EUROCONTROL

U.S. Department of Transportation
Federal Aviation Administration

2010 | U.S./Europe Comparison of ATM-Related Operational Performance

Produced by:
EUROCONTROL Performance Review Commission
FAA Air Traffic Organization System Operations Services

BACKGROUND

This document is a joint publication of the Air Traffic Organization System Operations Services of the FAA and the Performance Review Commission of EUROCONTROL in the interest of the exchange of information.

The objective was to make a factual high-level comparison of operational performance between the US and European air navigation systems. The initial focus was to develop a set of comparable performance measures in order to create a sound basis for factual high-level 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 Review Commission.

2010 U.S./Europe Comparison of ATM-related Operational Performance

Final Report – March 2012

ABSTRACT

Air Navigation Service Providers (ANSPs) are continually seeking to improve operations. Measures derived from operational databases are a key component to assessing performance and recommending improvements. This report examines several key performance indicators derived from comparable operations databases for both EUROCONTROL and the Federal Aviation Administration (FAA). This research effort developed a comparable population of operations data and harmonizes assessment techniques for developing reference conditions for assessing performance. In the end, measures that address efficiency, punctuality and predictability are presented that can compare high level performance between the two systems by phase of flight. This report provides an update to an initial report that used calendar year operations for 2008. Figures provided in this report are current as of calendar year 2010.

Produced by the EUROCONTROL Performance Review Commission and the Federal Aviation Administration Air Traffic Organization System Operations Services

CONTACT:	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
	EUROCONTROL Performance Review Commission	Performance Review Unit, EUROCONTROL, 96 Rue de la Fusée, B-1130 Brussels, Belgium. Tel: +32 2 729 3956, E-mail: pru@eurocontrol.int Web: http://www.eurocontrol.int/prc

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

INTRODUCTION

In October 2009, the EUROCONTROL Performance Review Commission (PRC) and the US Federal Aviation Administration (FAA) produced a comprehensive report on performance using operations data from the top 34 facilities in each region. In developing the report, EUROCONTROL and the FAA identified common databases and common performance indicators that could be used to evaluate many of the key performance areas (KPAs) specified in the International Civil Aviation Organisation (ICAO) Global Air Traffic Operational Management Concept.

With the exception of on-time performance, there is a lack of commonly agreed and comparable performance indicators world-wide (with multiple delay definitions even within ANSPs). However since the publication of the original report, the phase-of-flight indicators have been assessed by Civil Air Navigation Services Organisation (CANSO) working groups for use in global benchmarking. Also the direct flight indicator is now a European-wide tracking metric of operational and environmental efficiency.

The specific key performance indicators (KPIs) are based on best practices from both the System Operations Performance Office and PRC. In order to better understand the impact of air traffic management (ATM) and differences in ATM techniques, the analysis is broken down by phase of flight (i.e. pre-departure delay, taxi-out, en route, terminal arrival, taxi-in and arrival delay) as well as aggregate measures. The breakdown by phase of flight supports better measurements of fuel efficiency.

The report produced performance measures and trends based on operations data as of the end of calendar year 2008.

This report presents an update to the previous report using operations current for calendar year 2010.

Since 2008, the US has seen the merger of Delta and Northwest airlines, United and Continental airlines, and an announced merger of Southwest and Air Tran. These industry events affect traffic concentrations at major airports. The New York airports have been operating with a policy of schedule limitation from 2008 to 2010 and New York (JFK) has been using surface management techniques closer to the European mode of departure management. The end result has been less surface congestions with delay pushed farther back to the gate.

In Europe, the weak economic growth in 2009 compounded by exceptional events in 2010 (volcanic ash cloud, industrial actions, and unusually severe weather conditions) had a negative impact on traffic growth and performance. Approximately 111,000 flights were cancelled due to volcanic ash clouds in April and May 2010, which reduced air traffic by some 48% during 8 days in April and annual air traffic growth by an estimated 1.2% in 2010. Additionally, an estimated 26,000 flights were cancelled due to industrial action and some 45,000 flights due to bad weather conditions in winter.

In addition to updated figures based on 2010 traffic, explanatory portions of the report have been maintained. Where relevant, commentary has been added to address changes in trends that occurred since 2008.

The FAA and EUROCONTROL intend to continue the process of future reports that reflect current trends as well improved performance methodologies.

HIGH-LEVEL VIEW OF THE ATM SYSTEMS IN EUROPE AND THE US

Table I shows selected high-level figures for the European and the US air navigation systems.

TABLE I: US/EUROPE KEY ATM SYSTEM FIGURES [2010]

Calendar Year 2010	Europe	USA	Difference US vs. Europe
Geographic Area (million km^2)	11.5	10.4	≈ -10%
Number of en route Air Navigation Service Providers	38	1	
Number of Air Traffic Controllers (ATCOs in Ops.)	16 700	14 600	≈ -13%
Total staff	57 000	35 200	≈ -38%
Controlled flights (IFR) (million)	9.5	15.9	≈ +67%
Share of flights to/ from top 34 airports	66%	63%	
Share of General Aviation	4%	23%	≈ x 5.5
Flight hours controlled (million)	13.8	23.4	≈ +70%
Relative density (flight hours per km^2)	1.2	2.2	≈ x 1.8
Average length of flight (within respective airspace)	557 NM	493 NM	≈ -11%
Number of en route centres	63	20	≈ -68%
Number of airports with ATC services	>450	≈ 509	≈ +13%
Of which are slot controlled	> 90	3	
Source	Eurocontrol	FAA/ATO	

The total surface of continental airspace is similar in Europe and the US. However, the FAA controls approximately 67% more flights and handles significantly more Visual Flight Rules (VFR) traffic with some 13% fewer controllers and fewer en route facilities. The fragmentation of European ANS with 38 en route ANSPs is certainly a driver behind such difference.

Figure I shows the traffic density in the US and European en route centres measured in flight hours per square kilometre for all altitudes.

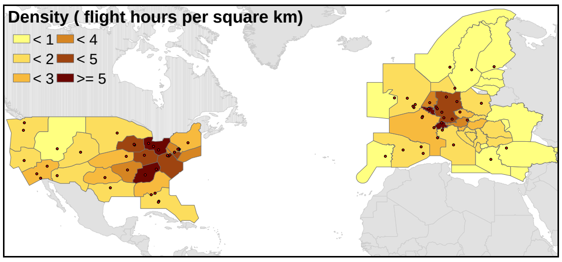


FIGURE I: TRAFFIC DENSITY IN US AND EUROPEAN EN ROUTE CENTRES

In Europe, the "core area" (including the Benelux States, Northeast France, Germany, and Switzerland) is the densest and most complex airspace. 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. Detailed comparisons on complexities are beyond the scope of this report.

Figure II shows the evolution of IFR traffic in the US and in Europe between 1999 and 2010.

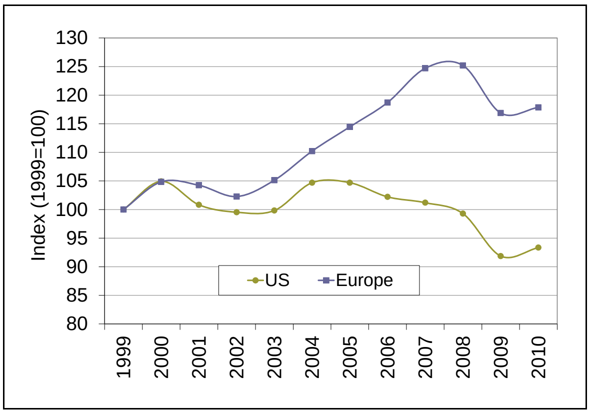


FIGURE II: EVOLUTION OF IFR TRAFFIC IN THE US AND IN EUROPE

Over this period, the number of controlled flights did not increase in the US, and increased approximately 25% in Europe (~4% p.a.). However, these average values mask contrasted growth rates within the US and Europe.

Due to the economic crisis, traffic declined significantly in the US and Europe in 2009 followed by a slight growth in 2010

In Europe, much of the air traffic growth was driven by strong growth in the emerging markets in the Eastern European States and low-cost carriers.

The US is a more homogenous and mature market which shows a different behaviour and less growth. Despite the virtually zero, if not declining growth rate in the US, growth of traffic was observed in airports such as Denver (DEN), Fort Lauderdale (FLL), Charlotte (CLT), Houston (IAH), and New York (JFK).

The US and Europe reports different shares of general aviation, which account for 23% and 4% of total traffic, respectively.

In order to improve comparability of data sets, the more detailed analyses were limited to controlled (IFR) flights from or to the 34 busiest airports in both the US and Europe.

Traffic to/from the main 34 airports in 2010 represents some 66% of all IFR flights in Europe and 63% in the US.

Table II provides high-level indicators for the main 34 airports in the US and in Europe.

TABLE II: SOME KEY AIRPORT DATA

Main 34 airports in 2010	Europe		US		Difference US vs. Europe
	2010	Vs. 2008	2010	Vs. 2008	
Average number of annual movements per airport ('000)	237	-9%	389	-6%	+64%
Average number of annual passengers per airport (million)	24	-3%	31	-3.1%	+29%
Passengers per movement	102	+6%	80	3.1%	-22%
Average number of runways per airport	2.5	0%	4.1	0.7%	+64%
Annual movements per runway ('000)	95	-9%	96	-6.7%	+1%
Annual passengers per runway (million)	9.7	-3%	7.7	-3.8%	-21%

The average number of runways and the number of movements are significantly higher (+64%) in the US while the number of passengers per movement (-22%) is much lower than in Europe.

Average seat size per scheduled flight differs in the two systems, with Europe having a higher percentage of flights using "large" aircraft than the US. Average seat size per scheduled flight over time is shown in Figure III.

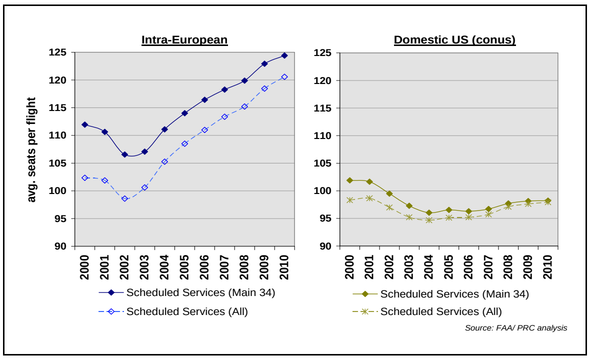


FIGURE III: AVERAGE SEATS PER SCHEDULED FLIGHT

AIR TRAFFIC FLOW MANAGEMENT TECHNIQUES

Both the US and Europe have established system-wide traffic management facilities to ensure that traffic flows do not exceed what can be safely handled by controllers, while trying to optimize the use of available capacity.

