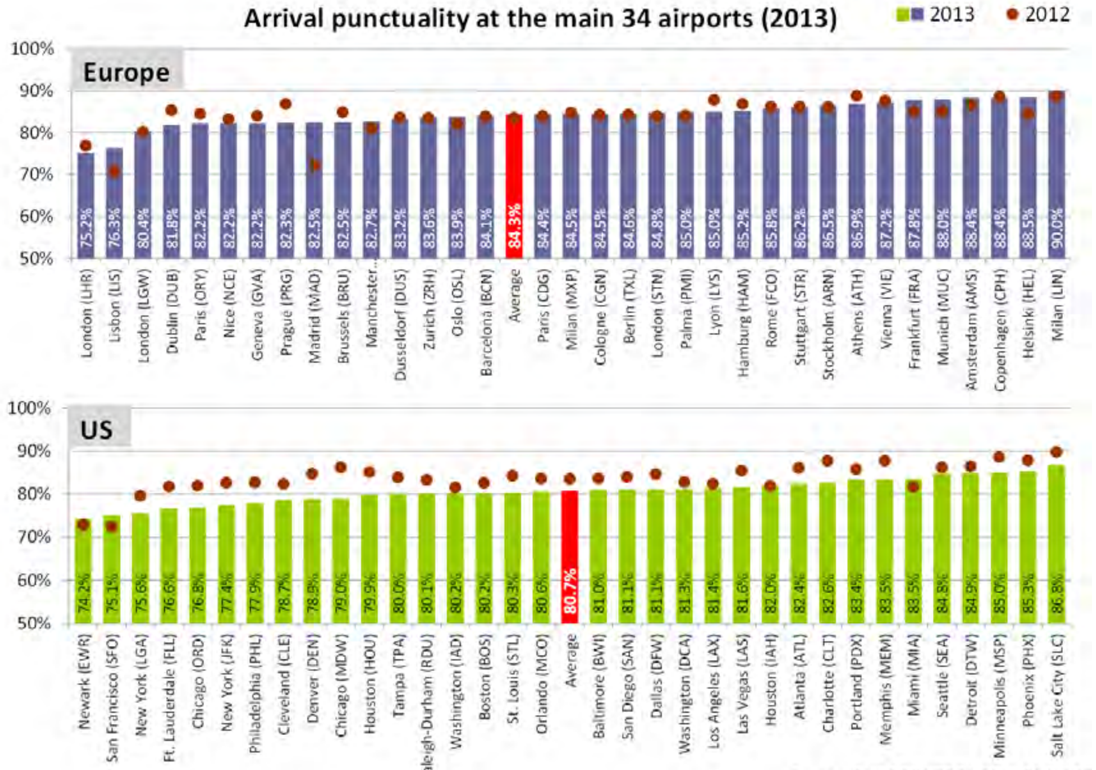
A notable difference was the gap between departure and arrival punctuality that occurred prior to 2010 in the US, and which was not observed for Europe. The reasons for this gap are not fully understood but may involve policy, differences in flow management techniques as well as other incentives to have high on-time departures.

While in the US, flow management strategies focus more on the gate-to-gate phase, in Europe flights are usually held at the gates with only comparatively few constraints once an aircraft has

29 New York (JFK) and Newark (EWR) airport became schedule limited in 2008.

left the gate. However from 2010-2013 this gap has largely disappeared with a trend similar to Europe.

The system-wide on-time performance is the result of contrasted situations among airports. Figure 4.2 shows the arrival punctuality at the 34 main European and US in 2013. The changes in arrival punctuality compared to 2012 are shown in Figure 4.3



Source: EUROCONTROL PRU; FAA-ATC

Figure 4.2: Arrival punctuality at the main 34 airports (2013)

In the US, Newark (EWR) had the lowest on-time performance (arrivals) followed by San Francisco (SFO) and New York La Guardia (LGA). Compared to 2012, only three airports showed improvements in arrival punctuality. These include San Francisco (+2.7%pt.[30]), Miami (+1.8%pt.), and Newark (+1.3%pt.).

In Europe, the two London airports (LHR, LGW) and Lisbon (LIS) had the lowest level of arrival punctuality in 2013 (top chart in Figure 4.2). Compared to 2012, Madrid (+10.2%pt.), Lisbon (+5.5%pt.), and Helsinki (+4.1%pt.) show the highest improvements.

30 Percentage point refers to the difference between two percentages.

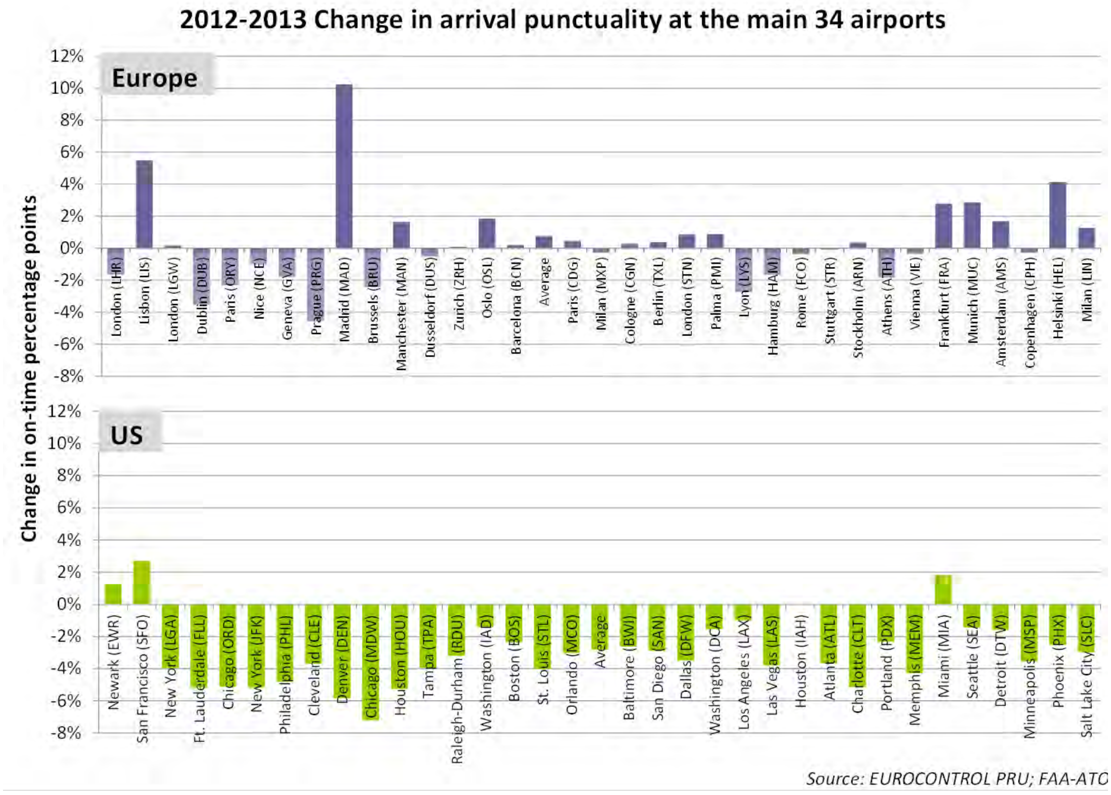


Figure 4.3: Change in arrival punctuality at the main 34 airports (2012-2013)

As already mentioned at the beginning of this chapter, 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 & 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.

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 may pad 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 Figure 4.4 and grey box on page 54).

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 utilisation of resources (e.g. aircraft, crews) and higher overall costs.

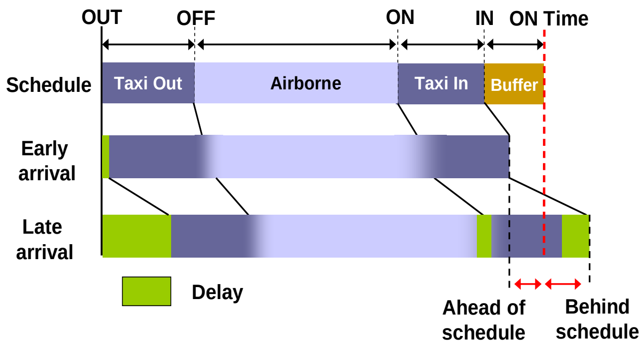


Figure 4.4: Time buffer included in airline schedules (illustration)

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.

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.

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 utilisation of aircraft and crews).

Figure 4.5 shows the evolution of airline scheduling times in Europe and the US. 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 metric[31]). Generally speaking, the scheduled block times follow the pattern of the actual block times of the previous season.

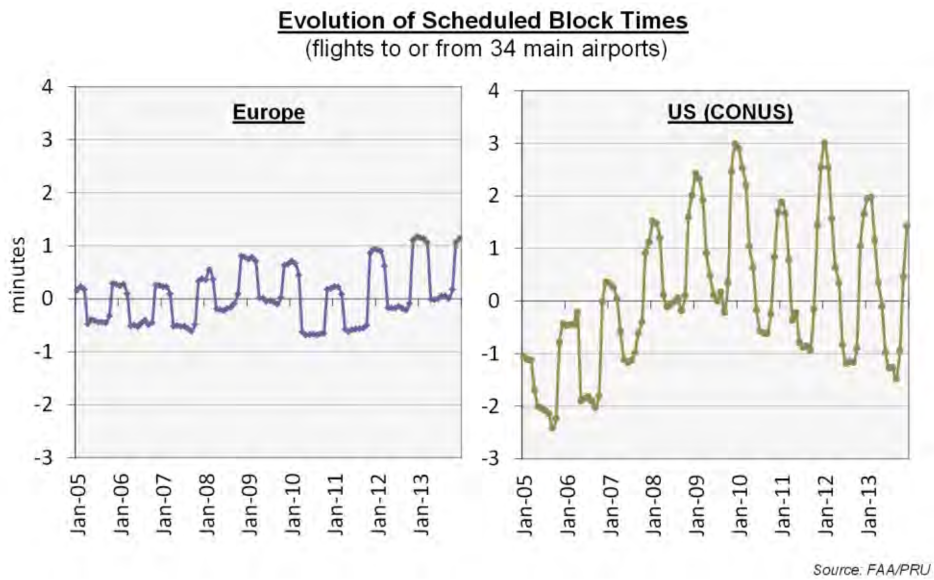


Figure 4.5: Scheduling of air transport operations (2005-2013)

[31] 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. It provides a relative change in performance without underlying performance driver.

At system level, scheduled block times remained largely stable in Europe with only a slight increase between 2008 and 2010 and again in 2012 and 2013. In the US, average block times increased continuously between 2005 and 2010 but have decreased since then.

Historically, Figure 4.1 and Figure 4.5 show that not only did on-time performance decrease between 2004 and 2007 but scheduled airline block times also increased in the US, meaning that the real performance deterioration was to some extent masked by costly airline schedule padding. Schedule padding can cost an airline more than $50 per minute and costs airlines even when flights are early (under most airline labour agreements, pilots and crew are paid the maximum of actual or scheduled time) [Ref. 29 and Ref. 30].

From Figure 4.1, system wide on-time arrival punctuality in the US saw a 2.9% decrease from 2012 to 2013. Figure 4.5 indicates that airlines have decreased block time and, across city pairs to and from the main 34 airports, overall airline scheduled block time decreased by an average of 0.45 minutes in 2013. However, the degree to which this system decrease affects overall arrival punctuality requires a detailed city pair assessment of airline block time changes and its relation to actual block time. A specific examination of these values by city pair shows airlines, on average, correctly anticipated changes in actual block time and these changes had a favourable impact on on-time performance. In fact, continued use of 2012 scheduled block times in 2013 would most likely have reduced arrival punctuality by an additional 0.5%.

These observed increases in schedule padding in the US may result from adding block time to improve on-time performance or could be tied to a tightening of turnaround times. More work is needed on a city pair level to accurately and more specifically identify the numerous factors influencing the changes in on-time performance.

Seasonal effects are visible in Figure 4.5 with scheduled block times being on average longer in winter than in summer. US studies have shown that the majority of the increase is explained by stronger winds on average during the winter period [Ref. 31].

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 US 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 US relate to the scheduled arrival times whereas in Europe they relate to the delays experienced at departure. Hence, for the US 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 US 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: The cause of the delay is due to circumstances within local control. This includes airlines or other parties, such as ground handlers involved in the turnaround process (e.g. maintenance or crew problems, aircraft cleaning, baggage loading, fuelling, 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 US, 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 US.

- 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 4.6 provides a breakdown of primary delay drivers in the US and Europe. Only delays larger than 15 minutes compared to schedule are included in the analysis. Clearly, US airlines attribute a larger fraction of causal delay to US ATM than what is seen in Europe. This change grew from 2012-2013. However US airlines also attributed much of the decline in performance to late arriving aircraft and reactionary delay. Figure 4.6 can also be contrasted with Figure 5.5 in Section 5 which shows delay allocation from the ANSP perspective. For FAA, ATM attributable delay is done largely in cases of equipment problems and weather is seen as the largest contributor to system delay.

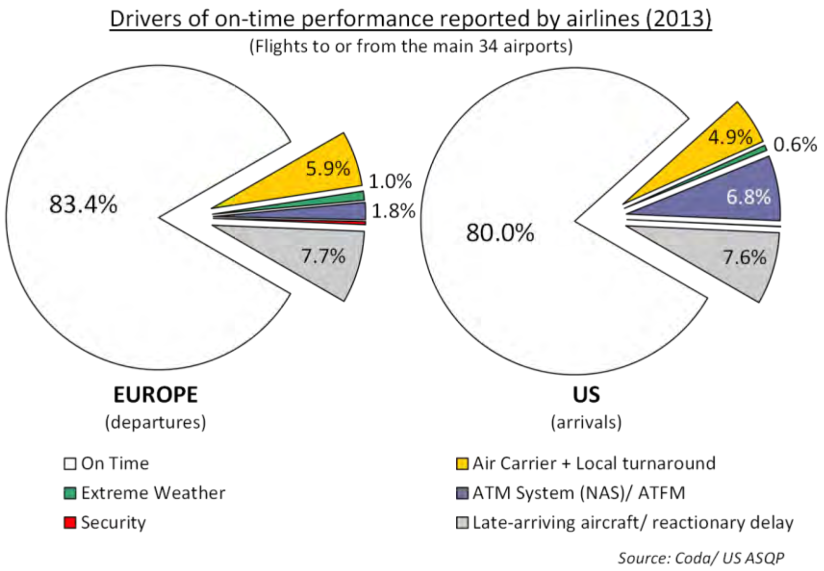


Figure 4.6: Drivers of on-time performance in Europe and the US (2013)

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 US 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).

It should be noted that the ATM system related delays in Figure 4.6 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 US [Ref. 32].

Figure 4.7 and Figure 4.8 show time series analyses of the delays reported by airlines for Europe and the US. In order to ensure comparability, only the share of flights with an arrival delay (all possible delay causes) of more than 15 minutes compared to schedule were included.

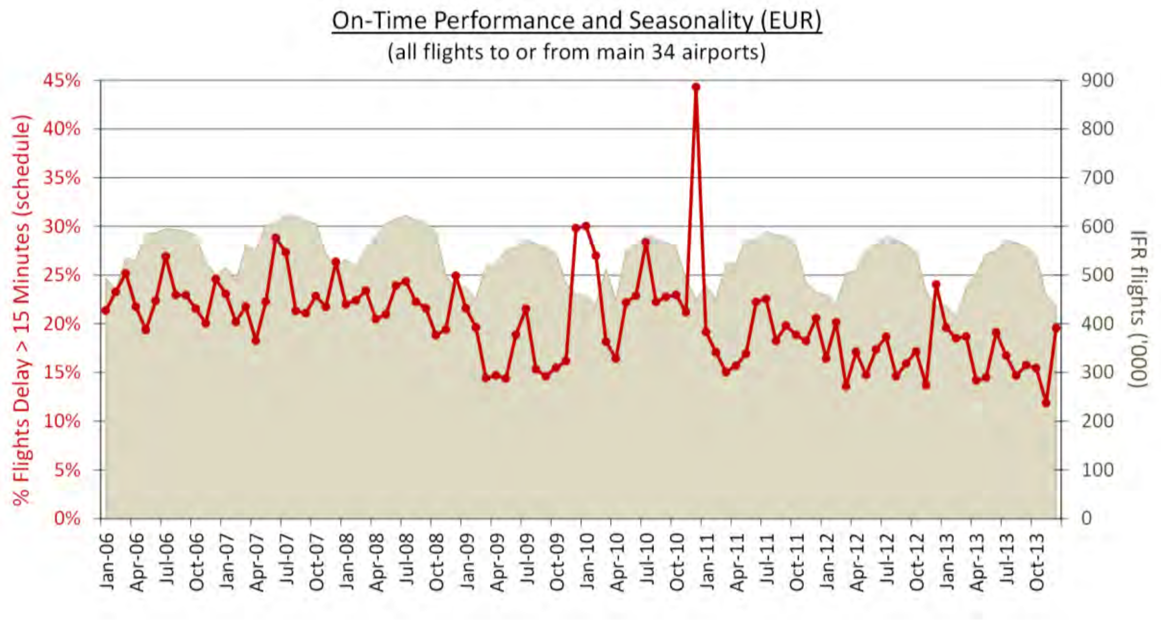


Figure 4.7: Seasonality of delays (Europe)

The red line in Figure 4.7 and Figure 4.8 shows the seasonality of delay for flights to or from the top 34 airports in Europe and the US. In Europe and the US, a clear pattern of summer and winter peaks is visible.