However, for a number of operational, geopolitical and even climatic reasons, Air Traffic Flow Management (ATFM) techniques have evolved differently in the US and in Europe:

- While both Air Navigation systems are operated with similar technology and operational concepts, there is only one service provider in the US, all US centres use the same automation systems and have procedures for cooperation on inter-centre flow management.
- In Europe, there are 38 en route service providers of various geographical areas each operating their own system, which makes it more difficult to implement arrival management across national boundaries (e.g. sequencing traffic into major airports of other States).
- Additionally, all States have their own military needs and requirements that must be accommodated. This can make ATC operations and airspace management more difficult.
- The two systems also differ considerably in terms of scheduling of operations at airports.
- In Europe, traffic at major (coordinated) airports is usually controlled (in terms of volume and concentration) in the strategic phase through the airport capacity declaration process, and the subsequent allocation of airport slots to aircraft operators months before the actual day of operation.
- In the US, airline scheduling is unrestricted at most airports with demand controlled by airlines and adapted depending on the expected cost of delays and the expected value of operating additional flights (without the risk of losing valuable airport slots as in Europe).
- The airport capacity declaration process at European airports could arguably result in capacities closer to instrument meteorological conditions (IMC) capacity while in the US, where demand levels are less controlled and visual meteorological conditions (VMC) conditions are more prominent, the airports are scheduled closer to VMC capacity.
- While the unrestricted scheduling at US airports encourages high airport throughputs levels, it also results in a higher level of variability when there is a mismatch between scheduled demand and available capacity.
- In the US, convective weather/thunderstorms are quite severe and widespread in the summer (mostly in the nation's eastern half) and may require ground holds and continent-wide reroutings of entire traffic flows.

The systems differ notably in the timing when and the phase of flight where flow management measures are applied.

In Europe, demand management measures are applied months in advance through the strategic agreements on airport capacities and slots. In addition, the focus in Europe is to anticipate demand/capacity imbalances and if necessary, to solve them by delaying aircraft on the ground (allocation of ATFM take-off slots). The European system operates airport streaming on a local and distributed basis.

In the US, demand management mainly takes place on the day of operation when necessary. The US system appears to have fewer en route capacity problems and is geared towards maximising airport throughput. With fewer en route capacity restrictions, the US has the capability to absorb large amounts of time through speed control and path stretching in en route airspace in order to achieve the metering required by terminal manoeuvring areas (TMA) and airports.

Ground-based flow management

In Europe when traffic demand is anticipated to exceed the available capacity in en route control centres or at an airport, ATC units may call for "ATFM regulations." Aircraft subject to ATFM regulations are held at the departure airport according to "ATFM slots" allocated by the Central Flow Management Unit (CFMU).

In the US, ground delay programmes are mostly used in case of severe capacity restrictions at airports when less constraining ATFM measures, such as Time Based Metering (TBM) or Miles in Trail (MIT) are not sufficient. The Air Traffic Control System Command Centre (ATCSCC) applies Estimated Departure Clearance Times (EDCT) to delay flights prior to departure. Most of these delays are taken at the gate.

Airborne flow management

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

In the US, in order to ensure maximum use of available capacity in en route centres and arrival airports, traffic flows are controlled through MIT and TBM. Flow restrictions are passed back from the arrival airport to surrounding centres and so on as far as necessary. Ultimately. MIT can also affect aircraft on the ground. En route-caused restrictions are small compared to airport driven flow restrictions in the US.

Terminal management area

In both the US and the European systems, the terminal area around a congested airport is used to absorb delay and keep pressure on the runways. Traffic management initiatives generally recognize maximising the airport throughput as paramount. With 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. With MIT and TBM, delays can be absorbed upstream at more fuel-efficient altitudes.

COMPARISON OF OVERALL AIR TRANSPORT PERFORMANCE

This section evaluates operational air transport performance compared to airline schedules in the US and in Europe. It furthermore analyses trends in the evolution of scheduled block times.

On-time performance (Punctuality)

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

After a continuous decrease between 2004 and 2007, on-time performance in Europe and in the US shows an improvement between 2008 and 2009. However, this improvement needs to be seen in a context of lower traffic growth as a result of the global financial and economic crisis and increased schedule padding in the US (see Figure V).

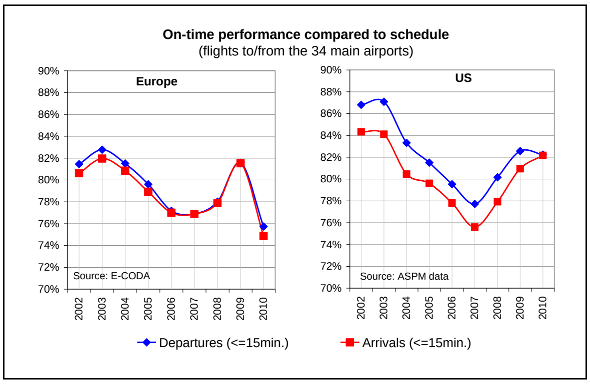


FIGURE IV: ON-TIME PERFORMANCE [2002-2010]

While in the US on-time performance continued to improve in 2010, in Europe, performance dropped to the worst level recorded since 2001 although traffic was still below 2007 levels and traffic growth was modest. The poor performance was mainly due to industrial actions and higher than usual weather related delay in the winter.

Evolution of scheduled block times

Figure V 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 (2000-2010).

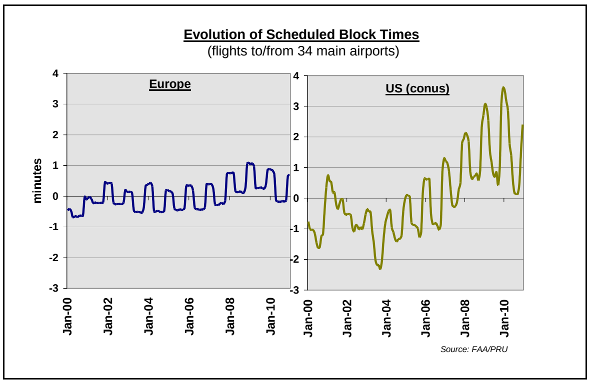


FIGURE V: SCHEDULING OF AIR TRANSPORT OPERATIONS [2000-2010]

Between 2000 and 2010, scheduled block times remained relatively stable in Europe while in the US, average block times have increased by some 3 minutes between 2005 and 2009 before declining in 2010. In general, airlines may absorb delay either through increased block time or by allowing for more time in the turnaround phase.

Seasonal effects are visible, scheduled block times being on average longer in winter than in summer. US studies by the former Free Flight Office have shown that the majority of increase is explained by stronger winds on average during the winter period.

Predictability of operations

Predictability evaluates the level of variability in each phase of flight as experienced by the airspace users. In order to limit the impact from outliers, variability is measured in Figure VI as the difference between the 80th and the 20th percentile for each flight phase.

Figure VI shows that in both Europe and the US, arrival predictability is mainly driven by departure predictability.

Departure time variability essentially follows the patterns observed for on-time performance on both sides of the Atlantic.

However, contrary to Europe, variability increased slightly in the taxi-out and flight phase in the US, which appears to be driven by the different approaches in both scheduling operations and absorbing necessary delay.

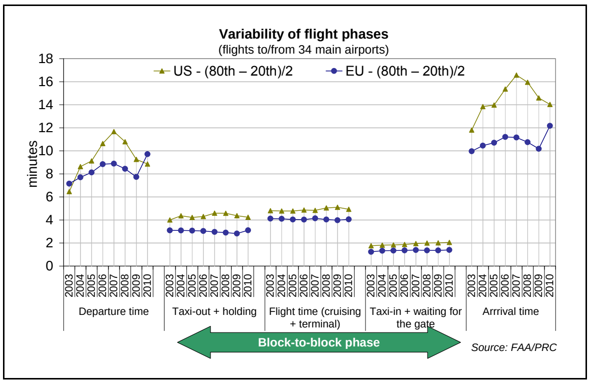


FIGURE VI: VARIABILITY OF FLIGHT PHASES [2003-2010]

As demand increases in congested areas, the variability in times in all flight phases also increases. Over the past years, the US has seen demand increases at congested major airports, driving the variability of the overall ATM system.

EFFICIENCY OF AIR TRANSPORT PERFORMANCE

"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 mean travel times and an optimum time.

Figure VII provides a first analysis of how the duration of the individual flight phases has evolved over the years in Europe and the US. The analysis is based on the DLTA Metric and compares actual times for each city pair with the long term average for that city pair over the full period (2003-2010).

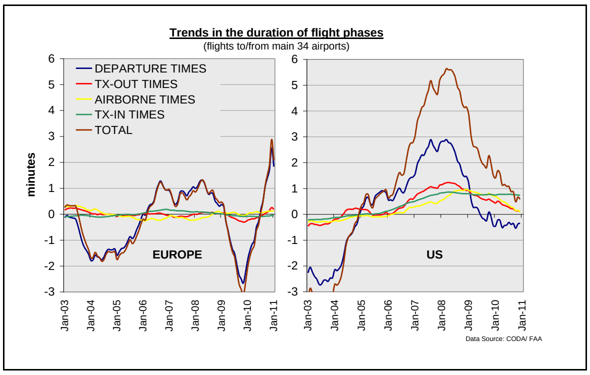


FIGURE VII: TRENDS IN THE DURATION OF FLIGHT PHASES

In Europe, performance is clearly driven by departure delays with only very small changes in the gate-to-gate phase. In the US, the trend is different: in addition to a deterioration of departure times, there is a clear increase in average taxi times and airborne times between 2005 and 2008 before performance improves again in 2009 and 2010.

Inefficiencies in the different flight phases have different impacts on aircraft operators and the environment. Whereas ANS-related holdings (ATFM/EDCT delay) result in departure delays mainly experienced at the stands, inefficiencies in the gate-to-gate phase generate additional fuel burn. The additional fuel burn has an environmental impact through gaseous emissions (mainly CO_2).

This section focuses particularly on the ANS contribution towards overall air transport performance. In order to account for differences in fuel burn, the following section is broken down by phase of flight. The section concludes with an overview of the estimated ANS contribution in individual flight phases.

Before looking at the ANS contribution in more detail, 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 for a system to run efficiently without under-utilisation of available resources.
- 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 actually flown distance to the great circle distance.
- A clear-cut allocation between ATM and non-ATM related causes is 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 performance (i.e. distribution of delay between air and ground) and thus on costs to airspace users.
- The approach measures performance from a single airspace user perspective without considering inevitable operational trade-offs, 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 measures 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.).

ANS-related departure/gate holdings

This section reviews ANS-related departure delays in the US and in Europe (EDCT versus ATFM). Aircraft that are expected to arrive during a period of capacity shortfall en route or at the destination airport are held on the ground at their various origin airports.

ATFM/EDCT departure delays can have various ATM-related (ATC capacity, staffing, etc.) and non-ATM related (weather, accident, etc.) reasons.

Table III compares ANS-related departure delays attributable to en route and airport constraints. Only EDCT and ATFM delays greater than 15 minutes were included in the calculation.

TABLE III: ANS-RELATED DEPARTURE DELAYS (MAIN 34 AIRPORTS)

Only delays > 15 min. are included.			En route related delays >15min. (EDCT/ATFM)			Airport related delays >15min. (EDCT/ATFM)		
		IFR flights (M)	% of flights delayed >15 min.	delay per flight (min.)	delay per delayed flight (min.)	% of flights delayed >15 min.	delay per flight (min.)	delay per delayed flight (min.)
US	2008	9.2	0.1%	0.1	57	2.6%	1.8	70
	2010	8.6	0.1%	0.05	44	1.6%	1.0	66
Europe	2008	5.6	5.0%	1.4	28	3.0%	0.9	32
	2010	5.0	5.7%	1.8	32	3.3%	1.2	36

The share of flights affected by ATFM/EDCT delays due to en route constraints differs considerable between the US and Europe. In Europe, flights are as much as 50 times more likely to be held at the gate for en route constraints.

For airport-related delays, the percentage of delayed flights at the gate is similar in the US and in Europe.

In the US, ground delays (mainly due to airport constraints) are applied only after TBM or MIT options are used, which consequently leads to a lower share of flights affected by EDCT delays but higher delays per delayed flight than in Europe. More analysis is needed to see how higher delays per delayed flight are related to moderating demand with airport slots 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.

Taxi-out efficiency

The analysis of taxi-out efficiency in the next sections 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 measure 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 restrictions, aircraft type, and remote de-icing to name a few.

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

For 2010, Figure VIII shows similar additional time in the taxi-out phase in the US (5.0 minutes per departure) and Europe (4.9 minutes per departure). This is a marked change from 2008 when US taxi-out delay was significantly higher.

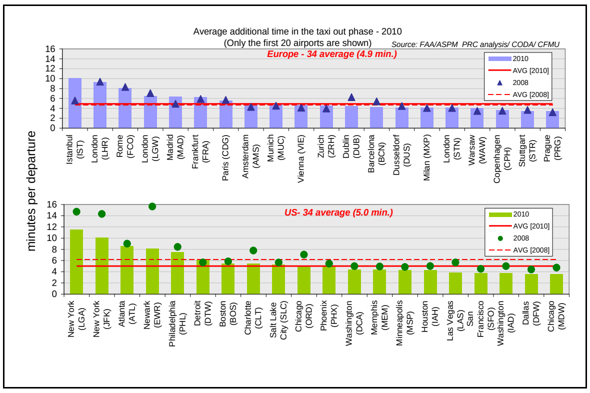


FIGURE VIII: COMPARISON OF ADDITIONAL TIME IN THE TAXI-OUT PHASE

Historically, the observed differences in inefficiencies between the US and Europe reflect the 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 adds to the focus of getting off-gate on time.

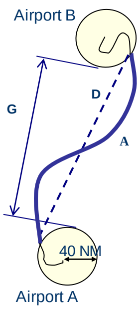
En route flight efficiency

Deviations from the optimum trajectory generate additional flight time, fuel burn and costs to airspace users. En route flight efficiency has a horizontal (distance) and a vertical (altitude) component.

This report focuses on horizontal en route flight efficiency, which is of much higher economic and environmental importance than the vertical component. However, more work on en route vertical flight inefficiency would form a more complete picture.

In Europe, en route flight efficiency is mainly affected by the fragmentation of airspace (airspace design remains under the auspices of the States). For the US, the indicator additionally includes some path stretching due to Miles in Trail restrictions.

The key performance indicator (KPI) for horizontal en route flight efficiency is en route extension. It is defined as the difference between the length of the actual trajectory (A) and the Great Circle Distance (G) between the departure and arrival terminal areas (radius of 40 nautical miles [NM] around the departure airport, 100 NM for the arrival).



This difference would be equal to zero in a theoretical (and unachievable) situation where each aircraft would be alone in the system and not be subject to any constraints. 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) or other reasons (route charges, avoid congestion) need to be considered.

Figure IX depicts the en route extension for flights to/from the main 34 airports within the respective region (Intra Europe, US CONUS) and the respective share of flights. "Direct route extension" and corresponding fuel burn are approximately 1-2% lower in the US for flights of comparable lengths.

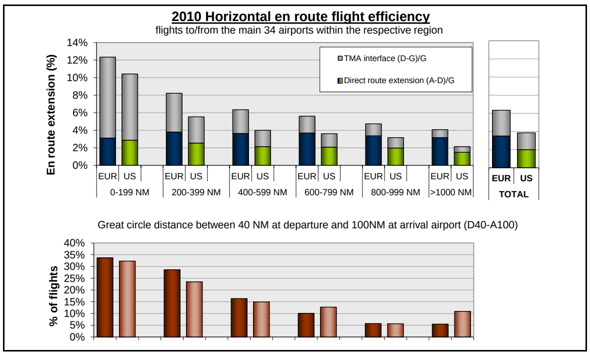


FIGURE IX: COMPARISON OF DIRECT EN ROUTE EXTENSION

Arrival Sequencing and Metering Area (ASMA) delays

The locally defined TMA is not suitable for comparisons due to considerable variations in shape and size. A standard Arrival Sequencing and Metering Area (ASMA) is defined as a ring of 100 NM radius around each airport. This is generally adequate to capture tactical arrival control measures (sequencing, flow integration, speed control, spacing, stretching, etc.) irrespective of local ATM strategies.

The figure below shows the additional time within the last 100 NM. 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 for each airport.

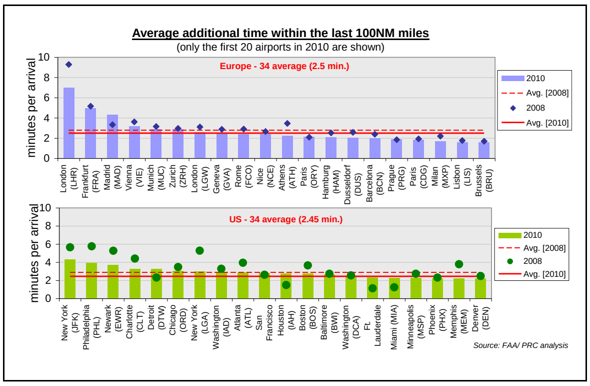


FIGURE X: AVERAGE EXCESS TIME WITHIN THE LAST 100 NM

At system level, the additional time within the last 100 NM is similar in the US (2.45 min.) and in Europe (2.5 min.). However, the picture is contrasted across airports.

In Europe, London Heathrow (LHR) is a clear outlier, having by far the highest level of additional time within the last 100 NM, followed by Frankfurt (FRA).

The US shows a less contrasted picture but there is still a notable difference for the airports in the greater New York area, which show the highest level of inefficiencies within the last 100 NM in 2010.

ESTIMATED BENEFIT POOL ACTIONABLE BY ANS

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 this "benefit pool" represents a theoretical optimum which is not achievable at system level due to inherent necessary (safety) or desired (capacity) limitations.

Table IV summarises the estimated level of inefficiency actionable by ANS in the individual flight phases, as analysed in the respective sections.

Although Table IV shows an estimated total to provide an order of magnitude, the interpretation requires a note of caution as inefficiencies in the various flight phases (airborne versus ground) have a very different impact on airspace users in terms of predictability (strategic versus tactical – percentage of flights affected) and fuel burn (engines on versus engines off).

TABLE IV: ESTIMATED TOTAL BENEFIT POOL ACTIONABLE BY ANS

Estimated benefit pool actionable by ANS for a typical flight [2010] (flights to/from the main 34 airports)		Estimated additional time (avg. per flight in min.)		Predictability (% of flights affected)		Fuel burn	Est. excess fuel burn (kg)	
		EUR	US	EUR	US	engines	EUR	US
Holding at gate per departure (only delays >15min. included)	en route-related	1.8	0.05	5.7%	0.1%	OFF	≈0	≈0
	airport-related	1.2	1.0	3.3%	1.6%	OFF	≈0	≈0
Taxi-out phase (min. per departure)		4.9	5.0	100%		ON	73 kg	75kg
Horizontal en route flight efficiency		2.1-3.8	1.3-2.5	100%		ON	176kg	114kg
Terminal areas (min. per arrival)		2.5	2.45	100%		ON	103kg	100kg
Estimated benefit pool actionable by ANS		≈12.5-14.2	≈9.8-11.0				352kg	289kg

Whereas for ANS-related holdings at the gate the fuel burn is quasi nil, those delays are not evenly spread among flights (small percentage of flights but high delays) and hence difficult to predict.

The estimated "inefficiencies" in the gate-to-gate phase are generally more predictable for airspace users (more evenly spread but smaller delays) but generate higher fuel burn.

Actual fuel burn depends on the respective aircraft mix and therefore varies for different traffic samples. For comparability reasons, the fuel burn shown in Table IV is based on typical average fuel burn which was equally applied to the US and Europe.

While ANS is often not the root cause of delay, the way the delay is managed and distributed along the various phases of flight has an impact on airspace users (predictability, fuel burn), the utilisation of capacity (en route and airport), and the environment (gaseous emissions).

In the descent phase, for example, there are opportunities for fuel saving improvements independent of reducing delay. Moving necessary delay from inside of 100 NM to the cruise phase of flight may support significant fuel savings without changing throughput or arrival times.

CONCLUSIONS

The analysis of schedule adherence reveals a similar level of arrival punctuality in the US and Europe, albeit with increasing time buffers in airline schedules and a higher level of variability in the US, part of which is assumed to be a result of a combination of airport scheduling closer to VMC capacity and resulting weather effects.

The analysis of actual operations is broken down by phase of flight (i.e. pre-departure delay, taxi-out, en route, terminal arrival, taxi-in, and arrival delay). This reveals strong and weak points on both sides.

- In the US, departure punctuality is better and taxi-out delays are now comparable with Europe. This was not the case in 2008 but it should be noted that Europe was affected by exceptional events in 2010.
- Horizontal en route flight efficiency is higher in the US, with corresponding fuel burn benefits. The fragmentation of European airspace appears to be an issue which affects overall flight efficiency and limits the ability of the en route function to support airport throughput. The development of Functional Airspace Block (FAB) within the Single European Sky Initiative is expected to help improve this.
- On average, the additional time within the last 100 NM is comparable. London and Frankfurt on the European side and the airports in the New York area on the US side show significantly higher arrival transit times on average.

Although safety and capacity constraints limit the practicality of ever fully eliminating these inefficiencies, there is value in developing a systematic approach to aggregating a benefit pool which is actionable by ANS.

Inefficiencies have a different impact (fuel burn, time) on airspace users, depending on the phase of flight (terminal area, cruise, or ground) and the level of predictability (strategic or tactical).

While ANS is often not the root cause of a delay, the aim should be to optimise how the delay is taken. The predictability of the different flight phases and the fuel cost will help determine how much and where delay needs to be absorbed. Further work is needed to assess the impact of efficiency and predictability on airspace users, the utilisation of capacity, and the environment.

The estimated inefficiency pool actionable by ANS and associated fuel burn is similar in the US and Europe (estimated to be 6-8% of the total fuel burn) but with notable differences in the distribution by phase of flight.

These differences possibly originate from different policies in allocation of airport slots and flow management, as well as different weather conditions. The impact on the environment, predictability, and flexibility in accommodating unforeseen changes may be different. In addition to weather and airport congestion management policy, a more comprehensive comparison of service performance would also need to address safety, capacity and other relevant performance affecting factors.