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 in the US and a lack of en route capacity in Europe. The strong increase in Europe in December 2010 is due to exceptional weather conditions (ice & snow).

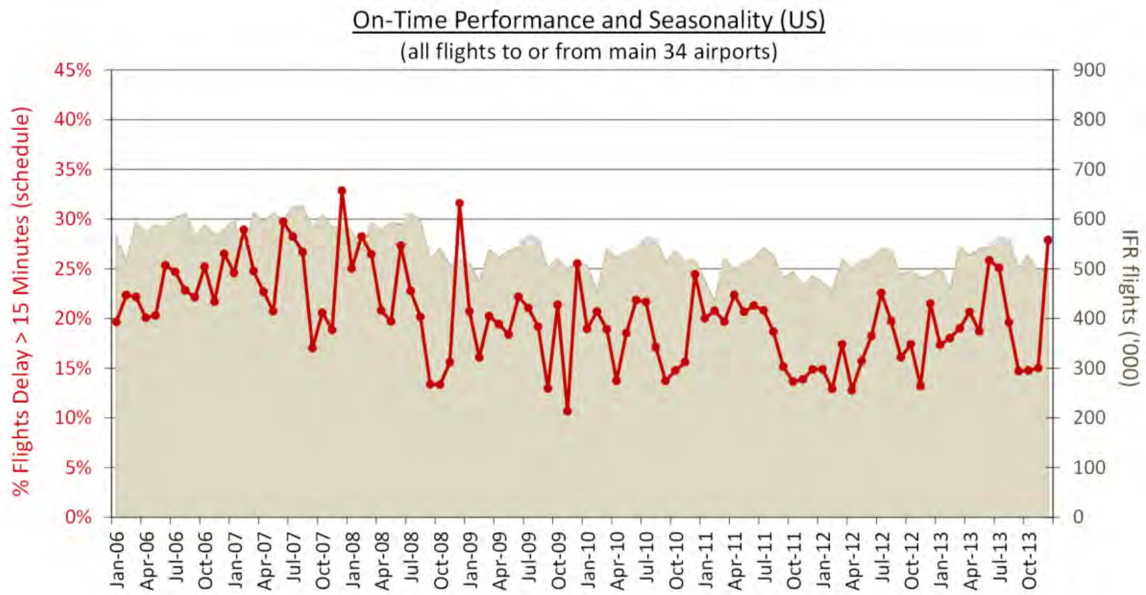


Figure 4.8: Seasonality of delays (US)

Figure 4.9 provides a first analysis of how the duration of the individual flight phases (gate departure delay[32], taxi-out, airborne, taxi-in, total) have evolved over the years in Europe and the US. The analysis is based on the DLTA Metric (see footnote 31 on page 52) and compares actual times for each city pair with the long-term average for that city pair over the full period (2003-2013). For example, in the US at the peak of the curve at the end of 2008, total average actual flight time among city pairs had increased over 8 minutes since 2004 and was 4 minutes above the long-term average.

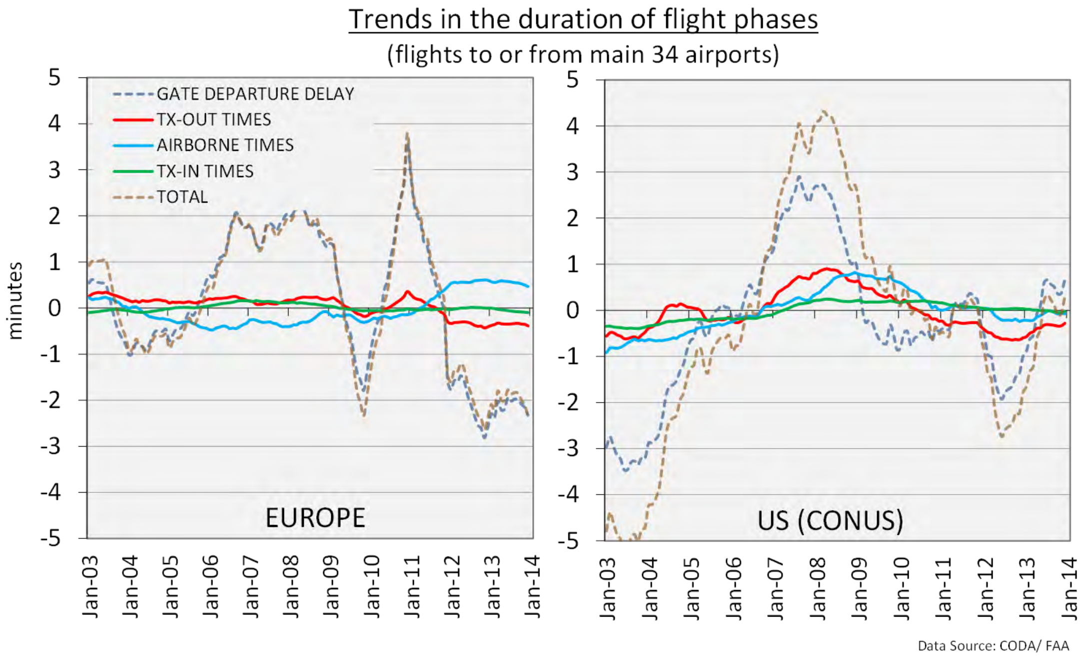


Figure 4.9: Trends in the duration of flight phases (2003-2013)

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

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 (industrial actions, extreme weather, technical upgrades). Since 2010, performance in almost all phases of flight improved again substantially.

In the US, the trailing 12-month average 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. A substantial improvement is also visible for taxi-out times as a result of the initiatives to improve performance in this area.

After a high level analysis of operational performance from the airline point of view, the next section 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.

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 Section 1.4 for more information 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 utilisation 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 users[33]. 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 would be representative of one standard deviation if in fact 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 US and Europe using a common methodology.

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

Figure 4.10 shows that in both Europe and the US, arrival predictability is mainly driven by gate departure predictability. Despite the lower level of variability, improvement in the gate-to-gate phase – especially in the taxi-out and terminal airborne phase – can warrant substantial savings in direct operational and indirect strategic costs for the airlines.

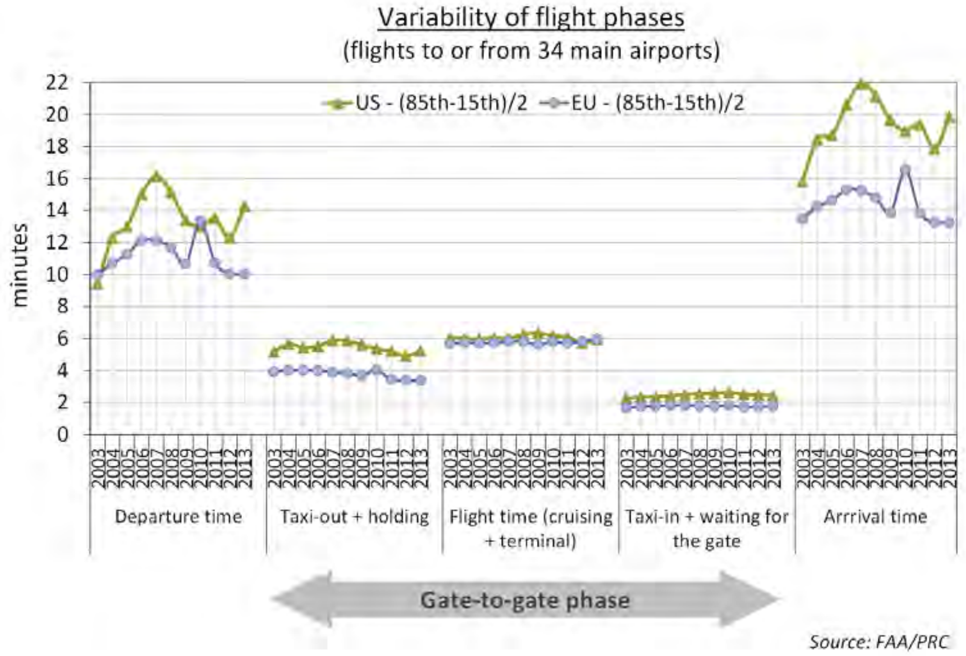


Figure 4.10: Variability of flight phases (2003-2013)

Variability in all flight phases is higher in the US than Europe. Historically, the differences between the US and Europe have been largest on the ground both at the gate and in taxi-out.

Between 2003 and 2007, gate departure time variability continuously increased on both sides of the Atlantic. Contrary to Europe, variability increased also in the taxi-out phase in the US, which appears to be driven by the different approaches in both scheduling operations and absorbing necessary delay.

Figure 4.11 shows a clear link between the various seasons and the level of variability in the US 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 US and in Europe is caused by wind effects and also partly captured in airline scheduling (see Figure 4.5).

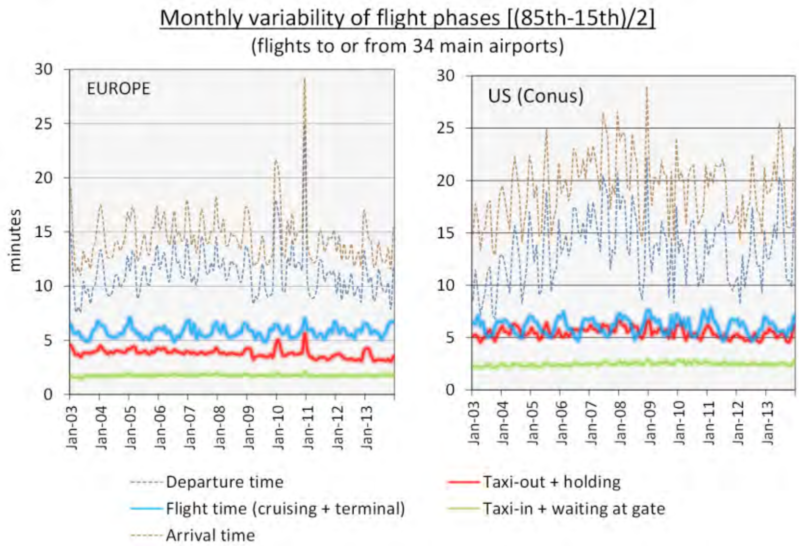


Figure 4.11: Monthly variability of flight phases (2003-2013)

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 analysed in more detail in Section 5.2.1. Due to the interconnected nature of the aviation system, variability originating at constrained airports can propagate throughout the entire network [Ref. 33].

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 (see Section 2.3).

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 US 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.

More detailed analysis is needed to evaluate the impact of the respective air traffic management system, weather, and airline scheduling on the level of variability in the individual flight phases.

5 COMPARISON OF ATM-RELATED OPERATIONAL SERVICE QUALITY

This section compares US and European performance using Key Performance Indicators 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 US 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 key performance indicators (KPIs) used in this report were developed using common procedures on comparable data from both the FAA-ATO and EUROCONTROL (see Section 1.4).

5.1 Approach to comparing ATM-related 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.

Figure 5.1 shows the conceptual framework for the analysis of ATM-related service quality by phase of flight applied in the next sections of this report. The high level passenger perspective (on-time performance) is shown at the top together with the airline scheduling. The various elements of ANS performance analysed in more detail in the following sections are highlighted in blue in Figure 5.1.

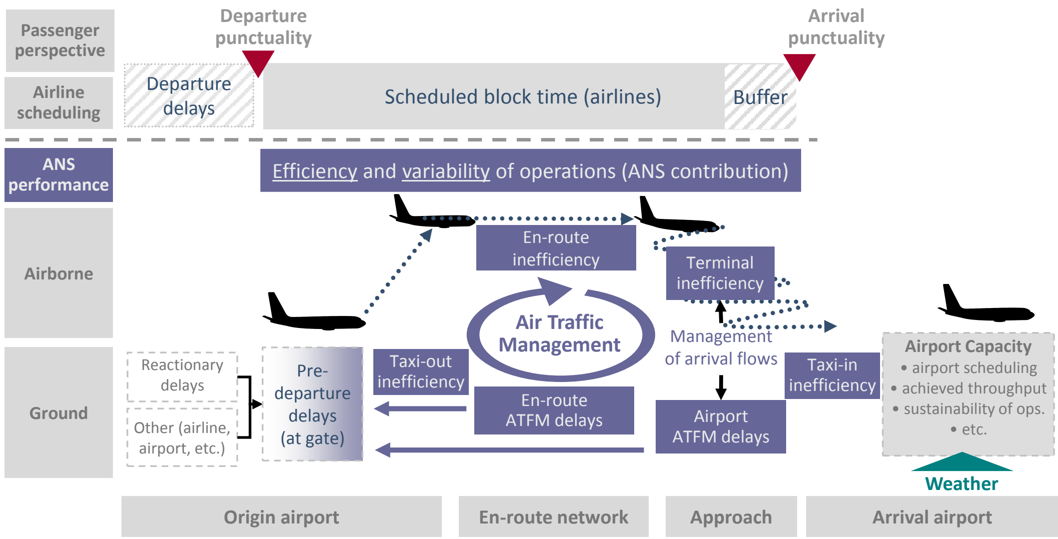


Figure 5.1: Conceptual framework to measuring ATM-related service quality

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.).

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.

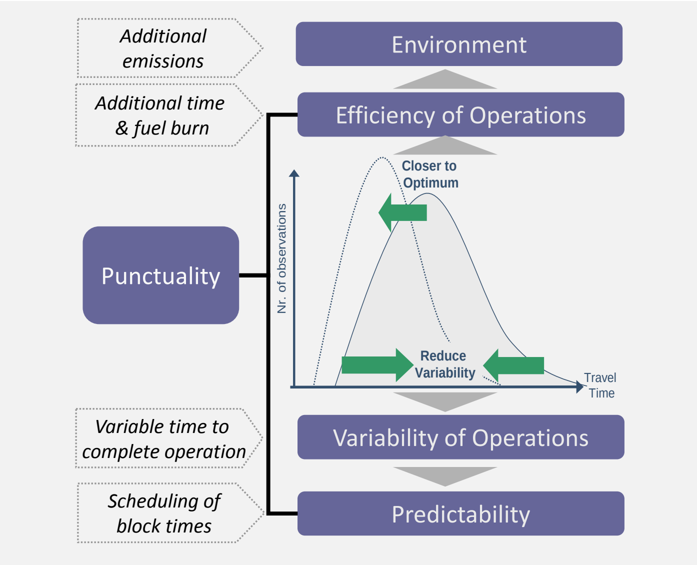
Due to inherent necessary (safety) or desired (noise, capacity, cost) limitations the reference values are not necessarily achievable at system level and therefore ATM-related 'inefficiencies" cannot be reduced to zero.

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 utilisation of capacity (en route and airport), and the environment (emissions).

The overarching goal is to minimise overall direct (fuel, etc.) and strategic (schedule buffer, etc.) costs whilst maximising the utilisation of available en route and airport capacity.

While maximising the use of scarce capacity, there are trade-offs[34] 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. 34] .



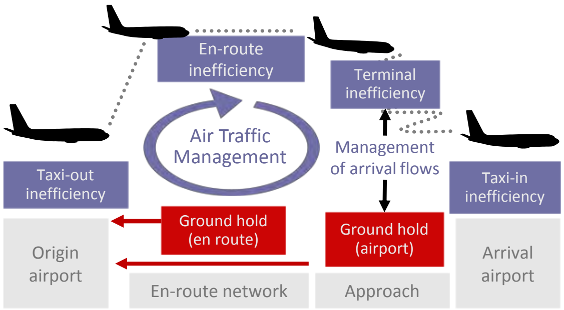
5.2 ATM-related efficiency by phase of flight

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.

34 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.

5.2.1 ATM-Related Departure Restrictions (Ground Holding)

As described in Section 2.3, the use of departure ATFM restrictions to balance capacity with demand differs between the US and Europe.



In Europe, departure ATFM restrictions are used as a primary means for en route and airport capacity shortfalls. In the US, ground delays at the departure airports are the last resort when less constraining flow measures such as MIT are insufficient.

Both the US and Europe report delay imposed on flights by the ANSP in order to achieve required levels of safety as well as to most effectively balance demand and capacity.

ATFM departure delays 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 US 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.

Mapping of ATFM delay causes

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

EUR Code	ATFM reason code (NM)	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 airport capacity	VOLUME
V	V-Environmental Issues	Noise restrictions	RUNWAY
I	I-Industrial Action (ATC)	Controllers' strike	OTHER
R	R-ATC Routeing	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 flights with ATFM delays larger than 15 minutes were included in the analyses in this section[35]. The delays are calculated with reference to the estimated take-off time in the last submitted flight plan (not the published departure times in airline schedules).

Figure 5.2 below tracks total ATFM delay (en route and terminal) per flight between 2008 and 2013. For other than 2010, which was a historically bad weather year for Europe, average ATFM delay has been on the decline since 2008. 2010 was also a bad year for Europe in terms of industrial actions by ANSPs.