There is high value in global comparisons and benchmarking in order to optimise performance and identify best practices. Moving forward, the conceptual framework enables operational performance to be measured in a consistent way and ATM best practices to be better understood. Identification and application of today’s best practices, with existing technology and operational concepts, could possibly help in raising the level of performance on both sides of the Atlantic.

1 INTRODUCTION

1.1 Background and objectives

1.1.1 In October 2009, the EUROCONTROL Performance Review Commission (PRC) and the US Federal Aviation Administration (FAA) produced a comprehensive report on performance using operations data from the top 34 facilities in each region [Ref. 1, Annex VI]. In developing the report, EUROCONTROL and the FAA identified common databases and common performance indicators that could be used to evaluate many of the Key Performance Areas (KPAs) specified in the International Civil Aviation Organisation (ICAO) Global Air Traffic Operational Management Concept. The report produced performance measures and trends based on operations data as of the end of calendar year 2008.

1.1.2 This report presents an update to the 2008 benchmark report using operations current for calendar year 2010. Overall, a weak economic climate has resulted in a decline in operations in both the US and Europe since 2008.

1.1.3 Since 2008, the US has seen the merger of several major airlines including Frontier and Midwest; Delta and Northwest; United and Continental; and Southwest and Air Tran. Merged airlines typically consolidate flights to improve their efficiency and in turn close less profitable hubs. These hub closures may reduce overall flights operating in domestic airspace while concentrating passengers at the remaining hubs. The New York airports have been operating with a policy of schedule limitation[1] from 2008 to 2010 and New York (JFK) has been utilising surface management techniques closer to the European mode of departure management. The end result has been less surface congestion with delay pushed farther back to the gate.

1.1.4 In Europe, performance was negatively influenced by exceptional events in 2010 (volcanic ash cloud, industrial actions, and unusually severe weather conditions). Approximately 111,000 flights were cancelled due to volcanic ash clouds in April and May 2010, which reduced air traffic by some 48% during eight days in April and annual air traffic growth by an estimated 1.2% in 2010. Additionally an estimated 26,000 flights were cancelled due to industrial action and some 45,000 flights due to bad weather conditions in winter.

1.1.5 In addition to updated figures based on 2010 traffic, explanatory portions of the report have been maintained. Where relevant, commentary has been added to address changes in trends that occurred since 2008. The FAA and EUROCONTROL intend to continue producing updates to these benchmark reports that reflect current trends and improved performance methodologies.

1.1.6 At the ICAO Assembly – 37th Session in October 2010, ICAO established a global goal of 2% annual improvement in fuel efficiency until the year 2050. Although no specific

[1] For reference, 73 FR 3510, 18 January 2008, provided limits to operations to JFK that targeted a maximum of 81 scheduled operations per hour with the rule taking effect 30 March 2008.

countries or aviation sectors are targeted, it is expected that Air Navigation Service Providers (ANSPs) will be required to estimate benefit pools on efficiency similar to what was done in the 2008 EU/US report. The Air Transport Action Group (ATAG) has also looked at targets for the aviation sector that improve overall fuel efficiency.

1.1.7 The Civil Air Navigation Services Organization (CANSO) has provided input into the ICAO and ATAG work largely though its Environmental Work Group and its report titled "ATM Global Environment Efficiency Goals for 2050" [Ref. 2]. The CANSO work makes use of the phase-of-flight methodology described in this benchmark report and is promoting the phase of flight approach described in this report as a means for ANSPs to assess flight efficiency.

1.1.8 As in any industry, global comparisons and benchmarking including data analysis can help optimise performance and identify best practices in Air Traffic Management (ATM). Over the years, various groups have sought to estimate the amount of inefficiency that can be addressed by improvements in the ATM system.

1.1.9 With the exception of on-time performance, there is a lack of commonly agreed and comparable performance indicators world-wide (there are multiple delay definitions even within ANSPs). However since the publication of the original report, the phase-of-flight indicators have been assessed by CANSO working groups for use in global benchmarking. Also, the direct flight indicator (Chapter 6) is now a European-wide tracking metric of operational and environmental efficiency.

1.1.10 This report presents an update to the measures that allow for a high-level comparison of operational performance between US and Europe air navigation systems and to provide updated key system-level figures. It builds on the techniques developed based on input received over the last two years.

1.1.11 In order to better understand the impact of ATM and differences in traffic management techniques, the analysis is broken down by phase of flight (i.e. pre-departure delay, taxi-out, en route, terminal arrival, taxi-in, and arrival delay). The breakdown by flight phase also supports better measurements of fuel efficiency.

1.1.12 Where possible, reasons for differences in system performance were explored in more detail in order to provide an understanding of underlying performance drivers or, where necessary, to stimulate more detailed analyses.

1.1.13 Lastly, these benchmark reports strive to explain the relationship between ATM performance and interdependencies outside of ATM. This may include competing goals within airlines, the airline schedules, weather and changes to airport infrastructure that affect capacity.

1.2 Study scope

1.2.1 Global comparisons and benchmarking requires 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. The specific key performance indicators (KPIs) used in this report are developed using common procedures on best available data from both the FAA Performance Analysis Office and PRC.

PERFORMANCE AREAS

1.2.2 Based on expectations of the ATM community, the ICAO Global Performance Manual [Ref. 3] identifies 11 Key Performance Areas (KPAs) and groups them by visibility, as shown in Figure 1.

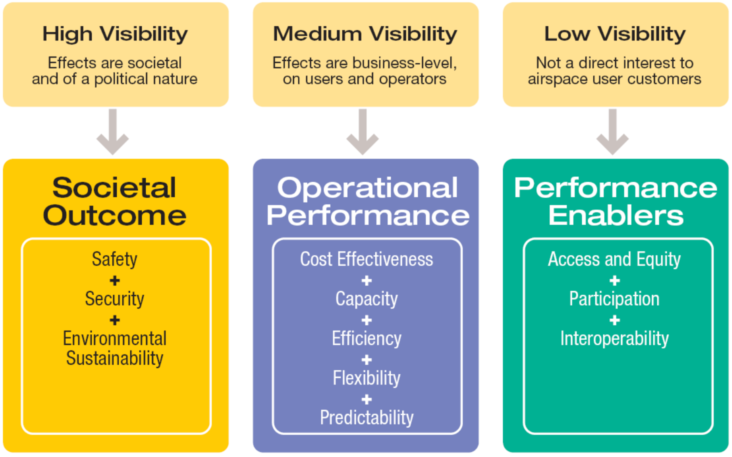


Figure 1: ICAO Key Performance Areas

1.2.3 The scope of this paper is limited to Operational Performance. The KPAs addressed are mainly Efficiency and Predictability and, indirectly, Environmental Sustainability when evaluating additional fuel burn.

1.2.4 There are many performance indicators for Efficiency. Flight efficiency can be defined as an actual flight time, distance, or fuel against an optimal or benchmark time, distance, or fuel. This report presents flight efficiency indicators by phase of flight. Actual fuel against an optimum fuel is a flight efficiency indicator closely linked to Environmental Sustainability and the root of the aspirational goals developed by ICAO in 2010.

1.2.5 The Punctuality measures reported in Section 4 measure actual time against a schedule time. These measures are possibly the most visible of the flight efficiency performance indicators.

1.2.6 In April 2010, the US implemented a Tarmac Rule that imposed heavy penalties for aircraft that remain on the tarmac for more than 3 hours without deplaning passengers, assuming the safe and secure deplaning of passengers is a viable option [Ref. 4]. Schedule limitations are also often developed in the context of meeting a delay goal. These actions are highly visible and are linked to Societal Outcomes in improving the passenger experience.

1.2.7 Flight efficiency and delay measures are heavily influenced by operator schedules, weather and airport infrastructure. Alternatively, throughput efficiency measures assess how well an ANSP performs given the conditions presented. For example, if a facility has a called or declared capacity, a measure is made of how well the capacity is utilised independent of delay.

1.2.8 Flexibility is currently difficult to measure. It would ultimately measure the ability of airspace users to exploit opportunities in order to optimise their daily operations (i.e. trade off speed/time for fuel efficiency or conversely, prioritise aircraft in arrival sequence at the expense of fuel, etc.). While this is a worthwhile topic, it is outside the scope of this report.

1.2.9 Capacity as a KPA is measured in several different ways. Using readily available performance databases, the effect of capacity can be measured as an increase in facility throughput. However, throughput is also dependent of weather and mix of aircraft type (i.e. US small/large/heavy or light/medium/heavy).

1.2.10 The report does not directly address other KPAs such as Safety or Cost Effectiveness. It is acknowledged that for a comprehensive comparison of service performance, information about safety, cost and operational performance is needed.

GEOGRAPHICAL SCOPE

1.2.11 In order to ensure comparability of data sets, the scope of the paper was influenced by the need to identify a common set of suitable data sources with a sufficient level of detail and coverage.

1.2.12 Unless stated otherwise, the analyses are limited to flights from and to the 34 busiest airports in terms of controlled commercial (IFR) traffic[2] in both the US and in Europe. A list of the airports included in this report can be found in Annex I with the operation counts provided in Figure 10.

1.2.13 For the purpose of this report, “Europe” is defined as Air Navigation Services (ANS) provided by the EUROCONTROL States[3] in the EUR region and Estonia excluding Oceanic areas and the Canary Islands.

1.2.14 “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.

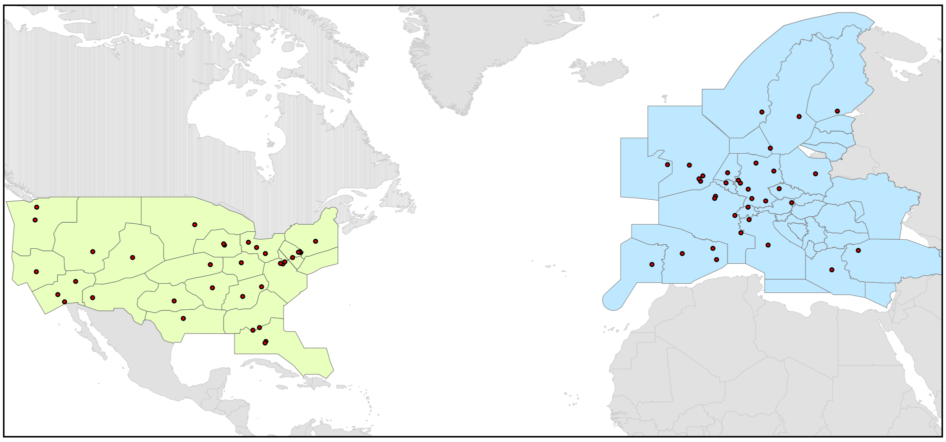


Figure 2: Geographical scope of the report

2 Calculated as the average over the previous three years (2008-2010)

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

TEMPORAL SCOPE

1.2.15 The economic crisis which started in the second half of 2008 resulted in a very significant reduction of air traffic in the US and in Europe. This report tracks changes that have occurred over time and reports joint performance indicators through calendar year 2010.