35 The FAA values are for flights with ATFM delays greater than or equal to 15 minutes.

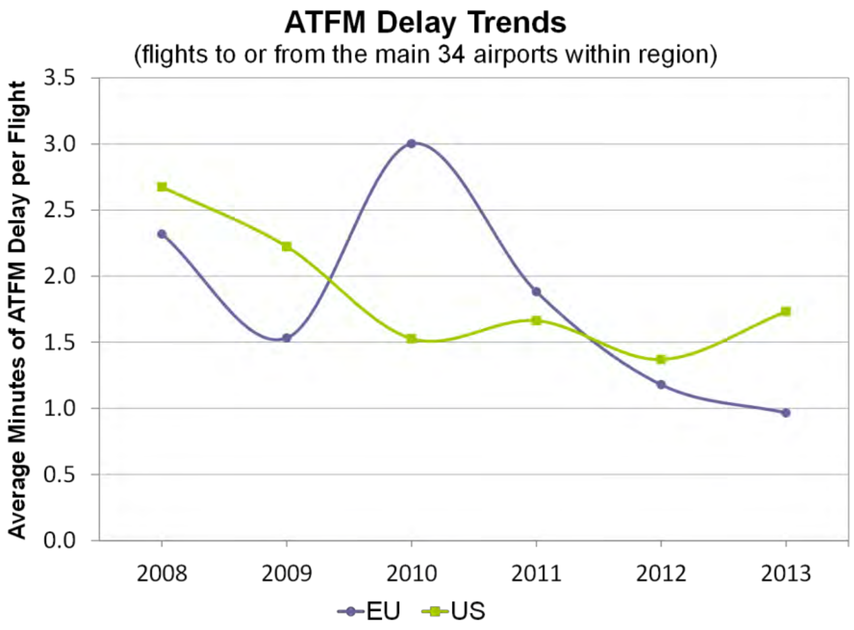


Figure 5.2: Evolution of total ATFM delay per flight (2008-2013)

The US has also shown a decline since 2008 which largely reflects improving weather and declining traffic levels. However from 2012 to 2013, even with a moderate decline in overall traffic, ATFM delay in the US increased by 25% while European ATFM delay decreased by 20.6%.

Figure 5.3 below shows this change from 2012 to 2013 both in absolute terms and by causal factor. In the US, the increase was largely due to weather (principally increased thunderstorm activity) while European decline is mostly attributable to an improvement in capacity.

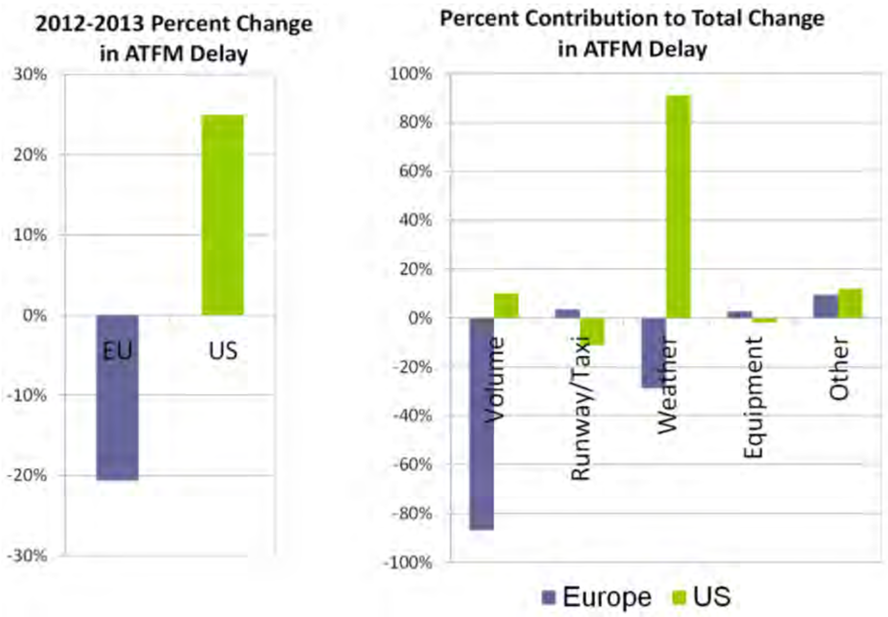


Figure 5.3: Percent change in ATFM delay by cause (2013)

Table 5-1 compares ATM-related departure restrictions imposed in the two ATM systems due to en route and airport constraints.

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

Only delays > 15 min. are included.		EUROPE				US (CONUS)			
		2008	2010	2012	2013	2008	2010	2012	2013
	IFR flights (M)	**5.5**	**5.0**	**4.9**	**4.8**	**9.2**	**8.6**	**8.4**	**8.3**
En route related delays >15min. (ATFM)	% of flights delayed	5.0%	5.8%	1.9%	1.4%	0.8%	0.5%	0.6%	0.6%
	delay per flight	1.4	1.9	0.5	0.4	0.3	0.2	0.2	0.2
	delay per delayed flight	28	32	28	31	41	37	37	37
Airport related delays >15min. (ATFM)	% of flights delayed	2.8%	3.1%	2.0%	1.7%	4.3%	2.5%	2.2%	2.6%
	delay per flight	0.9	1.1	0.6	0.5	2.3	1.3	1.2	1.5
	delay per delayed flight	32	36	32	33	55	53	53	57

As was expected, the share of flights affected by departure ground restrictions at origin airports differs considerably between the US and Europe. Despite a reduction from 5% in 2008 to 1.4% in 2013, flights in Europe are still over twice more likely to be held at the gate or on the ground for en route constraints than in the US where the percentage decreased slightly to 0.6% of flights. The significant improvement in Europe in 2013 is partly due to lower traffic levels than in 2008 but also due to an increased focus on this average ATFM en route delay per flight indicator in the first reference period of the Single European Sky performance scheme (2012-2014).

For airport related delays, the percentage of delayed flights at the gate or on the surface is higher in the US than in Europe. The delay per delayed flight in the US is almost twice as high as in Europe.

The reason for this is that in the US, ground delays due to en route constraints are rarely required and airport related ground delays are only applied after Time Based Metering or Miles In Trail options are used which consequently leads to a lower share of flights affected by ATFM delays but higher delays per delayed flight than in Europe.

In Europe, ground delays (ATFM) are used much more frequently for balancing demand with en route and airport capacity, which consequently leads to a higher share of traffic affected but with a lower average delay per delayed flight. The results in Table 5-1 are consistent with the differences in the application of flow management techniques described in Chapter 2.3.

Whereas in the US, en route delays are mostly driven by convective weather (see Figure 5.4), in Europe they are mainly the result of capacity and staffing constraints (and industrial actions in 2010) driven by variations in peak demand (see large differences between summer and winter in Europe in Figure 3.4 and Figure 3.5 on page 33).

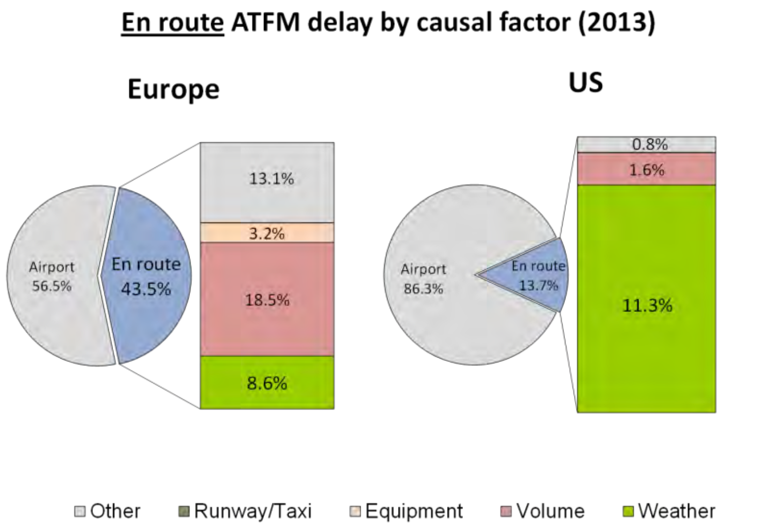


Figure 5.4: Breakdown of en route ATFM delay by cause (2013)

At system level, the causes for airport-related ATFM delays are similar in both the US and Europe. Weather is the predominant driver of ATFM delays in both Europe and the US (Figure 5.5).

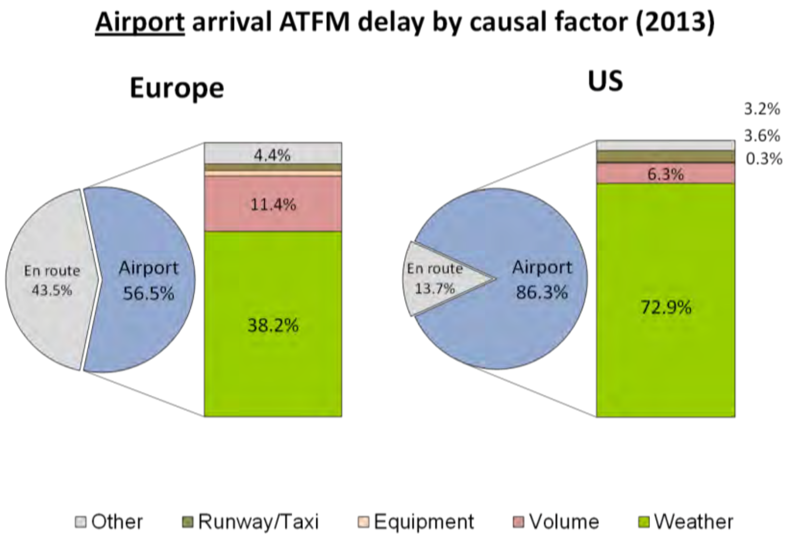


Figure 5.5: Breakdown of airport arrival ATFM delay by cause (2013)

Figure 5.6 compares the average minutes of airport-related ATFM departure delays attributed to the constraining destination airport. The airports are sorted in descending order by number of ATFM delay minutes; however, airports with a high number of flights will show lower average ATFM delays.

In Europe, delays are more evenly spread across airports with London (LHR), Amsterdam (AMS), Zurich (ZRH), Frankfurt (FRA), and Geneva (GVA) being the most constraining ones.

For the US, approximately 79% of the total delay minutes are concentrated at six airports in the US: Chicago (ORD), Newark (EWR), New York (LGA), San Francisco (SFO), Philadelphia (PHL), and New York (JFK).

From Figure 5.6, it can be seen that flights to New York-LaGuardia (LGA) and Newark (EWR) have average ATFM delay which is four times higher than London Heathrow (LHR). However for LGA, approximately 7 out of every 10 days or 70% of the time, ATFM delays are *equal to or better* than the average annual delay at LHR (2.25 minutes per flight). Furthermore, 96% of the total ATFM delay was taken in the remaining 3 out of 10 days that had an average greater than 2.25 minutes. At EWR, 6 out of 10 days have average delays of 2.25 minutes per flight or better. At both US airports, over 90% of the ATFM delay is caused by weather.

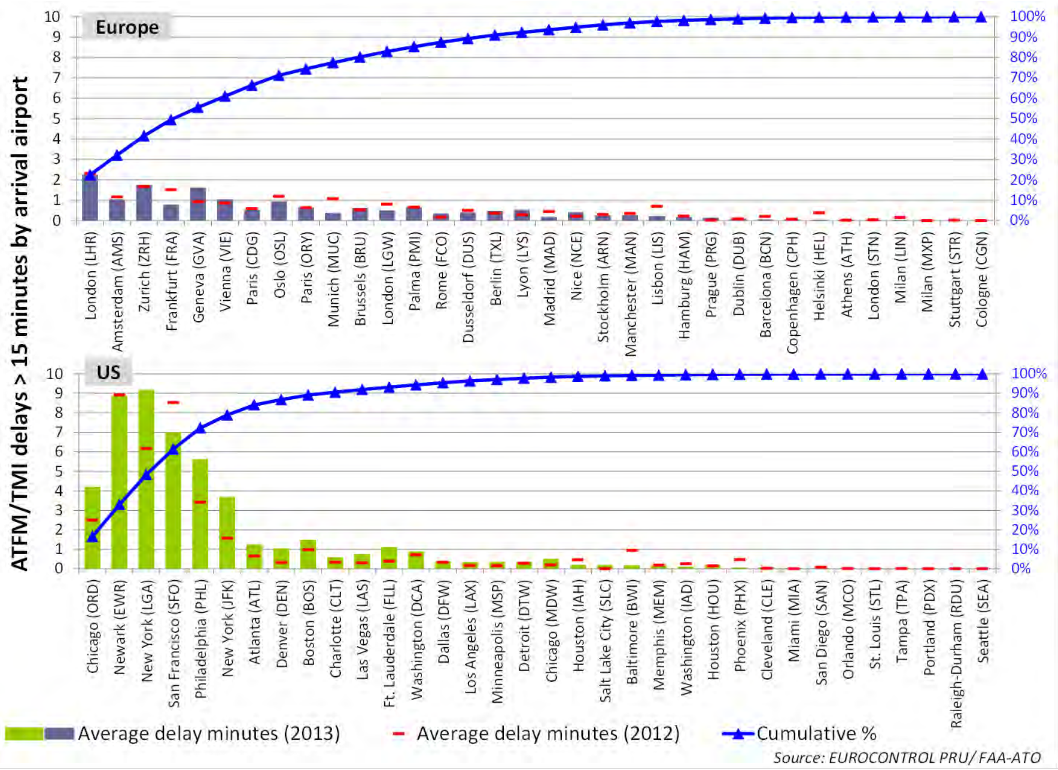


Figure 5.6: Airport charged ATFM delay by destination airport (2013)

As weather is the predominant driver of ATFM delays and worse weather was experienced in 2013 than in 2012 (Figure 3.16), ATFM delay at the 34 main US airports has also increased in 2013 compared to 2012. The US airport responsible for adding the most ATFM delay in the system from 2012 to 2013 is Chicago (ORD). The airport with the greatest reduction in ATFM delay was San Francisco (SFO).

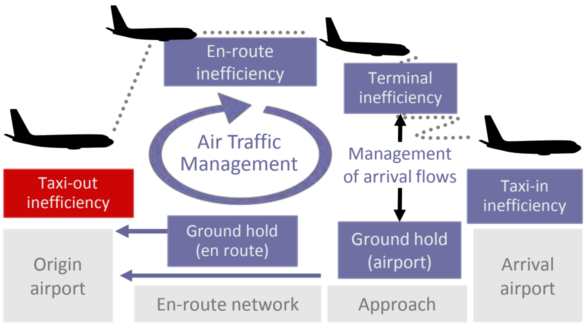
In the US, the airports which make up a large percentage of ATFM delays are also the airports having the highest capacity variation impact (see also Figure 3.14 on page 42). Since flights in the US are typically scheduled to VMC capacity, when weather conditions deteriorate, capacity at the airport is considerably reduced while demand levels remain the same. In case of a significant mismatch between demand and capacity, departure restrictions at the various origin airports are applied as a last resort.

The difference in ATFM strategy between the US 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 airborne delay (i.e. holding or extended final approaches). On the other hand, applying excessive ATFM delays risks underutilisation of capacity and thus, increases overall delay.

More analysis is needed to see how higher delays per delayed flight are related to moderating demand with "airport slots" in Europe.

5.2.2 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.



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 size[36] is considered to be the most important one for taxi-out efficiency [Ref. 35].

In the US, the additional time observed in the taxi-out phase also includes some delays due to local en route departure and MIT restrictions. 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).

In order to get a better understanding, two different methodologies were applied in Figure 5.7 and Figure 5.9. While the first method 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 US and European data. The breakdown by airport in Figure 5.9 is based on the more sophisticated methodologies by each of the performance groups in the US and Europe[37].

Three interesting points can be drawn from Figure 5.7:

- On average, additional times in the taxi-out phase appear to be higher in the US with a maximum difference of approximately 2 minutes more per departure in 2007. Between 2008 and 2012, US performance improved continuously which narrowed the gap between the US and Europe.
- In Europe, performance remained relatively stable but showed a notable deterioration in 2010, which was mainly due to severe weather conditions in winter.
- In 2013, European performance continued to improve whereas US performance deteriorated. The increase in additional taxi out times in the US may be linked to worsening weather conditions where additional time may be needed to de-ice aircraft or as a result of ATFM delay taken on the ground.
- Seasonal patterns emerge, but with different cycles in the US and in Europe. Whereas in Europe the additional times peak during the winter months (most likely due to weather conditions), in the US the peak is in the summer which is most likely linked to congestion.

---

36 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.

37 A description of the respective methodologies can be found in the Annex of the 2010 report [Ref. 2].

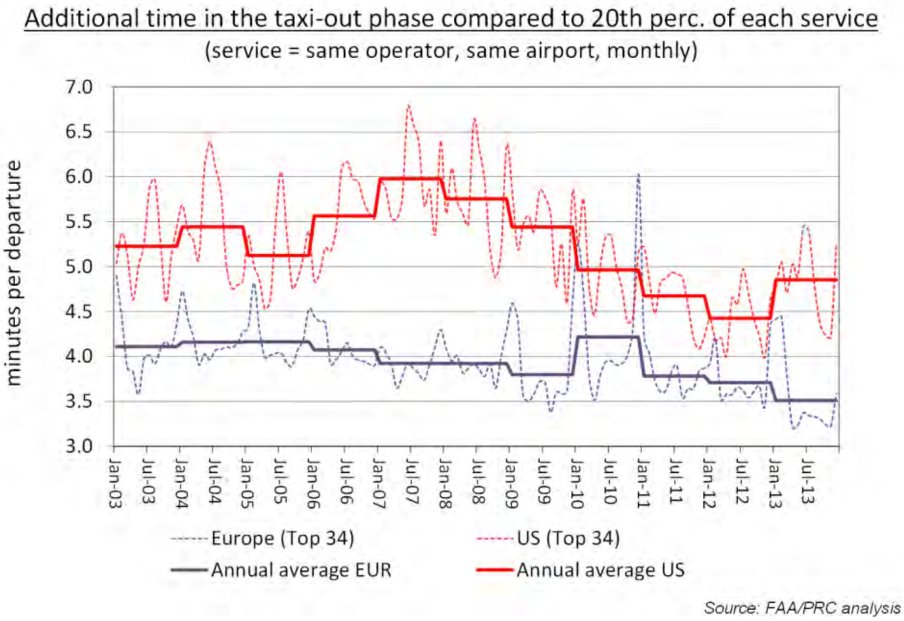


Figure 5.7: Additional times in the taxi-out phase (system level) (2003-2013)

The observed differences in inefficiencies between the US and Europe in 2008 were largely driven by different flow control policies and the absence of scheduling caps at most US airports. Additionally, the US Department of Transportation collects and publishes data for on-time departures which could add to the focus of getting off-gate on time.

Figure 5.8 below provides a system level view of the average additional minutes in the taxi out phase in the US and Europe using a more complex methodology for computing unimpeded times. Although some care should be taken when comparing the two indicators due to slightly differing methodologies, Figure 5.8 tends to confirm the trends seen in Figure 5.7. In 2013, taxi out performance at the 34 main airports in Europe improved (-0.1 minutes) whereas, performance deteriorated in the US (+0.4 minutes).

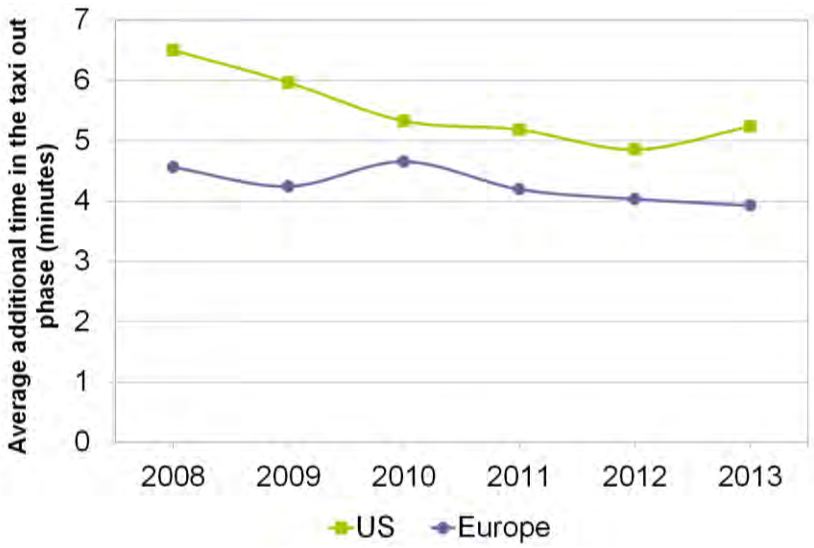


Figure 5.8 Evolution of average additional minutes in the taxi out phase (2008-2013)

The high-level result in Figure 5.8 is driven by contrasted situations among airports. Figure 5.9 shows a more detailed comparison of additional time in the taxi-out phase at the major airports in Europe and the US.

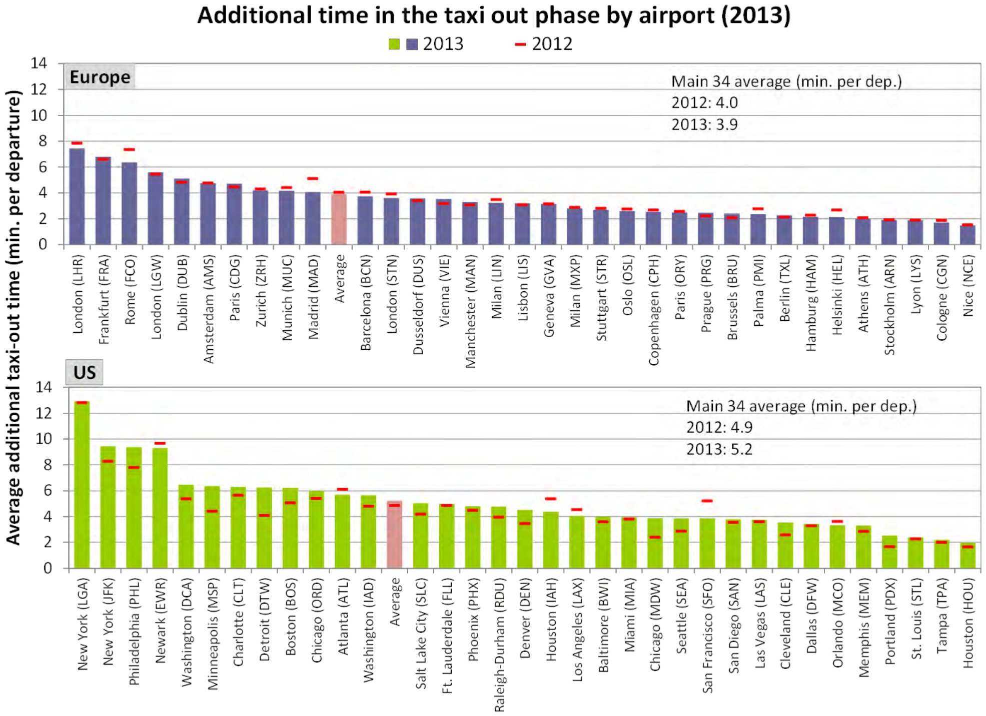


Figure 5.9: Additional time in the taxi-out phase by airport (2013)

Between 2012 and 2013, taxi-out performance improved at almost all European airports whereas performance at US airports declined. Figure 5.10 shows the difference in average additional time in the taxi-out phase by airport. The increase in additional taxi-out time at the US airports between 2012 and 2013 is driven by particularly large increases experienced on the taxi surface at Detroit (DTW), Minneapolis (MSP), Philadelphia (PHL), and Chicago (MDW). The increase in taxi-out time at many US airports can be linked to worse weather in 2013 compared to 2012. Much of the US experienced a more extended and severe winter season in 2013. San Francisco was one of the few airports with improvements in taxi-out performance.

In Europe, the improvement in taxi-out performance is a result of improvements at Frankfurt (FRA), the two London airports (LHR, STN), Madrid (MAD), and Amsterdam (AMS).

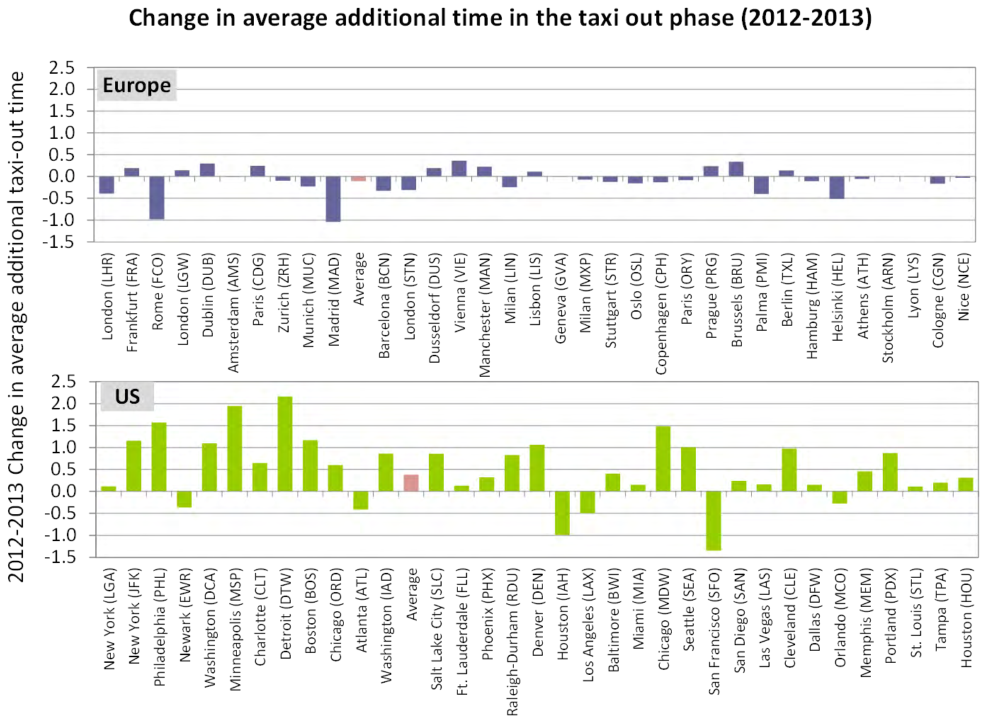


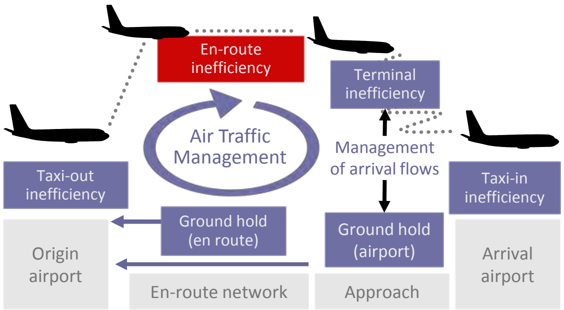
Figure 5.10: Difference in additional time in the taxi-out phase by airport (2012-2013)

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 optimise 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 maximise 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 set.

5.2.3 EN ROUTE FLIGHT EFFICIENCY

This section evaluates en route flight efficiency in the US and Europe. En route flight efficiency 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. 36]. Nevertheless there is scope for further improvement, and work on vertical en route flight efficiencies would provide a more complete picture.

The focus of this section is on the horizontal component of the en route phase. Two KPI's 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".

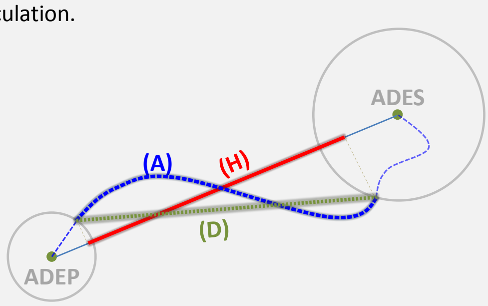
For a flight, the "inefficiency" is the difference between the length of the analysed trajectory (filed flight plan or actual flown) and an "achieved" reference distance (see also grey box). Where a flight departs or arrives outside the reference airspace, only that part inside the airspace is considered.

"En route" is defined as the portion between a 40NM radius around the departure airport and a 100NM radius around the arrival airport. The indicator is calculated as the ratio of the sum, over all flights 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.

The full methodology is described in more detail in the meta data which is available online [Ref. 37].

The methodology used for the computation of horizontal en route fight efficiency in this report is consistent with the flight efficiency indicators used in the Single European Sky performance scheme (described on page 11).

The flight efficiency in the last 100NM before landing which also includes airborne holdings is addressed in the next section of this report (5.2.4).

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.

Deviations from the "optimum" trajectory generate additional flight time, fuel burn and emissions with a corresponding impact on airspace users' costs and the environment. At present, performance databases do not contain an airline preferred "optimum" trajectory submitted by airlines which would take all the aforementioned criteria into account. It is possible that future ATC systems could provide this more detailed data that could establish benchmark trajectories according to weather, aircraft weight and user preferences.

In the absence of this additional data, the computation of flight efficiency compared to achieved distance is a stable indicator which provides valuable information on the overall level of flight efficiency. It is based on a direct flight idea which serves as a surrogate to an ideal trajectory.

The two KPIs refer to two separate domains: planning and operations. En route flight efficiency (flight plan and actual) can be affected by a large number of factors including:

- Route network design;
- Route availability (utilisation of civil military structures);
- Airspace user flight planning (use of software, etc.);
- Airspace user preferences (time, cost, fuel);
- Tactical ATC routings; and,
- Special events such as severe weather, ATC strikes.

Figure 5.11 below shows the evolution of horizontal en route flight efficiency (actual and flight plan) compared to achieved distance between 2008 and 2013. An "inefficiency" of 5% means for instance that the extra distance over 1000NM was 50NM. Due to data availability, the KPIs for Europe are only shown as of 2011.

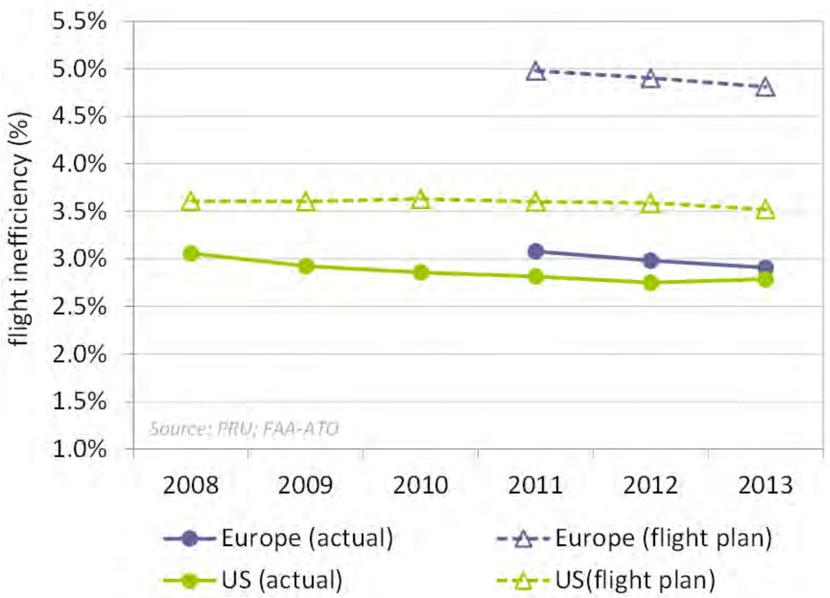


Figure 5.11: Evolution of horizontal flight efficiency (actual and flight plan) (2008-2013)

There are several differences between the US and Europe that can be seen in the en route phase of flight. Although much smaller in the US, there is a notable gap between flight plan and actual flight inefficiency in the US and in Europe. The difference between planned and actual operations reveals that 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.

Figure 5.12 Actual and flight plan trajectories from San Francisco to Los Angeles

In general the US reports less "inefficiency" in this area. Although Europe has been on a downward trend for both indicators, European airlines file on average almost 5% greater than their achieved distance compared to 3.5% in the US. For the US, many of the heaviest travelled city pairs such as SFO to LAX (see Figure 5.12) or Chicago to the New York area both file direct flight and achieve direct flight for the majority of flights.

The largest difference between flight plan and actual trajectory in the US is observed for city pairs impacted by special use airspace. This includes Las Vegas to San Francisco as well as East Coast flights operating into and out of the Florida airports. High values for this KPI in Europe may also be due to effects of SUA (see section 2.2.2 on page 19 and examples in Figure 5.17 of this section) or as a result of a charging scheme that encourages the filing of longer routes. However when actuals are compared, the gap is much more narrow and much less in terms of an efficiency score.

ACTUAL TRAJECTORY VS. ACHIEVED DISTANCE

The level of total horizontal en route flight inefficiency [(A-H)/H] for flights to or from the main 34 airports in Europe in 2013 was 2.91% compared to 2.71% in the US. Figure 5.13 depicts the en route extension for flights to/from the main 34 airports with total flight efficiency broken into terminal effects [(D-H)/H] and en route effects [(A-D)/H].

The flight population is for within the respective region (Intra Europe, US CONUS) with the respective share of flights shown at the bottom of Figure 5.13. For both the US and Europe, flight inefficiency decreases relative to the flight distance.

Overall, horizontal en route flight in-efficiency on flights to or from the main 34 airports in Europe is 0.20% higher than in the US in 2013. Due to the changes in methodology and data in Europe, the figure is not directly comparable to the figures published in the first two editions of the report.

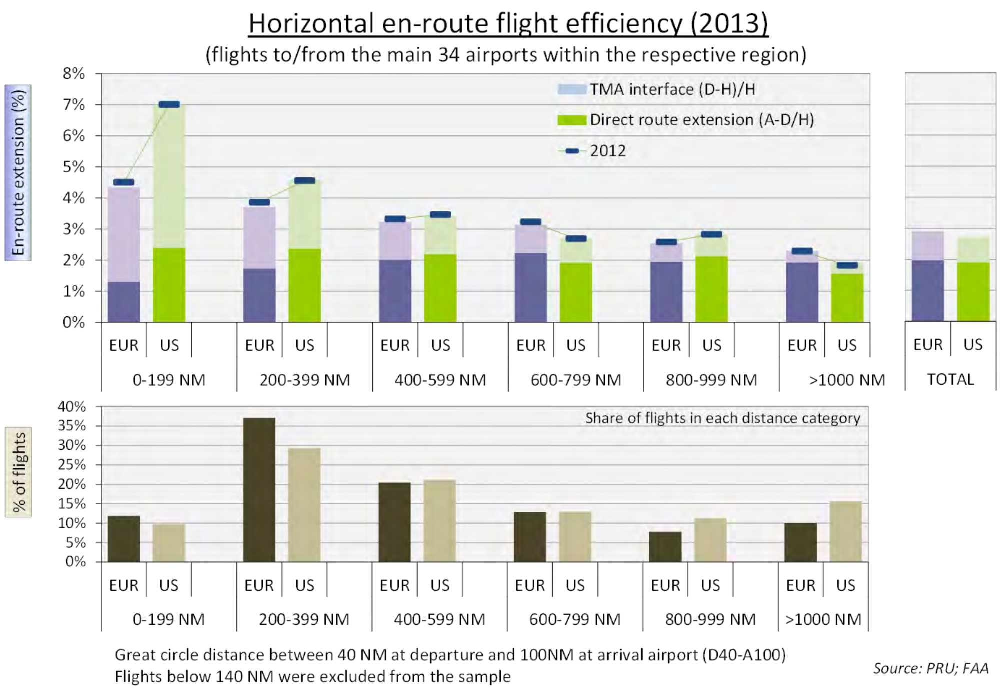


Figure 5.13: Comparison of total en route extension by component (2013)

The high-level result in Figure 5.13 is driven by contrasted situations among airports. Figure 5.14 shows the direct en route extension on flights arriving at the main US and European airports. The results show both magnitude (A-D) and percent [(A-D)/H]. Note that US flights for this population (607 NM) are longer on average than Europe (480 NM) as shown earlier in Table 3-2. Identical A-D values would result in a lower percent inefficiency for the US. Direct route extension (A-D) is predominantly driven by ATC routing (flow measures such as MIT but also more direct routing), route utilisation (route selection by airspace users), and en route design (route network).