1.3 Data sources

1.3.1 There are many different data sources for the analysis of ATM-related operational air transport performance. For consistency reasons, most of the data in this study were drawn from a combination of centralised airline reporting and operational ATM systems. In addition to system-wide traffic counts, more detailed performance measures are provided for the top 34 airports in terms of IFR traffic.

DATA FROM AIR TRAFFIC MANAGEMENT SYSTEMS

1.3.2 Both US and Europe obtain key data from their respective traffic flow management systems. For the US, data come from the Traffic Flow Management System (TFMS). In Europe, data are derived from the Enhanced Tactical Flow Management System (ETFMS) of the Central Flow Management Unit (CFMU) located in Brussels, Belgium. This source provides the total IFR traffic picture and is used to determine the "top" airports in terms of IFR traffic and the flight hour counts used to determine traffic density.

1.3.3 Both of these systems have data repositories with detailed data on individual flight plans and track sample points from actual flight trajectories[4]. They also have built-in capabilities for tracking ATM related ground delays[5] by airport and en route reference location.

1.3.4 The data set also provides estimates of actual trajectories which are used for the calculation of flight efficiency in terms of great circle distance, planned routes and actual flown routing. Initially, these data sets focused on the en route phase of flight but more recently, they include data in the transition and terminal areas of flight, thus allowing for terminal area benchmarking. For the US, 1-minute updated radar was used for flight efficiency calculations.

DATA FROM AIRLINES

1.3.5 The US and Europe receive both 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 measures where more precise times are required.

1.3.6 In the US, most performance measures are derived from the Aviation System Performance Metrics (ASPM) database which fuses detailed airline data with data from

---

4 The CFMU updates flight profiles if the position received deviates by more than a given threshold (vertical 007 FL, horizontal 20 NM, temporal 5 min.) from the current estimated trajectory. Work is in progress in Europe to further improve the data quality and to base future calculations entirely on correlated position reports (CPRs). In the US total distance is calculated by integrating the distance between all recorded data points.

5 Delays are calculated as the difference between the last estimated take-off time (ETOT) in the flight plan and the calculated take-off time (CTOT).

the traffic flow system. ASPM accounts for 85% of the IFR traffic at the main 34 airports with 79% 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 (plus other carriers that report voluntarily). In the US for 2010, there is airline reported performance data for 81% of the scheduled flights at the main 34 airports which represents 64% of all main 34 IFR flights.

1.3.7 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, Off the runway, On 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.

1.3.8 The US data also included flight itineraries for the domestic operations through tail number tracking of aircraft (international legs are not reported). This allows for more detailed analysis of what is called propagated or reactionary delay in later sections. For these cases, the causal reasons for delay are traced to earlier flight legs in the itinerary and possibly to events at airports visited earlier in the aircraft's itinerary.

1.3.9 The US data also contains cause codes for arrival delays over 15 minutes on a flight-by-flight basis. Cause categories include ATM system, Security, Airline, Extreme Weather, and Late Arrival (from previous leg).

1.3.10 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 within the European airspace more than 35,000 flights per year[6] are required to submit the data on a monthly basis according to Regulation (EU) No 691/2010 [Ref. 5].

1.3.11 Currently, the CODA coverage is approximately 60% of scheduled commercial flights and approximately 71% 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.

1.3.12 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

1.3.13 Post-operational analyses 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.

1.3.14 Both US and Europe performance groups use detailed weather information known as METAR data. This data is highly standardized and provides information on ceiling, visibility, as well as a host of other meteorological information. The FAA Air Traffic Organization (ATO) is collecting this data at major airports and uses commercially

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

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 well-observed 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.

1.4 Organisation of this report

1.4.1 The report is organised as follows:

- Chapter 2 provides a high-level overview of the two ATM systems providing key figures and a comparison of basic traffic characteristics in order to assess the comparability of the two traffic samples. It also provides an overview of the interrelated drivers affecting the US National Airspace System (NAS) performance.

- Chapter 3 provides a brief description of basic differences in Air Traffic Management Techniques between Europe and the US and presents the approach used for the assessment of ATM related service performance in the US and in Europe. Lastly, the chapter highlights some important points for the interpretation of the results in this report.

- Chapter 4 evaluates air transport on-time performance with respect to airline schedules, historic trends in the scheduling of block times, and underlying delay reasons as reported by airlines.

- Chapter 5 addresses the KPA "Predictability" which evaluates the level of variability in the ATM system as experienced by the airspace users.

- Chapter 6 provides an estimate of the level of "Efficiency" of air transport operations compared to an optimum reference time. In order to better understand the impact of ATM and differences in traffic management techniques, the analysis is broken down by phase of flight (i.e. pre-departure delay, taxi-out, en route, terminal arrival, taxi-in and arrival delay).

- The total estimated "benefit pool" which can be influenced by ANS is discussed in Chapter 7 and the main findings are summarised in Chapter 8.

- Chapter 9 illustrates areas for further research that would allow for a more complete benchmarking between the two systems.

2 KEY CHARACTERISTICS OF THE TWO ATM SYSTEMS

This chapter provides some key 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 for the more detailed analysis of ATM-related service quality by flight phase in Chapters 5 and 6.

2.1 Air traffic characteristics

2.1.1 Table 1 shows selected high-level figures for the European and the US Air Navigation systems.

Table 1: US/Europe ATM system figures [2010]

Calendar Year 2010	Europe[7]	USA[8]	Difference US vs. Europe
Geographic Area (million km^2)	11.5	10.4	≈ -10%
Number of en route Air Navigation Service Providers	38	1	
Number of Air Traffic Controllers (ATCOs in Ops.)	16 700 [9]	14 600 [10]	≈ -13%
Total staff	57 000	35 200	≈ -38%
Controlled flights (IFR) (million)	9.5	15.9[11]	≈ +67%
Share of flights to/ from top 34 airports	66%	63%	
Share of General Aviation	4%	23%	≈ x 5.5
Flight hours controlled (million)	13.8	23.4	≈ +70%
Relative density (flight hours per km^2)	1.2	2.2	≈ x 1.8
Average length of flight (within respective airspace)	557 NM	493 NM	≈ -11%
Number of en route centres	63	20	≈ -68%
Number of airports with ATC services	>450	≈ 509 [12]	≈ +13%
Of which are slot controlled	> 90	3 [13]	
Source	Eurocontrol	FAA/ATO	

2.1.2 The total surface of continental airspace is similar in Europe and the US. However, the FAA controls approximately 67% more IFR flights and handles significantly more visual Flight Rules (VFR) traffic with some 13% fewer controllers and fewer en route facilities. The fragmentation of European ANS with 38 en route ANSPs is certainly a driver behind such difference.

2.1.3 Notwithstanding the large number of airports in the US and European air traffic control systems, only a relatively small number of airports account for the main share of traffic.

---

7 EUROCONTROL States plus Estonia, excluding Oceanic areas and Canary Islands.

8 Area, flight hours and centre count refers to CONUS only. The term US CONUS refers to 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.

9 Of which 60% are allocated to en route units and 40% to approach and tower units.

10 FAA values are consistent with CANSO reporting and include FTE ATCOs in activities directly related to controlling traffic or a necessary requirement for controlling traffic. It also includes an additional 1289 controllers reported for the contract towers.

11 The total number of flights controlled within the entire US airspace in 2010 is approximately 16.5 million.

12 Total of 509 facilities of which 263 are FAA staffed and 246 contract towers.

13 LGA, JFK, EWR (DCA also considered restricted although not strictly for capacity).

The main 34 airports account for 66% and 63% of the controlled flights in Europe and the US, respectively.

AIR TRAFFIC GROWTH

2.1.4 Figure 3 shows the evolution of IFR traffic in the US and in Europe between 1999 and 2010.

2.1.5 Whereas IFR traffic in 2008 is at similar levels as in 1999 in the US, in Europe, traffic increased by approximately 25% relative to 1999.

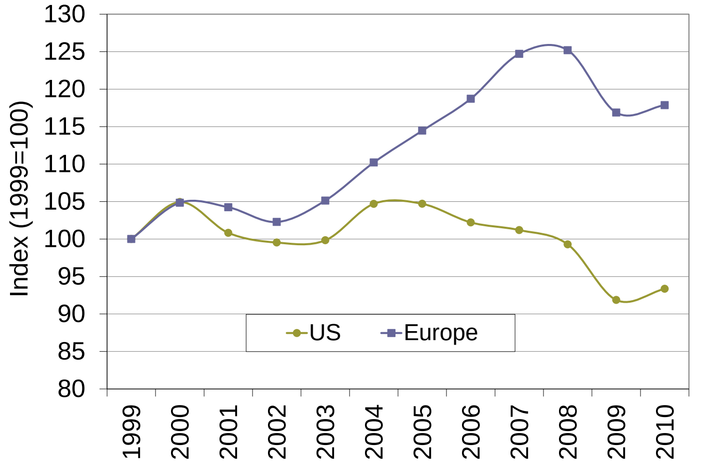


Figure 3: Evolution of IFR traffic in the US and in Europe

2.1.6 Due to the economic crisis, traffic declined significantly in the US and Europe in 2009 followed by a slight growth in 2010. Traffic growth in Europe in 2010 was also negatively affected by exceptional events (volcanic ash cloud, industrial actions, and severe weather conditions) which resulted in the cancellation of an estimated 182,000 flights in 2010.

2.1.7 These average values mask contrasted growth rates within the US and Europe:

- In Europe, much of the air traffic growth was driven by strong growth in the emerging markets in the Eastern European States and low-cost carriers.
- The US is a more homogenous and mature market which shows a different behaviour and less growth. Despite the virtually zero, if not declining, growth rate in the US, growth of traffic was observed in airports such as Denver (DEN), Fort Lauderdale (FLL), Charlotte (CLT), Houston (IAH) and New York (JFK). New York (JFK) is now under schedule limitations.

AIR TRAFFIC DENSITY

2.1.8 Figure 4 shows the traffic density in US and European en route centres measured in flight hours per square kilometre for all altitudes in 2010.

2.1.9 The density in Europe would increase relative to the US if only upper flight levels were considered (the propeller GA aircraft in the US would be excluded)[14]. Detailed comparisons on complexities are beyond the scope of this report.

[14] New York Centre shows as less dense due to the inclusion of a portion of coastal/oceanic airspace. If this portion was excluded, NY would be the centre with the highest density.