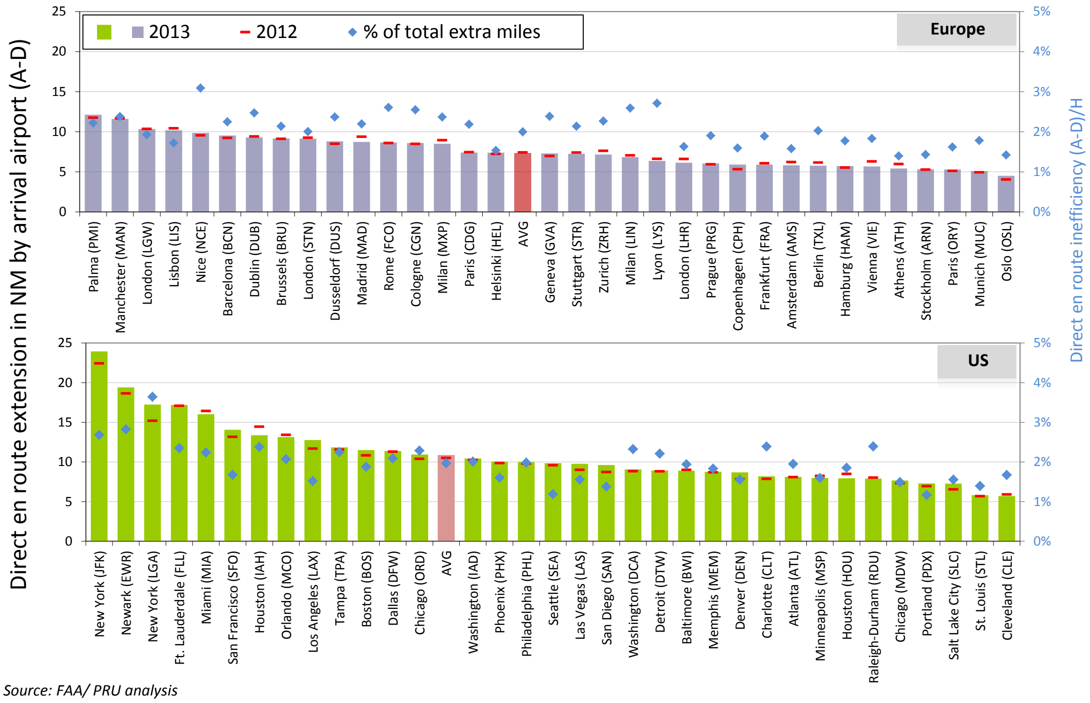


Figure 5.14: Direct en route extension by destination airport

US 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. Almost all direct flights between the New York area and Florida airports would require flight through special use airspace. This is illustrated in Figure 5.17 below. 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. Alternatively, 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 US is higher due to the longer flights but in relative terms the level of flight inefficiency is lower (i.e. inefficiency per flown distance). This is consistent with the observation in Figure 5.13.

Improvements in 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. In view of the fragmented European ATM system, a harmonised and well-coordinated implementation of initiatives aimed at improving the route network at system level is more difficult to achieve in Europe than in the US where only one entity is responsible for the optimisation of the route network.

For instance, the implementation of "Free Route Airspace (FRA) initiatives" in Europe aims at enhancing en route flight efficiency with subsequent benefits for airspace users in terms of time and fuel and a reduction of CO_2 emissions for the environment. FRA initiatives in Europe have been implemented in Ireland, Portugal, Sweden and Denmark and also partly in Finland, Poland, the Czech Republic, Austria, Croatia, Serbia, FYROM (Macedonia), and the en route centres, Maastricht and Karlsruhe. By the end of 2013, 23 of the 63 ACCs had implemented various steps of Free Route Operations. At present, airspace improvements are documented in the European Route Network Improvement Plan (ERNIP) [Ref. 38].

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.

The aim of the FRA Concept Document is to provide a consistent and harmonised framework for the application of FRA across Europe in order to ensure a co-ordinated approach.

The resulting benefits are clearly visible in Figure 5.15. The left map shows the filed flight plans for a typical weekday in May 2013. The higher degree of flexibility for flight planning is clearly visible as the flight plan trajectories are much more scattered in those areas where FRA has been implemented (red arrows). The brown areas in Figure 5.15 represent restricted/segregated airspace (see also next section).

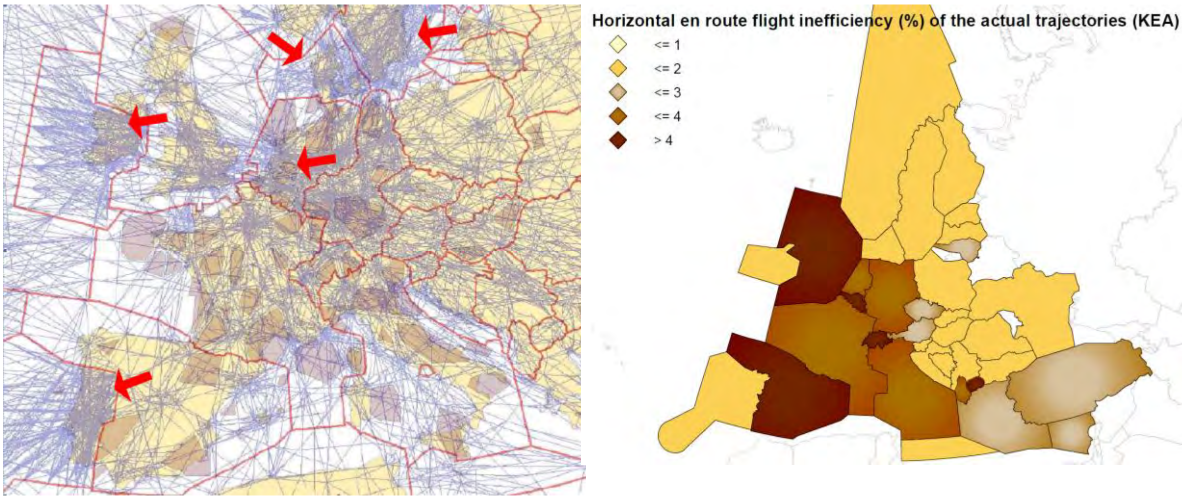


Figure 5.15: Flight efficiency improvements from free route implementation

The right side of Figure 5.15 shows the level of inefficiency (%) of the actual trajectories (KEA). The efficiency differences though the implementation of free route airspace are clearly visible in Scandinavia and by comparing the UK with Ireland or Portugal with Spain.

In the US, the FAA Metroplex project is working to reorganise airspace in the largest metro airports in the US. This project will work to create new standard arrival and departure routes that eliminate today's inefficiencies. The advanced routing capability afforded through NEXTGEN will permit procedure design that will reduce or eliminate inefficient routes and the need to carry additional fuel for the longer distances flown. More efficient departure profiles using NEXTGEN and area navigation capabilities will expedite the transition of aircraft to their desired route.

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 charges[38], avoid congested areas) affect en route flight efficiency.

En route flight inefficiencies are predominantly driven by (1) route network design (2) route availability, (3) route utilisation (route selection by airspace users) and (4) ATC measures such as MIT in the US (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;

---

[38] In Europe, the route charges differ from State to State.

- Strategic constraints on route/ airspace utilisation. Figure 5.16 shows a potential route extension on flights between Dallas Fort-Worth (DFW) and Newark (EWR). This example is consistent with other Texas to New York Area traffic. In these cases, the more northern traffic is joining a stream from ORD/MDW which is nearly direct.

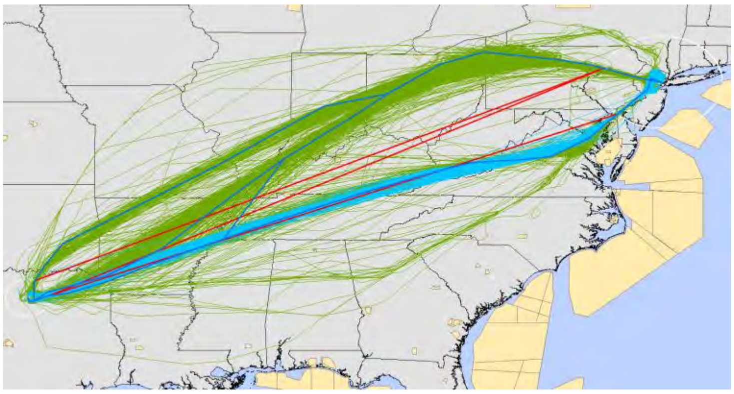


Figure 5.16: Flows into congested airspace

- Figure 5.17 illustrates the impact of Special Use Airspace (SUA) on flight efficiency. The example of the Zurich to Amsterdam route for May 2013 is shown on the left side of the figure. The trajectories of the filed flight plans are shown as dark blue lines whereas the actual trajectories are superimposed in purple. Almost all flights are planned to fly around the restricted/ segregated areas shown in green. However, the actual trajectories then cut through the special use airspace. The difference between flight plan and actual trajectory for this example is 11% which is considerable.

  The figure on the right is representative of the Florida to New York routings and shows actual trajectories in green and red compared to the most used flight plans in blue. While there is some opportunity for direct flight off the southern states of Florida and Georgia, the special use airspace off of the mid-Atlantic states is largely avoided.

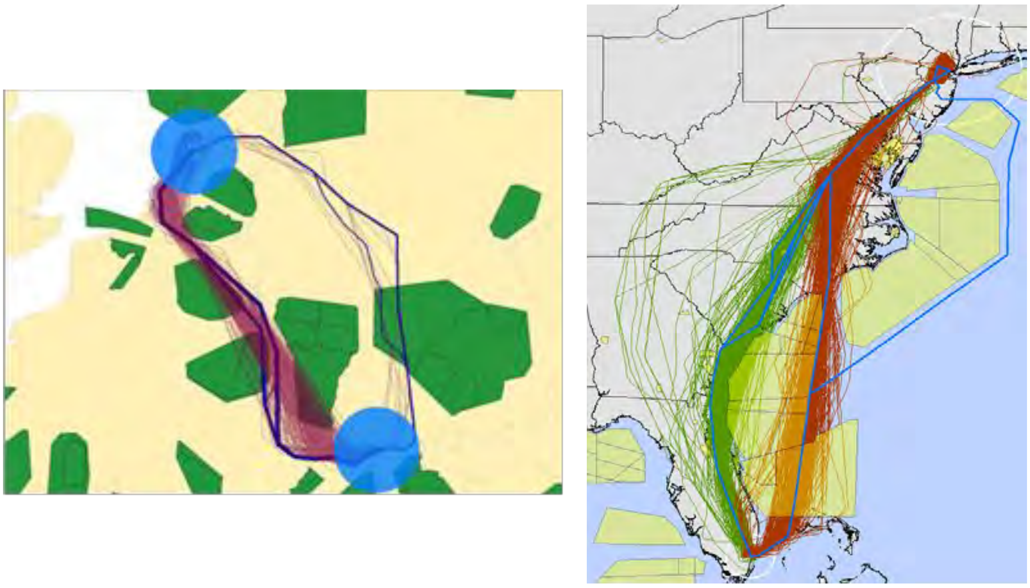


Figure 5.17: Impact of Special Use Airspace (SUA) on horizontal flight efficiency

- Interactions with major airports. Major terminal areas tend to be more and more structured. As traffic grows, departure traffic and arrival traffic are segregated and managed by different sectors. This TMA organisation 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 utilisation 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) [Ref. 39].

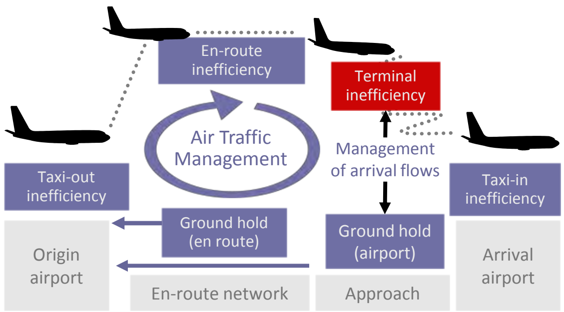
- For the US, the indicator additionally includes some vectoring due to MIT restrictions.

- Lastly, planned cruise speeds or altitudes are not known by ATC systems and may require detailed performance modelling or information on airline intent.

While technologies, concepts, and procedures have helped to further optimise 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.

5.2.4 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.

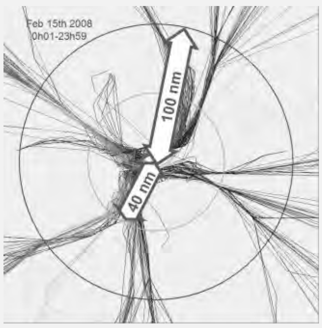
Hence, in order to capture tactical arrival control measures (sequencing, flow integration, speed control, spacing, stretching, etc.) irrespective of local ATM strategies, a standard Arrival Sequencing and Metering Area (ASMA) was defined (see grey box for explanation). For the analyses, the 100NM ring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

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.

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.



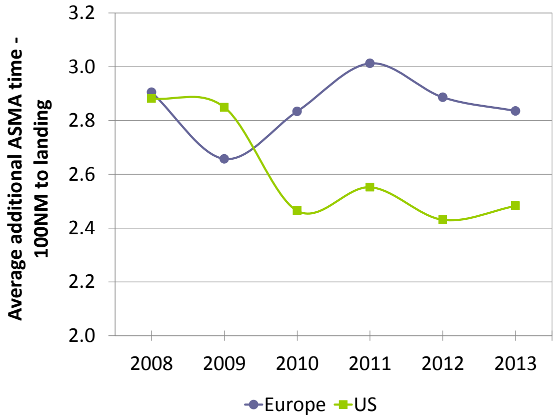


Figure 5.18: Evolution of average additional time within the last 100 NM (2008-2013)

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 times are developed for each arrival fix, runway configuration and aircraft type combination.

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.

Figure 5.18 shows the evolution of average additional time within the last 100 NM for the US and Europe from 2008 to 2013. At system level, the additional time within the last 100 NM was similar in the two regions in 2008 but has declined at a faster rate in the US since that time. Both, the US and Europe report lower values in 2013 relative to 2008. However, the picture is contrasted across airports. Figure 5.19 shows the average additional time within the last 100 NM by airport in 2013. The difference in average additional time within the last 100 NM by airport is reported in Figure 5.20.