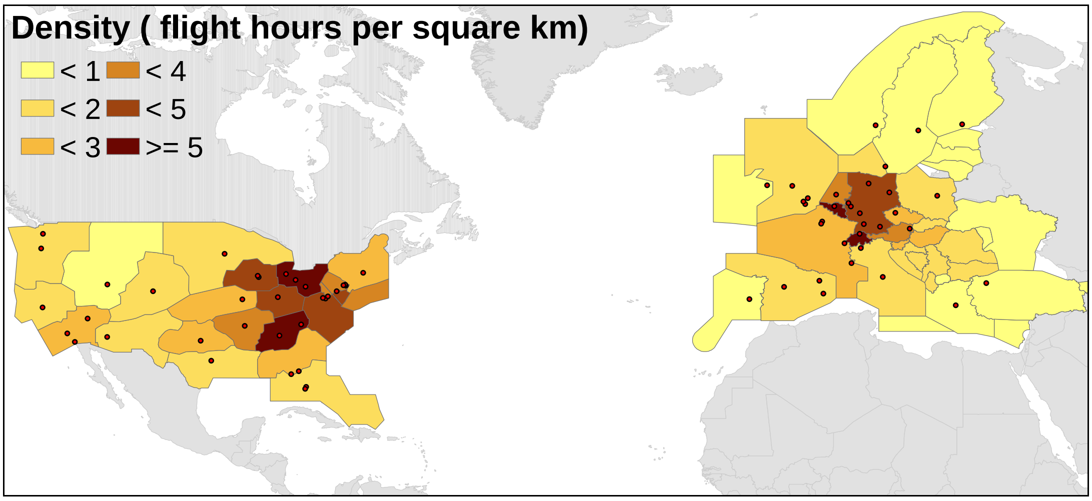


Figure 4: Traffic density in US and European en route centres [2010]

2.1.10 In Europe, the “core area” (including 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.

AVERAGE FLIGHT LENGTH

2.1.11 Table 2 provides a more detailed breakdown of IFR traffic and flight lengths for the US and Europe for the year 2010. The average great circle distances shown in Table 2 refer only to the distances flown within the respective airspace and not the length of the entire flight.

Table 2: Breakdown of IFR traffic [2010]

ALL IFR TRAFFIC 2010	EUROPE			US CONUS		
	N	% of total	Avg. dist. (NM)	N	% of total	Avg. dist. (NM)
Within region	**7.1 M**	**78.4%**	465 NM	**13.7 M**	**85.6%**	492 NM
Main 34 - Main 34	1.7 M	19.0%	515 NM	**3.1 M**	19.2%	822 NM
Main 34 - Other	3.3 M	36.1%	463 NM	**5.5 M**	34.5%	470 NM
Other - Other	2.1 M	23.4%	428 NM	**5.1 M**	31.9%	316 NM
To/from outside region	**1.8 M**	**20.3%**	891 NM	**1.9 M**	**11.8%**	521 NM
To/from Main 34	1.3 M	14.2%	942 NM	**1.5 M**	9.6%	538 NM
Other	0.5 M	6.0%	769 NM	**0.3 M**	2.2%	449 NM
Overflights	**0.1 M**	**1.3%**	924 NM	**0.4 M**	**2.6%**	425 NM
Total IFR traffic	**9.1 M**	**100%**	557 NM	**15.9 M**	**100%**	493 NM

Traffic to/from main 34 airports (2010)	EUROPE (2010)			US CONUS		
	N	% of total	Avg. dist. (NM)	N	% of total	Avg. dist. (NM)
Within region	5.0 M	79.4%	481 NM	8.6 M	84.9%	596 NM
To/from outside region	1.3 M	20.6%	942 NM	1.5 M	15.1%	538 NM
Total	**6.3 M**	**100%**	576 NM	**10.1 M**	**100%**	587 NM

2.1.12 When all flights are taken into account, the average flight length within each respective airspace is longer in Europe (557 NM) compared to the US (493 NM), as shown in Table 2. However, when only flights from and to the main 34 airports are considered, the average flight lengths are slightly longer in the US (587 NM) compared to Europe (576 NM).

2.1.13 Figure 5 shows a continuous increase in average flight length for Europe from 2005 until 2010. In the US, average flight length reaches a peak in 2007 before reducing to approximately the 2006 value.

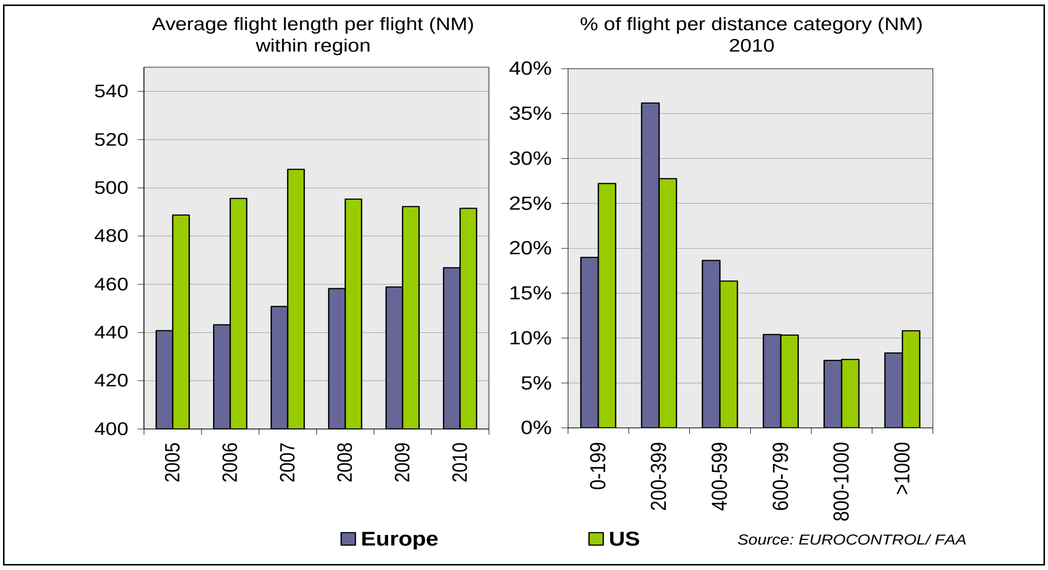


Figure 5: Evolution of average flight lengths (within region)

Seasonality

2.1.14 Seasonality and variability of air traffic 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.

2.1.15 Whereas weekly traffic profiles are similar in Europe and the US (with the lowest level of traffic during weekends) at system level, seasonality is higher in Europe than in the US.

2.1.16 Figure 6 shows the seasonal traffic variability in the US and in Europe at centre level for 2010. In Europe, traffic is about 20% higher in summer months than in winter months whereas in the US, traffic is only 6% higher in the summer.

2.1.17 In Europe, a very high level of seasonality is observed for the holiday destinations in the South. Especially in Greek airspace, the relatively low number of flights in winter contrasts sharply with high demand in summer.

2.1.18 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 6)

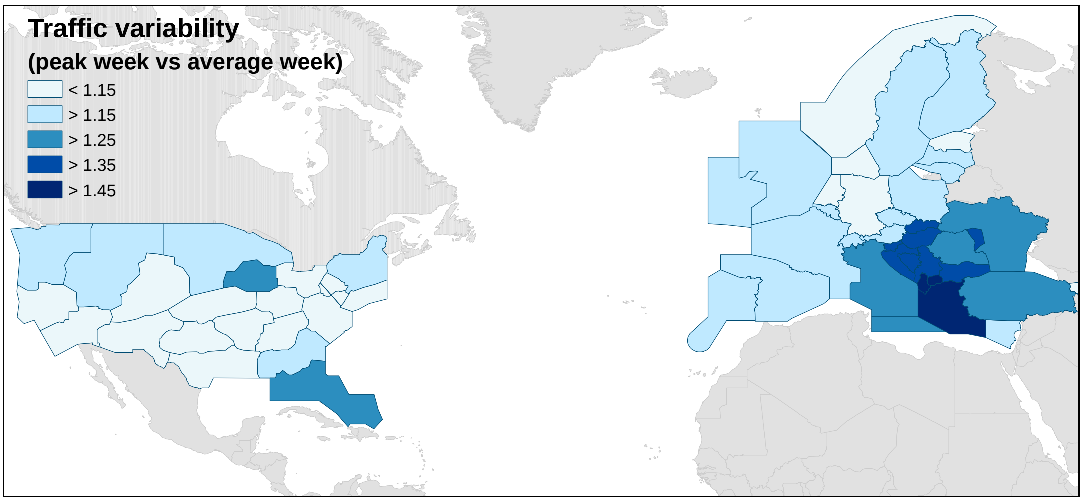


Figure 6: Seasonal traffic variability in US and European en route centres [2010]

TRAFFIC MIX

2.1.19 Figure 7 shows the distribution of physical aircraft classes for the US and Europe. A notable difference between the US and Europe is the share of general aviation which accounts for 23% and 4% of total traffic in 2010 respectively (see Table 1). This is confirmed by the large share of smaller aircraft in the US when analysing all IFR traffic (left side of Figure 7).

2.1.20 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.

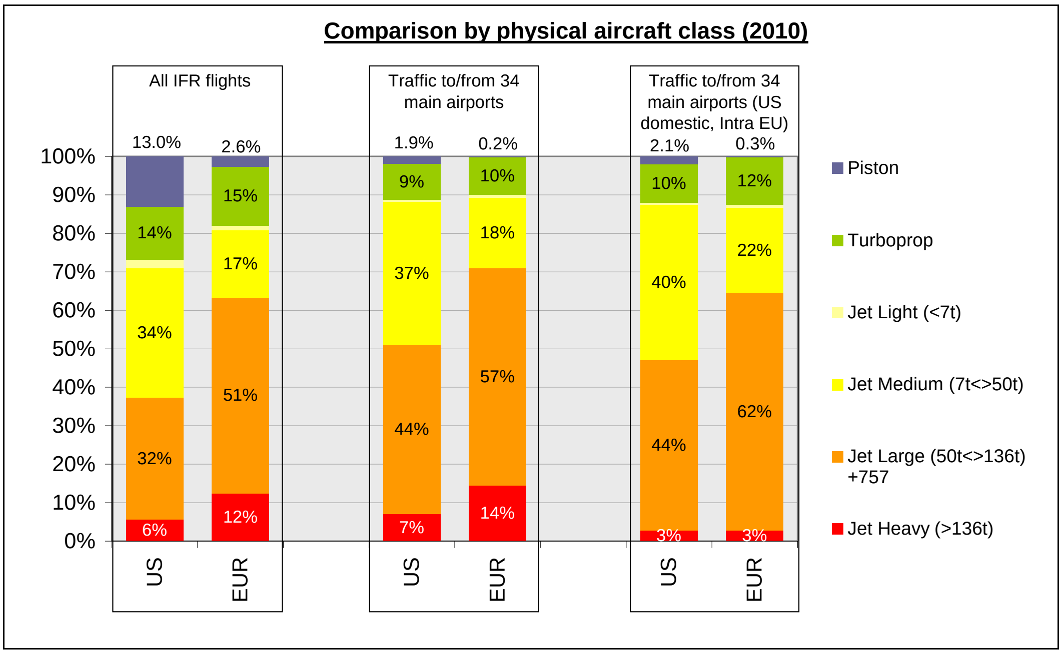


Figure 7: Comparison by physical aircraft class [2010]

2.1.21 In order to improve comparability of data sets, the more detailed analyses in Chapters 5 and 6 were limited to controlled (IFR) flights either originating from or arriving to the main 34 US and European airports shown in Figure 9. Traffic to or from the main 34 airports in 2010 represents some 66% of all IFR flights in Europe and 63% in the US.