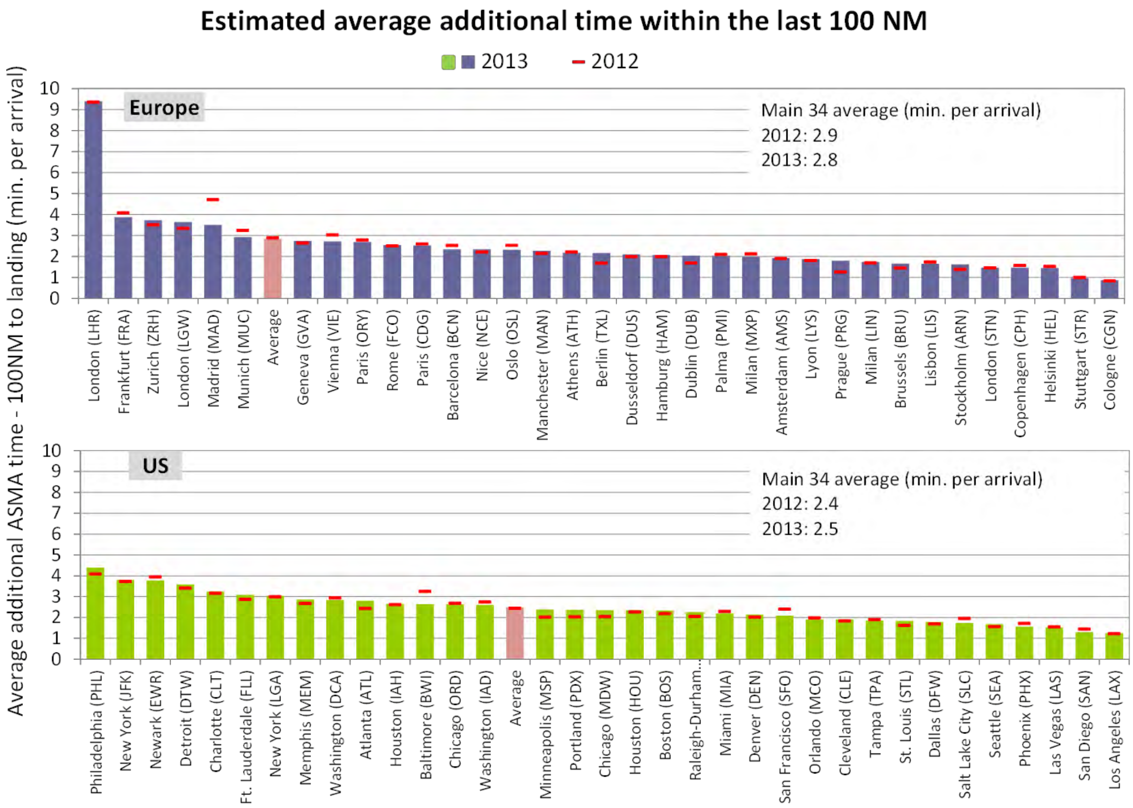


Figure 5.19: Estimated average additional time within the last 100 NM (2013)

In Europe, London Heathrow (LHR) is a clear outlier[39], having by far the highest level of additional time within the last 100 NM, followed by Frankfurt (FRA), Zurich (ZRH), London Gatwick, and Madrid (MAD) which show less than half the level observed at London Heathrow. London (LHR) alone accounted for over 20% of all the additional time observed at the main 34 European airports in 2013. As seen in Figure 5.20, Prague (PRG) and Berlin (TXL) are two European airports where increases in average additional time in the last 100 NM were reported from 2012 to 2013. A notable decrease in additional time was reported at Madrid (MAD).

The US showed a modest increase in system average from 2012 to 2013 and less contrast in additional time reported among airports. 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. Figure 5.20 below shows that all US airports reported a change of less than half a minute in additional time within the last 100 NM from 2012 to 2013 with the exception of Baltimore (BWI).

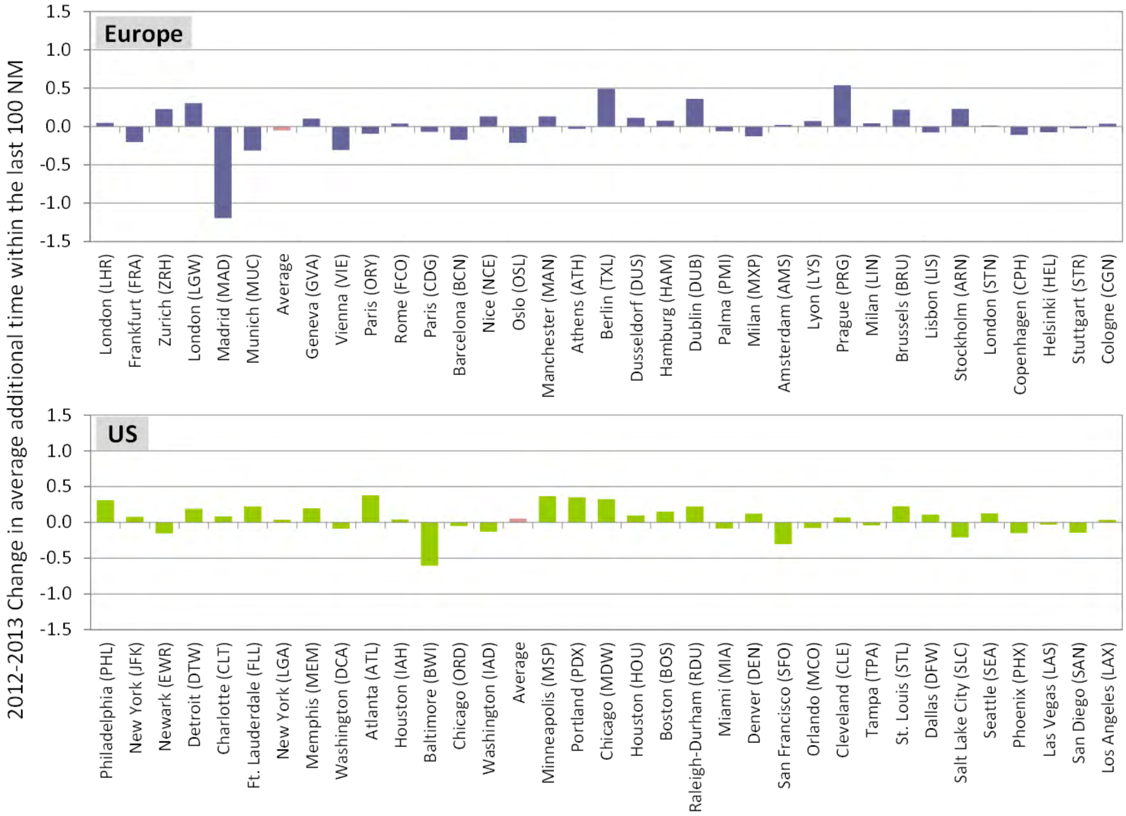


Figure 5.20: Difference in average additional time within the last 100 NM (2012-2013)

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 US air traffic management system is the ability to maximise airport capacity by taking action in the en route phase of flight, such as in trail spacing. Larger ATFM delay in the US also may indicate that much of this additional time is pushed back to the departure airport and taken on the ground.

---

39 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.

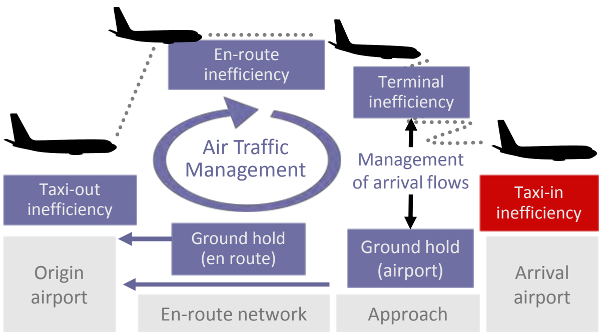
In Europe, the support of the en route function is limited and rarely extends beyond the national boundaries. Hence, most of the sequencing and holding is done at lower altitudes around the airport. Additional delays beyond what can be absorbed around the airport are taken on the ground at the departure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

The impact of the respective air traffic management systems on airport capacity utilisation in the US and in Europe is not quantified in this report, but 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.

5.2.5 TAXI-IN EFFICIENCY

The analysis of taxi-in efficiency in this section refers to the period between the time when the aircraft landed and the time it arrived 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 5.21 mirrors the methodology applied for taxi-out efficiency in Figure 5.7. 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 US and European data.

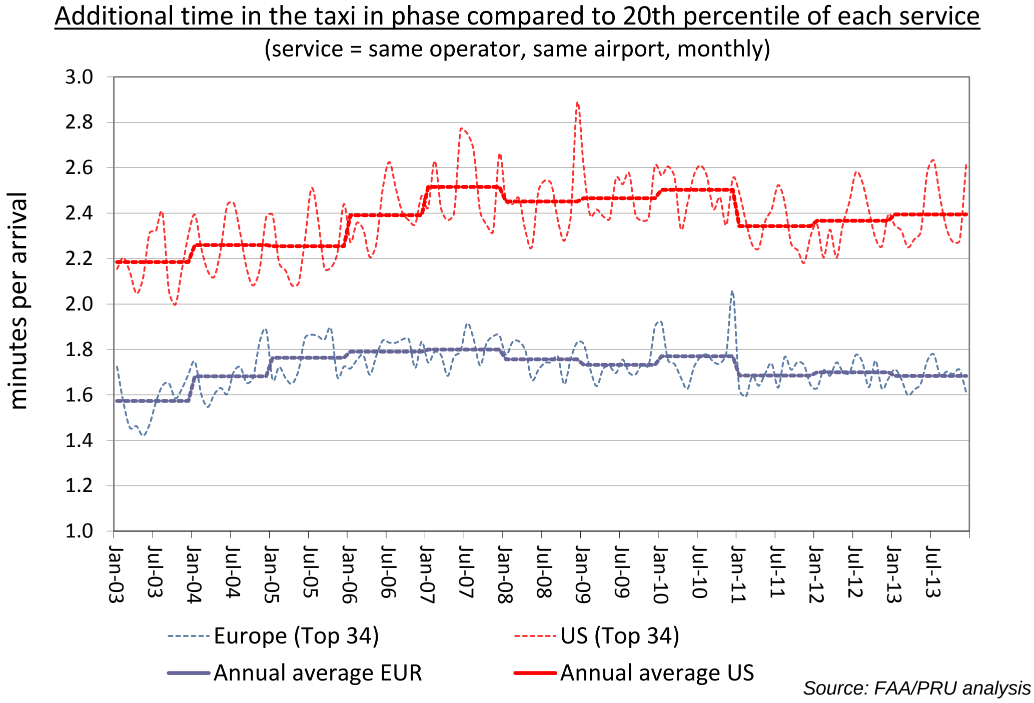


Figure 5.21: Additional times in the taxi-in phase (system level) (2003-2013)

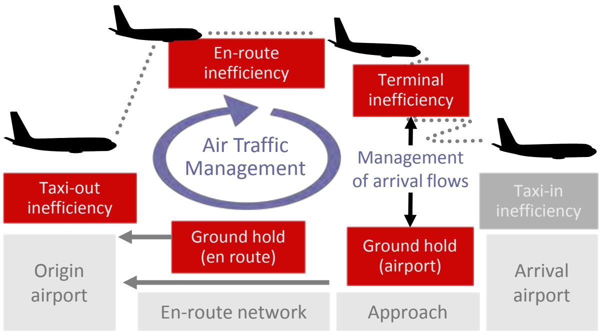
As can be observed in Figure 5.21, at system level, additional time in the taxi-in phase is slightly higher in the US than in Europe but remains relatively stable over time in both systems. Some seasonal patterns are visible (particularly in the US) where an increase can be noted during summer.

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.).

It 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 estimated benefit pool actionable by ATM in Chapter 5.3.

5.3 Summary of main results & Estimated 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 estimated benefit pool for a typical flight, based on the analysis of traffic from and to the 34 main airports in Europe and the US.

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 estimated benefit pool actionable by ATM. For the interpretation of the estimated 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 underutilisation 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 maximise 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 85).
- 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 optimise 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 (un-congested 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.

5.3.1 Estimated benefit pool actionable by ATM

By combining the analyses for individual phases of flight in Section 5.2, an estimate of the "improvement pool" actionable by ATM can be derived. It is important to stress that this "benefit pool" represents a theoretical optimum (averages compared to unimpeded times), which is not achievable at system level due to inherent necessary (safety) or desired (capacity) limitations[40].

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 ATFM/TMI	High	OFF	Quasi nil	Time
		En route ATFM/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 (ATFM/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 (i.e. "tactical" delays) but the impact on fuel burn and the environment is negligible. It is however acknowledged that – due to the first come, first served principle[41] 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

---

40 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.

41 "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.

related to inefficiencies embedded in the route network or congestion levels which are similar every day. From an airspace user point of view, the impact on on-time performance is usually low as those inefficiencies are usually already embedded in the scheduled block times ("strategic delays") 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 minimise fuel burn and reducing greenhouse gas emissions[42].

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 utilisation.

Previous research [Ref. 40] shows that at system level, the total estimated benefit pool actionable by ATM and associated fuel burn are of the same order of magnitude in the US and Europe (approx. 6-8% of the total fuel burn).

Table 5-3 summarises the current best estimate of the ATM-related impact on operating time. The inefficiency estimate is based on the best available radar trajectories and airline reported surface times available to FAA and EUROCONTROL.

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.

Estimated 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 33).

Those differences would 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 travels an average distance of 450NM in each ATM system.

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

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, estimated benefit pool actionable by ATM in Table 5-3 is based on the assumption that the same aircraft type performs a flight of 450NM in the en route phase in the US and the European ATM system (see also grey box for more information).

Although in a context of declining traffic, system wide ATM performance improved considerably in the US and in Europe over the past five years. The resulting savings in terms of time and fuel in both ATM systems had a positive effect for airspace users and the environment.

---

42 The emissions of CO_2 are directly proportional to fuel consumption (3.15 kg CO_2 /kg fuel).

Overall, ATM performance in the US improved at a higher rate than in Europe over the past five years making the two ATM systems comparable in terms of total estimated average additional time in 2013. The distribution of the estimated benefit pool along the phase of flight is consistent with the differences in flow management strategies described throughout the report.

Table 5-3: Estimated benefit pool actionable by ATM (2013 vs. 2008)

Estimated benefit pool actionable by ATM for a typical flight (flights to or from the main 34 airports)		**Estimated average additional time (min.)**						**Fuel burn**	**Estimated excess fuel burn (kg)**[43]			
		EUR			**US**			engines	**EUR**		**US**	
		2008	**2013**		**2008**	**2013**			**2008**	**2013**	**2008**	**2013**
Holding at gate per departure (only delays >15min. included)	en route-related (% of flights)	1.4 (5.0%)	0.4 (1.4%)	↓	0.3 (0.8%)	0.2 (0.6%)	→	OFF	≈0	≈0	≈0	≈0
	airport-related (% of flights)	0.9 (2.8%)	0.5 (1.7%)	↓	2.3 (4.3%)	1.5 (2.6%)	↓	OFF	≈0	≈0	≈0	≈0
Taxi-out phase (min. per departure)		4.6	3.9	↓	6.5	5.2	↓	ON	68	59	98	79
Horizontal en route flight efficiency		2.4[44]	1.8	↓	1.9	1.8	↓	ON	108	84	87	81
Terminal areas (min. per arrival)		2.9	2.8	↓	2.9	2.5	↓	ON	119	116	118	102
Total estimated benefit pool		12.1	9.5	↓	13.8	11.2	↓		296	259	303	261

The improvement in Europe over the past five years was mainly driven by a reduction of en route ATFM delay at the departure gates and improvements in the level of horizontal flight efficiency.

For the US, a remarkable improvement of taxi-out efficiency and a substantial reduction of airport related ATFM (gate) delays can be observed between 2008 and 2013. The notable reduction in the gate to gate phase (mainly taxi-out efficiency) not only considerably reduced the additional time but also additional fuel burn.

Inefficiencies in the vertical flight profile for en route and in the TMA departure phase (40NM ring around the departure airport) was not analysed in more detail in this report. The magnitude can change by region or airport and it is acknowledged that there is scope for future improvement in those areas as well as a need to include them in future benefit pool estimations in order to get an even more complete picture. With continued adoption of higher fidelity data, the assessment of those flight phases may be more readily accomplished on a system wide scale in the future.

However, just as there are facets of the benefit pool 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.

43 Fuel burn calculations are based on averages representing a “standard” aircraft in the system.

44 The EUR 2008 figure is based on an estimate as the radar data was not yet available at system level in 2008.

6 CONCLUSIONS

This report represents the fourth in a series of operational performance reports between the FAA and Europe. The current report highlights system trends from 2008 while focusing on recent changes that have occurred from 2012 to 2013. This section summarises the high level conclusions for the key fundamental changes that have occurred including those that are most believed to affect performance.

In order to ensure comparability, the detailed analyses of ATM-related operational performance by flight phase were limited to flights to or from the main 34 airports in the US and in Europe.

6.1 Staffing and Infrastructure

Staffing and facility comparisons provide a first order look at the investment needed to manage the operations to a target level of performance. This report utilizes the ATCOs in operation definition employed by the EUROCONTROL ACE and CANSO benchmarking reports. Under this definition, full time equivalent (FTE) ATCOs are defined as participating in an activity that is either directly related to the control of traffic or is a necessary requirement for ATCOs to be able to control traffic. Also reported are the controllers designated as “on-the-job training” in Europe or as a “developmental” at the FAA. According to the FAA controller workforce plan, a “developmental” controls live traffic with an ability to staff a limited subset of the positions at a facility.

Using these definitions, the US operated with 22 percent less full time ATCOs than Europe in 2013. This percentage narrows to 17% less ATCOs when FAA developmental controllers are considered. Although there are undoubtedly less total ATCOs in the US than in Europe, more work is needed to compare European “on-the-job training” controllers with FAA developmentals in order to draw firmer conclusions on the staffing comparisons in both systems.

For the ATM system, Europe shows a higher level of fragmentation and operates with more physical facilities than the US. The European study region comprises 37 ANSPs (and a similar number of different regulators) and 63 Area Control Centres (ACC). In contrast, the US has one ANSP and 20 Air Route Traffic Control Centres (ARTCC). The US has 163 Terminal Radar Approach Control Facilities (TRACONs) and Combined Facilities servicing a number of airports each, compared to Europe’s 260 Approach control units (APPs). Some TRACONs in the US are so large in terms of size of airspace and service provided that they could be compared to some of the lower airspace en route ACCs in Europe.

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 FABs under Single European Sky initiative), ATM is still largely organised according to national boundaries which is reflected by the considerably higher number of en route centres than in the US and a diversity of flight data processing systems.

Moreover, all States in Europe have their individual military needs and requirements that need to be accommodated within their respective national airspace. This contrasts with the ATM system in the US where only one single service provider (FAA) is responsible for the organisation, coordination, and development of a single airspace. As a consequence, there is a notable difference in the number and location of Special Use Airspace (SUA). In Europe, the number of

SUA is higher and they are more scattered which potentially affects the level of flight inefficiency from the system point of view.

Flight lengths were higher in the US than in Europe for traffic between the main airports that were assessed. This has some effect on the variability indicators and the horizontal flight efficiency indicators. Specifically, longer flights will have higher variability due to the effects of winds and other variables that cannot be predicted with certainty.

6.2 External Interdependencies (Demand, Capacity and Weather)

Changes in demand, capacity as provided by the airport and weather will influence many of the performance indicators in this report and often mask the effect of changes in ATM. From 2012 to 2013, the US and Europe reported modest changes in demand and capacity. Overall demand declined in the US and Europe while capacity remained relatively constant. Good weather as measured by ceiling and visibility criteria declined in both regions from 2012 to 2013. However, an analysis on weather-related ATFM delay reveals an increase in delay in the US and a decrease in Europe. These differing trends despite worse weather as measured by ceiling and visibility may be due to different sensitivity levels of weather on operations and capacity, in addition to the different capacity declaration processes and preferences in the two regions. Changes in the KPIs as discussed in Section 6.3 must be seen in context with the external factors experienced at the individual airports.

In terms of traffic, the US airports with the highest decrease in traffic include Memphis (MEM), Denver (DEN), and Baltimore (BWI). However, not all US airports experienced a decrease. The US airports experiencing notable increases from 2012 to 2013 include Houston (HOU), Dallas (DFW), and Boston (BOS). In Europe, the airports with the highest decrease in terms of departures were Madrid (MAD), Paris (CDG), and Munich (MUC). The airports showing an increase in departures compared to 2012 include Stockholm (ARN) and Dublin (DUB).

Capacity at airports can be tied to demand at the facility, physical airport infrastructure (e.g. runways, gates), and also by external factors, such as weather conditions. Along with declining overall traffic levels in the US from 2012 to 2013, many facilities had lower average called capacity rates declared by ATC. Furthermore, the period from 2012 to 2013 saw several airport development projects resulting in capacity changes at US airports. The addition of a new runway at Chicago O'Hare (ORD) resulted in marginally higher arrival called rate in 2013. Baltimore (BWI) saw an increase in average arrival capacity in 2013 compared to 2012 due to lower average capacities in 2012 as a result of runway closures and reconstruction projects. The runway expansion project at Fort Lauderdale (FLL) greatly lowered the average arrival ATC called rate at the airport from 2012 to 2013.

In the US, there was an increase in weather-related ATFM delay from 2012 to 2013 at system level. Consequently, weather conditions as measured by ceiling and visibility criteria also reflect an increase in instrument conditions or IMC. Increases in thunderstorms, winter events, and low visibility contributed to the overall increase in weather-related ATFM delay for the US.

In Europe, weather-related ATFM delay declined slightly at system level predominately due to decreases in thunderstorm and visibility caused restrictions. However, weather conditions as measured by ceiling and visibility criteria reflect an increase in IMC. Different from the US, the declared capacity in Europe is set closer to IMC levels; therefore when weather constraining events occur, the European system may tend to be less impacted initially and issue fewer ATFM restrictions than the US.

The New York area airports in particular experience very high weather-related ATFM delay with a large portion attributed to thunderstorms and severe weather. In response, the FAA has developed a traffic management initiative known as SWAP (severe weather avoidance program) to specifically handle air traffic during thunderstorm events. As a result of the prevalence of severe weather in the already congested airspace and the resulting long and widespread delays, the high impact airports in the US (New York area, SFO, PHL, ORD) may be more likely to issue ATFM delays when weather forecast anticipate a capacity constraining event. These airports experience ATFM delay levels on a magnitude higher than any other airport within the US or in Europe.

However, close examination of the distribution of delay at LGA and EWR shows that for the majority of days (LGA, 70%), the ATFM delay is on par with Europe and other US airports. The large averages are truly driven by a smaller percentage of days. Policies that would further restrict demand would result in an under-utilization of capacity for these times. US performance will continue to be driven by the mix of policy and operational measures taken to improve operations in this key area.

On-time punctuality as compared to the schedule may be the result of many external factors including demand, capacity, and weather. At system level, the US saw a decrease in on-time punctuality from 2012 to 2013 whereas punctuality in Europe continued to improve.

The airports with the lowest arrival punctuality in 2013 include Newark (EWR), and San Francisco (SFO) in the US and London (LHR) and Lisbon (LIS) in Europe. However in the US, Newark (EWR), San Francisco (SFO), and Miami (MIA) are the only airports showing an improvement in arrival punctuality in 2013 compared to 2012. Better weather, higher capacity, and stable demand in 2013 may be linked to the punctuality improvements seen at Newark (EWR) and San Francisco (SFO).

Conversely in Europe, many airports show improvements in on-time punctuality most notability Madrid (MAD), Lisbon (LIS), Frankfurt (FRA), Munich (MUC), and Milan (LIN). The increase in punctuality in Madrid (MAD), Frankfurt (FRA), Munich (MUC), and Milan (LIN) may be a result of decreased demand at these airports.

Overall, worse weather along with falling demand drove performance changes described in the next section. However, it remains difficult to proportion the share of these changes in performance to the known causal influence of weather, capacity or ATM improvements.

6.3 Operational Performance Indicators

The 2012-2013 reporting period shows marked differences in performance trends for Europe and the US. Across almost all KPIs, performance in Europe improved while performance in the US degraded. Examination of external factors such as weather indicates that 2012 was a favourable weather year and much of the difference is attributed to increased thunderstorm/winter operation events. The KPIs also show that the US continues to maintain slightly higher performance in the airborne phase of flight. The report notes that, although lower in the airborne phase, the KPIs show Europe has been on a steadily improving trend.

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 is further assessed by phase of flight to better understand the ATM contribution and differences in traffic management techniques between the US and Europe.

Both the US and Europe report ATFM delay imposed on flights by the ANSP in order to achieve required levels of safety as well as to most effectively balance demand and capacity. In Europe, departure ATFM restrictions are used as a primary means for en route and airport capacity shortfalls. In the US, ground delays at the departure airports are the last resort when less constraining flow measures such as MIT are insufficient. Both systems track the constraining facility which allows delay to be reported as either due to terminal/airport or en route constraints.

Despite a moderate decline in overall traffic, total ATFM delay to or from the main 34 airports in the US increased by 25% while European ATFM delay decreased by 20.6%. In the US, the increase was largely due to weather (principally attributed to thunderstorm activity) while European decline is mostly attributable to an improvement in capacity.

Although decreasing from 5% in 2008 to 1.4% in 2013, flights in Europe are still over twice more likely to be held at the gate for en route constraints than in the US where this percentage decreased slightly to 0.6%. For airport related delays, the percentage of delayed flights at the gate or on the surface is higher in the US (2.6%) and in Europe (1.7%). However the delay per delayed flight in the US is almost twice as high as in Europe.

At system level, the causes for en route-related ATFM delays are mostly driven by convective weather in the US whereas in Europe they are mainly the result of capacity and staffing constraints (and industrial actions in 2010) driven by variations in peak demand. For airport-related ATFM delays, weather is the predominant driver in both Europe and the US

As weather is the predominant driver of airport-related ATFM delays and worse weather was experienced in 2013 than in 2012, ATFM delay at the 34 main US airports has increased from 2012 to 2013. Chicago (ORD) is the airport responsible for adding the most ATFM delay in the system due to worse weather in 2013. San Francisco (SFO) experienced better weather in 2013 and saw the greatest reduction in ATFM delay in the US.

In the US, the airports which make up a large percentage of ATFM delays are also the airports having the highest capacity variation impact. Since flights in the US are typically scheduled to VMC capacity, when weather conditions deteriorate, capacity at the airport is considerably reduced while demand levels remain the same. In case of a significant mismatch between demand and capacity, ATFM restrictions at the various origin airports are applied as a last resort.

Surface indicators studied in this report include taxi-out efficiency and taxi-in efficiency, which both can be measured as the average additional time beyond an unimpeded reference time. At a high level, seasonal patterns are visible with different cycles in the US and Europe. Overall, additional time has been decreasing relative to 2008 levels. Whereas in Europe the additional times peak during the winter months (most likely due to weather conditions), in the US the peak is in the summer which is most likely linked to congestion as well as convective weather. On average, additional times in the taxi-out phase appear to be higher in the US, however from 2012 to 2013, additional taxi out time in the US increased by 0.4 minutes whereas in Europe additional taxi out time decreased by 0.1 minutes. The US airports with the greatest system increase in additional taxi-out time are Detroit (DTW), Minneapolis (MSP), New York (JFK), and Denver (DEN). The European airports that drove the system decrease in taxi out time include London (LGW), Dublin (DUB), Prague (PRG), and Frankfurt (FRA).The gap in additional taxi-out time narrows considerably between the US and Europe from 2008 to 2012; however in 2013, the gap widens slightly. On the arrival side, the additional time in the taxi-in phase is slightly higher in the US than in Europe but remains relatively stable over time in both systems.

Airborne efficiency for Europe and US is reported for both the en route phase and terminal/arrival phase.

For the en route phase, horizontal flight efficiency indicators are used to compare the actual flight trajectory length and the flight plan length to a benchmark achieved distance for each flight. Comparing the actual and flight plan lengths to the achieved distance reveal that there is a notable gap between plan and actual flight inefficiency in the US and in Europe, with the gap being much smaller in the US. The difference between planned and actual operations reveals that flights fly more direct than their flight plan in both systems. Although Europe has been on a downward trend for both indicators, European airlines file on average almost 5% greater than their achieved distance compared to 3.5% in the US.

Overall, the total horizontal en route flight inefficiency for flights to or from the main 34 airports in Europe was 2.91% compared to 2.71% in the US, with Europe having 0.20% greater en route inefficiency. For both the US and Europe, flight inefficiency decreases relative to the flight distance. At the airport level, direct route extension (A-D) in NM for US flights are longer on average than in Europe, but as a percentage (A-D/H), US flights are less inefficient due to the US having longer flight lengths (607 NM vs. 480 NM). For the US, many of the direct flight inefficiencies can be traced to separating traffic in larger metroplex airspace (New York and Atlanta) as well as the need to coordinate with and avoid Special Use Airspace (SUA). Therefore, many of these calculated inefficiencies are most likely not a recoverable part of the estimated benefit pool. Future assessments may directly compute the flight inefficiency due to SUA.

For the terminal arrival phase, flight efficiency in the last 100 NM before landing aims to estimate the level of inefficiencies due to airborne holding, metering, and sequencing of arrivals. At system level, the additional time within the last 100 NM was similar in 2008 but is lower in both the US and Europe in 2013. In Europe, London Heathrow (LHR) has by far the highest level of additional time within the last 100 NM. This is followed by Frankfurt (FRA) and Zurich (ZRH) which show less than half the level observed at London Heathrow. Although consistent with decisions taken during the airport capacity declaration process regarding average holding in stack, it is remarkable that London (LHR) alone accounted for 20% of the total additional time observed at the main 34 European airports in 2013.

The US shows a less contrasted picture with only a modest increase in system average between 2012 and 2013. Philadelphia (PHL) and the New York area airports still show the highest level of additional time within the last 100 NM. However, all US airports reported a change of less than half a minute in additional time within the last 100 NM from 2012 to 2013 with the exception of Baltimore (BWI). One of the main differences of the US air traffic management system is the ability to maximise airport capacity by taking action in the en route phase of flight, such as in trail spacing whereas in Europe, most of the sequencing and holding is done at lower altitudes around the airport and additional delays beyond what can be absorbed around the airport are taken on the ground at the departure airports.

Although the US saw an overall decline in operational performance, this can be expected given the less favourable conditions in 2013 compared to 2012. Ceiling and visibility weather indicators point to potentially greater impact from weather and this is largely reflected in the increase in weather-related ATFM delay. From 2012 to 2013, most US airports reported a decrease in airport arrival capacity which tracks with overall lower traffic levels.

Conversely, the period from 2012 to 2013 saw an overall improvement in operational performance in Europe. Despite less favourable ceiling and visibility weather indicators, the level of weather-related ATFM delay actually decreased from 2012 to 2013 which may indicate differing sensitivities to adverse weather in Europe and the US. Overall demand is down in both the US and Europe from 2012 to 2013 and putting less stress on the system. It is therefore difficult to predict future performance if traffic begins to increase or changes in weather or capacity occur.

By combining the analyses for individual phases of flight, an estimate of the improvement pool actionable by ANS can be derived. It is important to stress that the overall results represent a theoretical optimum which is – due to inherent safety and capacity limitations - not achievable at the system level. It should also be noted that there are other flight components not considered which may also lead to improved fuel efficiency. Some of these, such as preferred flight speed are not fully under the control of ATM.

7 EMERGING THEMES AND NEXT STEPS

The findings in this report continue to demonstrate that it is practical to examine two different aviation systems and develop key performance indicators using harmonized procedures. This common approach allows both groups to examine the essential questions on the extent performance differences are driven by policy, ATM operating strategies, or prevailing organisational, meteorological and/or economic conditions.

In Europe, the main questions revolve around the fragmentation of service provision and its impact on system wide flow management and ATM performance. At airports, the main issue is related to strategic scheduling and its impact on airport throughput and the ability to sustain throughput when weather deteriorates. There is also the issue on the degree to which the US system offers more flexibility in mitigating demand/capacity imbalances through the use of traffic flow initiatives that are coordinated across multiple en route centres.

In the US, impacts to performance are highly linked to capacity variation at airports with demand levels that are near the upper range of the declared capacity of the facility. This capacity variation is most often driven by weather and for the US, performance trends from 2012-2013 were heavily influenced by an increase in the impact due to thunderstorms and winter operations. The bulk of this increase is seen for the New York area airports of JFK and LaGuardia as well as Philadelphia. The data continues to support the theme that US solutions to improved performance will need to address extreme weather in the New York area. Future work would need to make this a priority area.

The report presents many Key Performance Indicators and supporting indicators that help explain changes in KPIs year over year. Although many are reported, the analysis supports that most of what can be learned from performance can be discerned from the indicators called out in the European Performance Scheme. These indicators can be used to answer direct questions that can be readily understood by ANSP management and stakeholders. These include:

- What is the magnitude of airport constraints in the delay of flights?
- What is the magnitude of en route facility constraints in the delay of flights?
- Are airlines filing longer or shorter flight plans year-over-year?
- Are airlines flying longer or shorter flight trajectories year-over-year?

These four operational indicators, often portioned by facility or causal factors may be sufficient in tracking and managing most improvements to overall system performance. Future work would focus on these indicators and their drivers. As both the SESAR and NextGen programs implement new technology, the indicators can assess how effective the programs will be in improving performance and addressing the causal factors quantified in this report.

FAA and Europe were able to advance many of the priority areas identified in the last report. These include adding indicators that utilize the flight plan, common indicators for weather and its impact on performance and improvements in how ATFM delay and its causal factors can be assessed in both regions. Given the key elements affecting performance in the two systems and the projected improvements in data availability, EUROCONTROL and FAA intend to jointly advance a common performance assessment capability in the following areas.

1. Quantifying the Magnitude and Effect of Traffic Flow Initiatives: The FAA employs a range of traffic flow initiatives that are tailored to normal variation in demand/capacity imbalances to the more extreme and disruptive events of thunderstorms. ATFM delay databases and traffic management logs offer the opportunity to quantify the use of these indicators and the potential for use in the European system. This may lead to improvements to the ASMA indicator for Europe where more additional time in the

terminal area is observed in Europe whereas the US shows larger values where delay has been pushed back to the departure airport.

2. Vertical flight efficiency: Vertical flight efficiency is not explicitly addressed in the comparison but is a frequent topic for discussion in various working groups. The planned improvement of the surveillance data in the central ETFMS system to an update rate of 30 seconds will enable better identification of level off segments and inefficiencies in vertical profiles in Europe. More work is required to improve the assessment of vertical flight efficiency that can be attributed to ATM, and to develop commonly agreed indicators for the measurement of those inefficiencies.

3. Impact of environmental constraints on ATM performance: More and more airports operate under some environmental constraints which invariability affects runway throughput as well as traffic patterns in the terminal area. To fully assess ATM influence on performance, these restrictions must be understood and potentially quantified similar to other stakeholder interactions such as those of Special Use Airspace. Future reports would provide an initial framework for gauging the effect of these comparisons on performance.

4. Airport ground-side performance: Year-over-year, the EU/US benchmarking shows more variability of time on the surface departure side for the US than in Europe. This variation is clearly a product of ANSP, airline and airport causal factors. However, in both systems, the US and Europe strive to absorb delay at the departure airport through ATFM initiatives. This delay may be taken at gate or in taxi-out and in both systems, airports have been implementing technology and procedures to improve overall departure management. Future benchmarking would target this phase of flight to determine if variability and additional time in taxi-out is related to the airline or airport, ATFM initiatives or is an indicator that can be improved upon independent of other factors.

5. Departure phase and Continuous Climb Operations: Current benchmarking does not include the departure phase of flight largely due to system-wide RADAR fidelity and the ability to obtain an ideal benchmark trajectory which may be flight specific. Based on data quality, future reports could contain initial indicators that assess the departure phase. This would include quantifying level flight and the benefit pool from continuous climb operations.