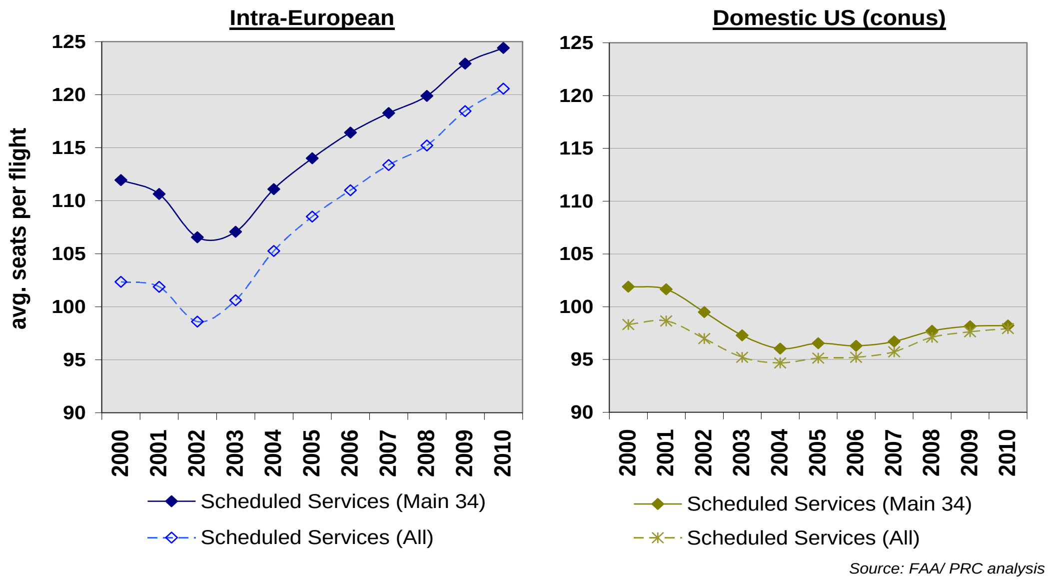


Figure 8: Average seats per scheduled flight [2000-2010]

2.1.22 Figure 8 shows the evolution of the number of average seats per scheduled flight in the US and in Europe, based on Official Airline Guide (OAG) data for passenger aircraft. For 2010, the average number of seats per scheduled flight is 27% higher in Europe for traffic to/from main 34 airports. This is consistent with the observation in Figure 7 showing a higher share of larger aircraft in Europe.

2.1.23 Whereas in Europe the average number of seats per flight increased continuously between 2002 and 2010, the number of seats per aircraft declined in the US from 2001 to 2004, with modest increases since then. More analysis is needed to better understand the factors driving the differing trends in average aircraft size between the US and Europe.

Operations at the main 34 airports

2.1.24 Table 3 provides high-level indicators for the main 34 airports in the US and in Europe using data reported largely from the airport. Note the passenger per movement statistic below uses all operations for movements whereas Figure 8 above is limited to scheduled operations.

Table 3: Passenger/Operations indicators for the 34 main airports [2010]

	Europe		US		Difference US vs. Europe
Main 34 airports	2010	vs. 2008	2010	vs. 2008	
Average number of annual IFR movements per airport (‘000)	237	-9%	389	-6%	+64%
Average number of annual passengers per airport (million)	24	-3%	31	-3.1%	+29%
Passengers per IFR movement	102	+6%	80	3.1%	-22%
Average number of runways per airport	2.5	0%	4.1	0.7%	+64%
Annual IFR movements per runway (‘000)	95	-9%	96	-6.7%	+1%
Annual passengers per runway (million)	9.7	-3%	7.7	-3.8%	-21%

2.1.25 The average number of runways and the number of movements are significantly higher (+64%) in the US while the number of passengers per movement (-22%) is much lower than in Europe, which is consistent with the observations made in Figure 7 and Figure 8. Annual movements per runway are slightly higher in the US but of less magnitude than movements per airport. This may be interesting to note for airport capacity purposes.

2.1.26 Although the US lists 138 runways at the main 34 airports, it is estimated that only 104 (75%) are on average available for use at one time. This is because many of the runways may not be operated independently. Furthermore, many of the 138 are less than 5,000 feet and not available for all operations. Figure 9 below shows two extreme examples of this for Boston Logan (BOS) and Chicago Midway (MDW). These two airports technically have 11 runways. However, operations data shows only 4 or 5 are used on average. Capacity/throughput measures 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.

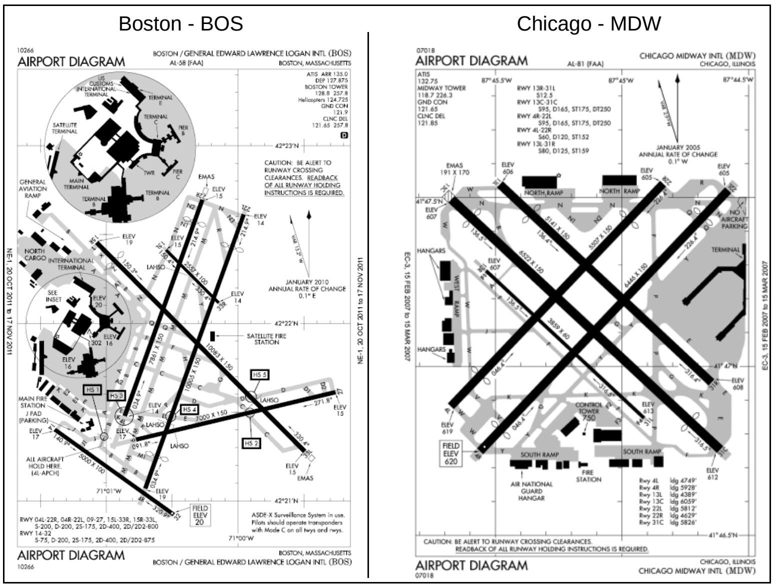


Figure 9: Airport Layouts for Boston (BOS) and Chicago Midway (MDW) [2010]

2.1.27 Figure 10 shows the average daily IFR departures for the 34 main European and US airports included in this study in order to provide an order of magnitude of the operations of the airports.

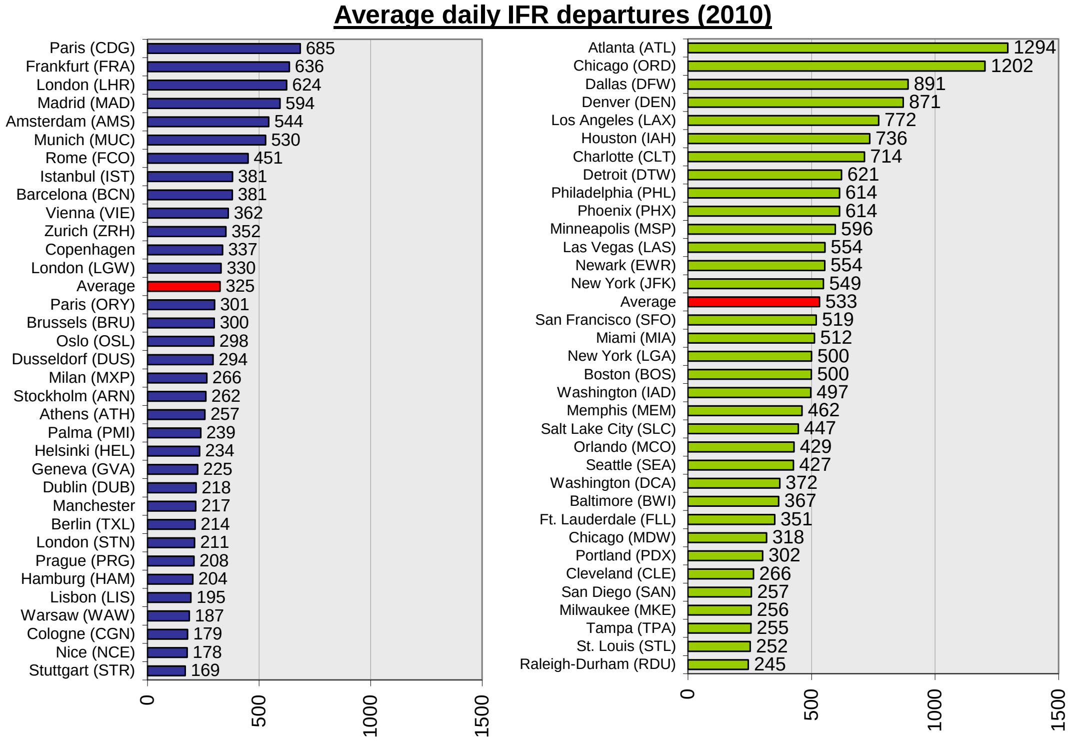


Figure 10: Average daily IFR departures at the main 34 airports [2010]

2.1.28 The average number of IFR departures per airport (533) is considerably higher (64%) in the US, compared to 325 average daily departures at the 34 main airports in Europe in 2010[15]. The difference in IFR departures and the drop in traffic as measured by IFR departures tracks well with the overall operations as reported in Table 3. The ATM performance measurements used throughout this report will make use of radar and operator reporting databases available to both FAA and EUROCONTROL. Subsequent trends and analysis will make use of the IFR population shown in Figure 10.

2.2 Organisational and geopolitical characteristics

2.2.1 Both the US and Europe have established system-wide traffic management facilities to ensure that traffic flows do not exceed what can be safely handled by controllers, while trying to optimise the use of available capacity.

2.2.2 However, for a number of operational, geopolitical and even climatic reasons, Air Traffic Flow Management (ATFM) techniques have evolved differently in the US and in Europe.

OPERATIONAL SETUP

2.2.3 While both Air Navigation systems are operated with similar technology and operational concepts, there is only one service provider in the US. All US Centres use the same

[15] Figure 10 only shows IFR flights. Some airports - especially in the US - have a significant share of additional VFR traffic. Overall, VFR flights account for an additional 3% at the top 34 airports in the US. The top four VFR contributors in the US are Las Vegas (+19%), Salt Lake City (+13%), Ft. Lauderdale (+8%) and Phoenix (+6%).

automation systems and have procedures for cooperation on inter-centre flow management.

2.2.4 In Europe, there are 38 en route service providers of various geographical areas each operating their own system. This makes it more difficult to implement arrival management across national boundaries (e.g. sequencing traffic into major airports of other States) and may affect the level of coordination in ATFM and ATC capacity. Ground ATFM delays principally originate from en route capacity shortfalls in Europe, which is not the case in the US.

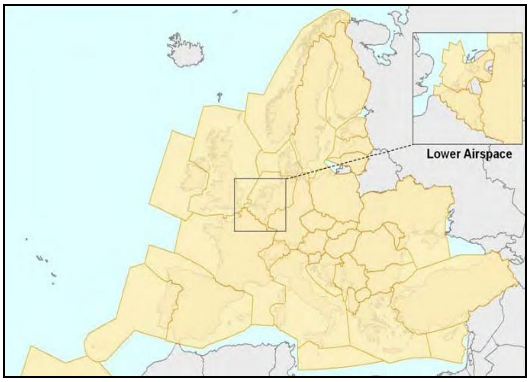


Figure 11: Fragmentation in Europe

2.2.5 Additionally, all states have their own military needs and requirements that must be accommodated. This can make ATC operations and airspace management (ASM) more difficult. More study is needed to better understand the impact of ATM civil/military arrangements on performance. A potential measure for comparison between the US and Europe would be the share of flights that would enter shared civil/military airspace if great circle routes were used.