6. Indicators for Special Use Airspace: This report notes that there is a high density of special use airspace in the core of Europe which reduces the flexibility in managing traffic flows. Europe's Single European Sky Performance Scheme contains indicators for assessing Flexible Use Airspace and conditional routing through these areas. Future reports could provide indicators on Special Use Airspace activity and its potential impact on the horizontal efficiency indicator.

7. Evaluation of technology implementation. Both the US and Europe are investing heavily in new generation technology as part of either the NextGen or SESAR programs. Programs that optimize airspace or implement performance based navigation should demonstrate improvements in the delay, flight efficiency and predictability indicators assessed in these benchmark reports. Future reports should identify current programs and evaluate if the benefits of implementation can be measured using the EU/US harmonized KPIs. In addition, these KPIs will contribute to supporting ICAO's goal of monitoring the benefits associated with the deployment of ASBUs.

ANNEX I LIST OF AIRPORTS INCLUDED IN THIS STUDY

Table I-1: Top 34 European airports included in the study (2013)

EUROPE	ICAO	IATA	COUNTRY	Avg. daily IFR departures in 2013	2013 vs. 2012	2013 vs. 2008
Paris (CDG)	LFPG	CDG	FRANCE	655	-3.6%	-14.3%
Frankfurt (FRA)	EDDF	FRA	GERMANY	648	-1.7%	-2.4%
London (LHR)	EGLL	LHR	UNITED KINGDOM	646	-0.4%	-1.1%
Amsterdam (AMS)	EHAM	AMS	NETHERLANDS	597	0.8%	-0.9%
Munich (MUC)	EDDM	MUC	GERMANY	519	-3.8%	-11.4%
Madrid (MAD)	LEMD	MAD	SPAIN	456	-10.5%	-28.9%
Rome (FCO)	LIRF	FCO	ITALY	414	-3.5%	-12.6%
Barcelona (BCN)	LEBL	BCN	SPAIN	379	-4.4%	-13.8%
Zurich (ZRH)	LSZH	ZRH	SWITZERLAND	350	-2.2%	-2.7%
London (LGW)	EGKK	LGW	UNITED KINGDOM	343	1.7%	-4.9%
Vienna (VIE)	LOWW	VIE	AUSTRIA	339	-5.1%	-14.3%
Copenhagen (CPH)	EKCH	CPH	DENMARK	336	1.1%	-7.0%
Oslo (OSL)	ENGM	OSL	NORWAY	330	2.6%	2.5%
Paris (ORY)	LFPO	ORY	FRANCE	320	0.1%	0.0%
Stockholm (ARN)	ESSA	ARN	SWEDEN	301	5.0%	-1.2%
Brussels (BRU)	EBBR	BRU	BELGIUM	289	-2.9%	-15.9%
Dusseldorf (DUS)	EDDL	DUS	GERMANY	288	-2.7%	-7.3%
Geneva (GVA)	LSGG	GVA	SWITZERLAND	243	-1.4%	1.3%
Berlin (TXL)	EDDT	TXL	GERMANY	237	2.6%	9.7%
Palma (PMI)	LEPA	PMI	SPAIN	232	-2.0%	-11.9%
Dublin (DUB)	EIDW	DUB	IRELAND	232	4.6%	-18.5%
Manchester (MAN)	EGCC	MAN	UNITED KINGDOM	231	0.6%	-16.5%
Helsinki (HEL)	EFHK	HEL	FINLAND	230	-2.0%	-9.0%
Milan (MXP)	LIMC	MXP	ITALY	226	-5.5%	-24.1%
Lisbon (LIS)	LPPT	LIS	PORTUGAL	200	1.5%	1.4%
London (STN)	EGSS	STN	UNITED KINGDOM	196	1.2%	-25.0%
Nice (NCE)	LFMN	NCE	FRANCE	192	-1.2%	-1.8%
Hamburg (HAM)	EDDH	HAM	GERMANY	187	-5.1%	-15.6%
Athens (ATH)	LGAV	ATH	GREECE	186	-9.1%	-29.8%
Prague (PRG)	LKPR	PRG	CZECH REPUBLIC	171	-2.3%	-27.9%
Cologne (CGN)	EDDK	CGN	GERMANY	160	-4.3%	-16.1%
Lyon (LYS)	LFLL	LYS	FRANCE	159	-2.6%	-11.1%
Stuttgart (STR)	EDDS	STR	GERMANY	156	-4.6%	-22.0%
Milan (LIN)	LIML	LIN	ITALY	153	-5.2%	-12.1%
Average				**312**	**-2.0%**	**-10.6%**

Table I-2: US main 34 airports included in the study (2013)

USA	ICAO	IATA	COUNTRY	Avg. daily IFR departures in 2013	2013 vs. 2012	2013 vs. 2008
Atlanta (ATL)	KATL	ATL	USA	1238	-1.7%	-7.2%
Chicago (ORD)	KORD	ORD	USA	1203	0.8%	0.1%
Dallas (DFW)	KDFW	DFW	USA	928	4.6%	3.6%
Los Angeles (LAX)	KLAX	LAX	USA	836	1.7%	-0.2%
Denver (DEN)	KDEN	DEN	USA	804	-4.7%	-6.1%
Charlotte (CLT)	KCLT	CLT	USA	758	1.5%	5.2%
Houston (IAH)	KIAH	IAH	USA	691	-0.8%	-13.6%
Phoenix (PHX)	KPHX	PHX	USA	596	-2.7%	-10.9%
Philadelphia (PHL)	KPHL	PHL	USA	592	-1.8%	-9.8%
Minneapolis (MSP)	KMSP	MSP	USA	591	2.0%	-3.6%
Detroit (DTW)	KDTW	DTW	USA	582	-0.4%	-8.1%
San Francisco (SFO)	KSFO	SFO	USA	572	-0.1%	9.5%
Newark (EWR)	KEWR	EWR	USA	564	0.1%	-4.9%
New York (JFK)	KJFK	JFK	USA	557	1.0%	-7.8%
Las Vegas (LAS)	KLAS	LAS	USA	554	-2.3%	-14.0%
Miami (MIA)	KMIA	MIA	USA	540	2.1%	6.6%
New York (LGA)	KLGA	LGA	USA	508	0.8%	-2.5%
Boston (BOS)	KBOS	BOS	USA	495	3.0%	-2.2%
Washington (IAD)	KIAD	IAD	USA	451	-1.9%	-15.4%
Seattle (SEA)	KSEA	SEA	USA	430	2.5%	-8.5%
Orlando (MCO)	KMCO	MCO	USA	406	-2.2%	-13.1%
Washington (DCA)	KDCA	DCA	USA	398	1.8%	5.5%
Salt Lake City (SLC)	KSLC	SLC	USA	392	-0.5%	-17.0%
Baltimore (BWI)	KBWI	BWI	USA	344	-4.4%	-5.9%
Chicago (MDW)	KMDW	MDW	USA	332	1.7%	-5.0%
Ft. Lauderdale (FLL)	KFLL	FLL	USA	332	-1.9%	-12.0%
Memphis (MEM)	KMEM	MEM	USA	316	-13.9%	-35.9%
Portland (PDX)	KPDX	PDX	USA	279	-0.1%	-16.1%
Houston (HOU)	IHOU	HOU	USA	258	5.5%	2.6%
St. Louis (STL)	KSTL	STL	USA	256	-1.2%	-23.8%
San Diego (SAN)	KSAN	SAN	USA	255	1.7%	-15.8%
Cleveland (CLE)	KCLE	CLE	USA	248	0.4%	-22.8%
Tampa (TPA)	KTPA	TPA	USA	244	-0.9%	-21.0%
Raleigh-Durham (RDU)	KRDU	RDU	USA	230	-1.9%	-20.7%
Average				**523**	**-0.3%**	**-7.2%**

ANNEX II GLOSSARY

AAR	Airport Arrival Acceptance Rates
ACC	Area Control Centre. That part of ATC that is concerned with en route traffic coming from or going to adjacent centres or APP. It is a unit established to provide air traffic control service to controlled flights in control areas under its jurisdiction.
ACI	Airports Council International (http://www.aci-europe.org/)
ADR	Airport Departure Rates
AIG	Accident and Incident Investigation (ICAO)
AIP	Aeronautical Information Publication, sets out procedures used by pilots and air traffic controllers
AIS	Aeronautical Information Service
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
APP	Approach Control Unit
ARTCC	Air Route Traffic Control Center, the equivalent of an ACC in Europe.
ASM	Airspace Management
ASMA	Arrival Sequencing and Metering Area
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	US Air Traffic Control System Command Centre
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 centres 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.
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.
CAA	Civil Aviation Authority
CANSO	Civil Air Navigation Services Organisation (http://www.canso.org)
CDA	Continuous Descent Approach
CDM	Collaborative Decision Making

CDR	Conditional Routes
CFMU	See NOC
CO_2	Carbon dioxide
CODA	EUROCONTROL Central Office for Delay Analysis
CONUS	see US CONUS
CTOP	Collaborative Trajectory Options Program
CTOT	Calculated take-off Time
EC	European Commission
ECAC	European Civil Aviation Conference.
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.
ETFMS	Enhanced Tactical Flow Management System
EU	Austria, Belgium, Bulgaria, 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 27 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 (2014)	Albania, Armenia, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Finland, France, Georgia, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Moldova, Monaco, Montenegro, 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	US Federal Aviation Administration
FAA-ATO	US Federal Aviation Administration - Air Traffic Organization
FAB	Functional Airspace Blocks
FDP	Flight data processing
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.
FMP	Flow Management Position
FMS	Flight Management System
FUA Level 1 Level 2 Level 3	Flexible Use of Airspace Strategic Airspace Management Pre-tactical Airspace Management Tactical Airspace Management
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
General Aviation	All flights classified as “G” (general aviation) in the flight plan submitted to the appropriate authorities.
IATA	International Air Transport Association (www.iata.org)
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules. Properly equipped aircraft 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
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)
NOC	Eurocontrol Network Operations Centre located in Brussels (formerly CFMU)
OEP	Operational Evolution Partnership (a list of 35 US 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 US).
OPS	Operational Services
OPSNET	The Operations Network is the official source of NAS air traffic operations and delay data. The data is used to analyse the performance of the FAA's air traffic control facilities.
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
RAD	Route availability document
Reactionary delay	Delay caused by late arrival of aircraft or crew from previous journeys
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://europa.eu.int/comm/transport/air/single_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
STATFOR	EUROCONTROL Statistics & Forecasts Service
Summer period	May to October inclusive

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.
TBM	Time Based Metering
TFMS	Traffic Flow Management System
TMA	Terminal Manoeuvring Area
TMS	Traffic Management System
TRACON	Terminal Radar Approach Control
UAC	Upper Airspace Area Control Centre
US	United States of America
US 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
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions

ANNEX III REFERENCES

1 Performance Review Commission and FAA-ATO, "U.S./Europe Comparison of ATM-related Operational Performance 2008", (October 2009).

2 Performance Review Commission and FAA-ATO, "U.S./Europe Comparison of ATM-Related Operational Performance 2010", (April 2012).

3 Performance Review Commission and FAA, "A comparison of performance in selected US and European En-route Centres", (May 2003).

http://www.eurocontrol.int/documents/comparison-performance-selected-us-and-european-en-route-centres

4 ICAO Manual on Air Navigation Services Economics (Document 9161).

5 Performance Review Commission, "U.S. - Europe continental comparison of ANS cost-efficiency trends (2002-2011)", (November 2013).

6 ATM Cost-effectiveness (ACE) 2011 Benchmarking Report. Report commissioned by the Performance Review Commission, April 2013.

7 CANSO, "Global Air Navigation Services Performance Report 2012", (January 2013).

8 CANSO, "Methodologies for Calculating Delays/Improvement Opportunity Pools by Phase of Flight", (May 2013).

9 Airservices Australia, and University of New South Wales, "Analysis of Australian ATM-Related Operational Performance", October 2012.

10 Commission Regulation (EC) No 691/2010 of 29 July 2010 laying down a performance scheme for air navigation services and network functions, OJ L 201, 3.8.2010, p.1.

11 Commission Implementing Regulation (EU) No 390/2013 of 3 May 2013 laying down a performance scheme for air navigation services and network functions, OJ L 128, 9.5.2013, p.1.

12 Commission Decision of 21 February 2011 setting the Union-wide performance targets for the air traffic management network and alert thresholds for the years 2012 to 2014 OJ L 48, 23.2.2011, p.16.

13 Commission Implementing Decision of 11 March 2014 setting the Union-wide performance targets for the air traffic management network and alert thresholds for the second reference period 2015-19 OJ L 71, 13.3.2014, p.20.

14 ICAO Manual on Global Performance of the Air Navigation System (Doc 9883).

15 Commission Regulation (EU) No 677/2011 of 7 July 2011 laying down detailed rules for the implementation of air traffic management (ATM) network functions and amending Regulation (EU) No 691/2010.

16 Evaluation of Civil/Military Airspace Utilisation, Report commissioned by the Performance Review Commission, November 2007. http://www.eurocontrol.int/sites/default/files/publication/files/prc-civil-military-2007.pdf

17 Commission Regulation (EC) No 2150/2005 of 23 December 2005 laying down common rules for the flexible use of airspace (OJ, 24.12.2005).

18 US DOT, Federal Aviation Administration, "Facility Operation and Administration Order JO 7210.3Y," (April 2014). http://www.faa.gov/documentLibrary/media/Order/JO_7210.3Y.pdf

19 Ngaire Underhill, Rich DeLaura, Michael Robinson, Massachusetts Institute of Technology Lincoln Laboratory, "Severe Weather Avoidance Program Performance Metrics for New York Departure Operations," (2010).

20 Kirt Squires, Kyle Struckmann, NOAA/National Weather Service, “Verification of Severe Weather Avoidance Plan (SWAP) Forecasts for the New York Air Route Traffic Control Center (ARTCC) Issued by the National Weather Service Center Weather Service Unit (CWSU), Ronkonkoma, NY,” Eastern Region Technical Attachment No. 2009-02. (April 2009). http://www.erh.noaa.gov/er/hq/ssd/erps/ta/ta2009-02.pdf

21 http://www.nats.aero/news/trial-aims-cut-heathrow-holding-times.

22 Yi Liu, Mark Hansen, and Bo Zou, "Aircraft Gauge Differences between the US and Europe and their Operational Implications," Journal of Air Transport Management, Vol 29, 2013.

23 Amy Chow, John Gulding, “Capacity Variation Algorithms for Simulation Modeling and Performance Analysis,” 2013 AIAA Aviation Technology, Integration, and Operations Conference, 12-14 August 2013, Chapter DOI: 10.2514/6.2013-4355.

24 Amedeo Odoni and Thomas Morisset, “The declared capacity: A critical decision for major airports,” May 2009.

25 Algorithm to describe weather conditions at European Airports (ATMAP weather algorithm) prepared by the Performance Review Unit in consultation with the ATMAP MET Working Group. May 2011 http://www.eurocontrol.int/documents/algorithm-weather-conditions-airports

26 Alexander Klein, Richard Jehlen, Diana Liang, Weather Index with Queuing Component for National Airspace System Performance Assessment, USA-Europe ATM R&D Seminar, July 2007, http://www.atmseminar.org/seminarContent/seminar7/papers/p_024_AAPM.pdf.

27 US DOT, Bureau of Transportation Statistics, “Airline On-Time Performance and Causes of Flight Delays”, http://www.rita.dot.gov/bts/help_with_data/aviation/index.html

28 https://www.eurocontrol.int/articles/coda-publications;

29 http://www.airlines.org/economics/cost+of+delays

30 University of Westminster, “European airline delay cost reference values” (March 2011), http://www.eurocontrol.int/documents/european-airline-delay-cost-reference-values

31 FAA Free Flight Performance Metrics Reports 199-2001.

32 http://www.transtats.bts.gov/OT_Delay/ot_delaycause1.asp?type=4&pn=1.

33 http://earthobservatory.nasa.gov/IOTD/view.php?id=6679.

34 “Estimating ATM Efficiency Pools in the Descent Phase of Flight”, Gulding, J., Knorr, D., Rose, M., Xing Chen, Enaud, P., Hegendoerfer, H., 9th USA/Europe ATM R&D Seminar, Berlin 2011.

35 Husni Idris, John-Paul Clarke, Rani Bhuva and Laura Kang, Massachusetts Institute of Technology, “Queuing Model for Taxi-Out Time Estimation,” ATC Quarterly 2001.

36 Performance Review Commission, “Evaluation of Vertical Flight-efficiency” (March 2008) (http://www.eurocontrol.int/documents/vertical-flight-efficiency).

37 http://prudata.webfactional.com/wiki/index.php/Category:SES_Meta-Data.

38 European Route Network Improvement Plan (ERNIP) available at: http://www.eurocontrol.int/services/european-route-network-improvement-plan-ernip

39 Performance Review Commission, Performance Review Report 2008 (PRR 2008). An Assessment of Air Traffic Management in Europe during the Calendar Year 2008 (May 2009).

40 Performance Review Commission, Performance Review Report 2012 (PRR 2012). An Assessment of Air Traffic Management in Europe during the Calendar Year 2012 (May 2013).

EUROCONTROL

Performance Review Unit
96 Rue de la Fusée
B-1130 Brussels, Belgium
Tel: +32 2 729 3956

U.S. Department of Transportation
Federal Aviation Administration

Performance Analysis Office
800 Independence Ave., S.W.
Washington, DC 20591
Tel: 202-527-2845

2014-AJR-202 • Produced by FAA Communications.