2.3 Factors affecting ANSP performance (Interdependencies)

2.3.1 The performance measures presented in this report are intended to provide indicators of how well ANSP operations are improving over time using punctuality and flight efficiency as KPIs. However there are several external factors that are outside of ATM that complicate the assessment. Weather affects system performance through decreased throughput at airports during bad weather conditions. Operator demand can have a large effect on performance. For 2008-2010, overall demand was down at most of the major airports in the US and in Europe. Facilities that had small changes in demand may still see large improvements in performance if schedules become less "peaked" over the course of the day. Changes in block time and its potential effect on ANS on-time statistics are addressed in Chapter 4. Lastly, there are investments in airport infrastructure that improve capacity at the airport. Certainly, there are portions of improved ATM performance that are attributable to the ANSP. However, it is not always possible to isolate what has been directly influenced by ANSPs from the impact of events outside the control of the ANSP.

WEATHER CONDITIONS

2.3.2 Both US and Europe performance groups use detailed weather information known as METAR data and both groups have developed procedures for assessing weather's impact on aviation performance [Ref. 6 and 7].

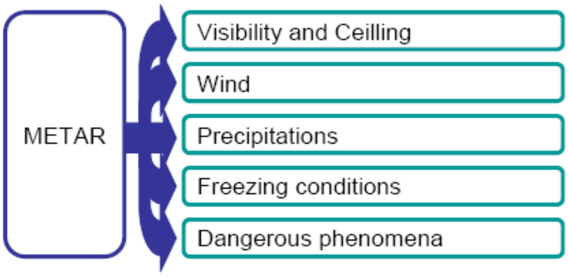


Figure 12: METAR and weather classes

2.3.3 One basic measure that may be used is to separate out performance during instrument meteorological conditions (IMC). Precise definitions differ between US and Europe but for this report, ceiling less than 1,000 feet and visibility less than 3 miles 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 in the US as Marginal VMC. For simplicity, the following thresholds were used *for all airports* to provide a basic assessment of weather impact on performance.

Table 4: Ceiling and visibility criteria

Condition	Ceiling (C)		Visibility (V)
Visual	C >= 3000 ft.	and	V >= 5 miles
Marginal	1000 ft. <= C < 3000 ft.	or	3 miles <= V < 5 miles
Instrument	C < 1000 ft.	or	V < 3 miles

2.3.4 Using the above criteria, performance groups can quantify how measures such as delay or punctuality vary by weather condition. Assessing weather is complicated by the fact that weather may change during the flight time from source airport to destination airport and complex processing is required to link flight trajectories to weather events. For this report, weather conditions at the time of scheduled arrival or scheduled departure were used to determine representative weather for a flight. Figure 13 shows average departure delay by weather condition for the US top 34 airports in 2010. The average delay per flight in IMC is more than double the average delay in VMC.

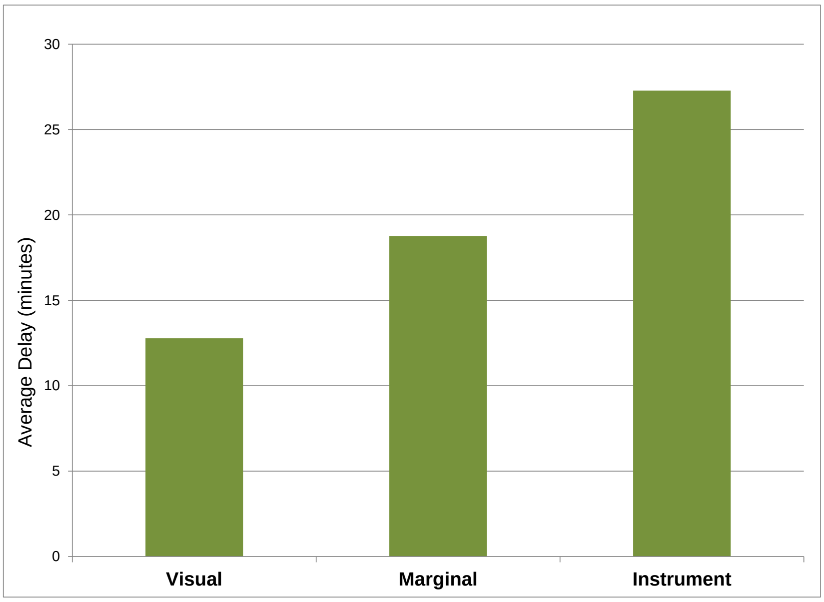


Figure 13: Average departure delay at the US main 34 airports [2010]

2.3.5 The number of flights operating when instrument conditions occur varies by airport. On average, approximately 85% of the flights at the top 34 airports in the US experience VMC conditions with 5% occurring in instrument and 10% occurring in marginal conditions. In the US, 10 airports account for 60% of the operations experiencing IMC conditions while accounting for 50% of the total operations at the main 34 airports. In terms of performance, both traffic volume, and frequency of IMC conditions will drive overall system efficiency.

2.3.6 Transition to IMC may have a high impact on US airports as traffic is often scheduled to operate in VMC. Figure 14 shows the difference in average delay between IMC and VMC conditions by airport. Seven airports report greater than 20-minute differences in departure delay when conditions change from VMC to IMC.

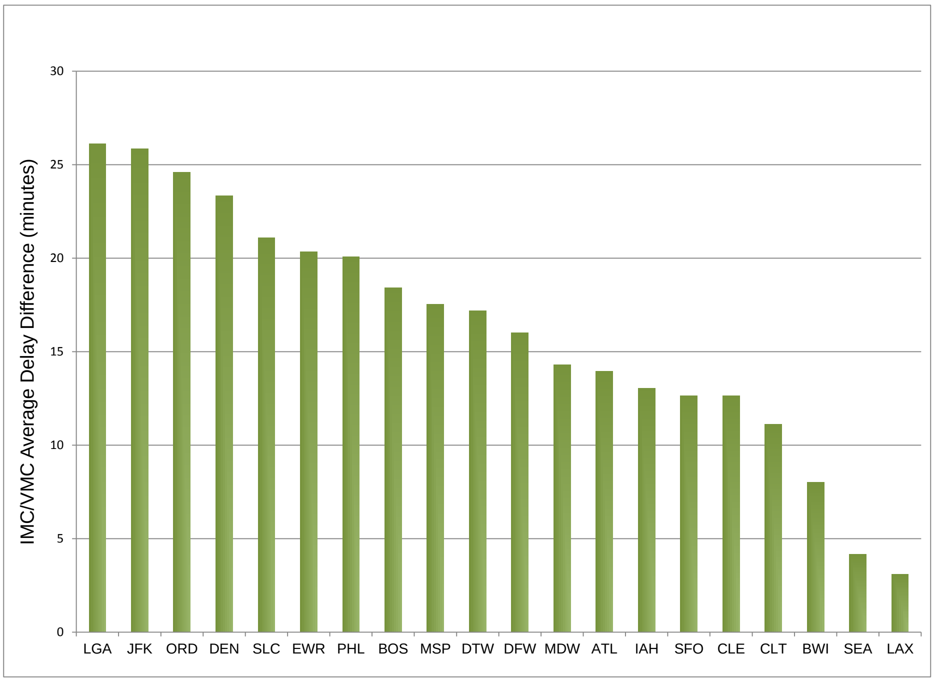


Figure 14: Difference in IMC and VMC average departure delay [2010]

2.3.7 There may be many reasons why some airports show very large increases in average delay as conditions change from VMC to IMC. In the US, VMC allows the use of visual separations, which on average, are smaller than radar separations. In addition, Visual Flight Rules reduce dependencies between operations on different runways, increasing overall capacity. The FAA assesses and reports this capacity variation due to weather in its Airport Capacity Benchmark Report [Ref.8].

2.3.8 The benchmark report includes facility-reported Airport Arrival Acceptance Rates (AAR) and Airport Departure Rates (ADR). Figure 15 quantifies the capacity variation observed in the updated 2010 called rates for the facilities shown in Figure 14. The left side of the chart shows the percent capacity variation between VMC and IMC. San Francisco (SFO) and Cleveland (CLE) report the largest percent reductions in capacity when weather transitions from VMC to IMC.

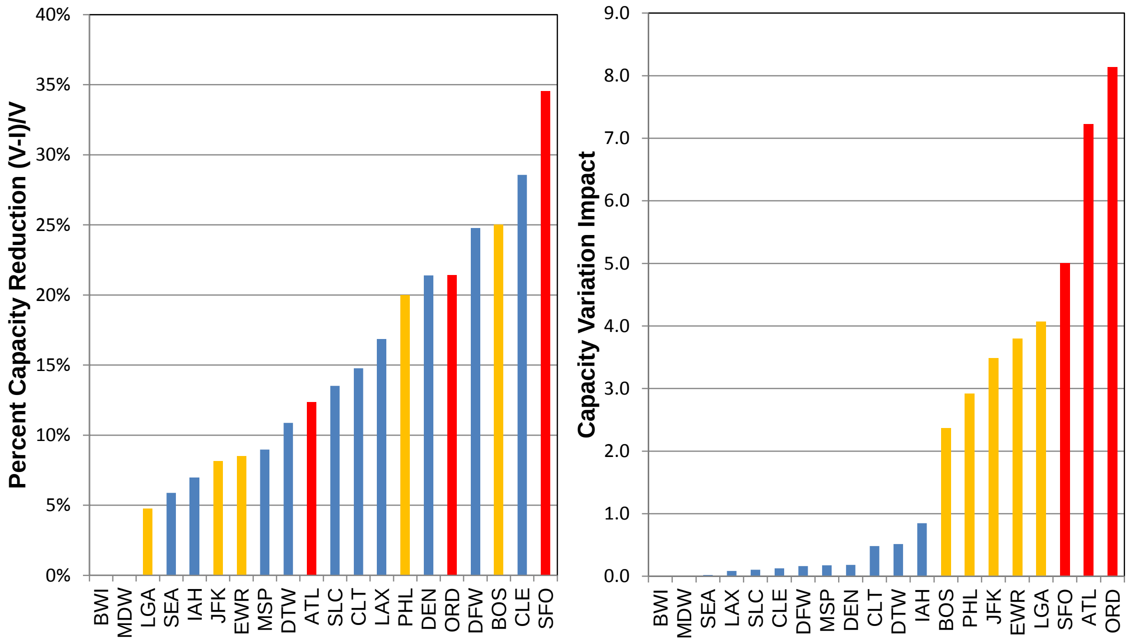


Figure 15: Capacity variation in the US [2010]

2.3.9 The right side of Figure 15 shows a measure 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 the airport is operating at 80% of its optimal VMC capacity. Airports with high demand are more likely to have performance affected by the reduction caused by low visibility conditions. By this measure, the New York area airports are shown to be much more impacted along with Atlanta (ATL), Chicago O'Hare (ORD), and San Francisco (SFO).

2.3.10 Tracking flights, total delay minutes, and average delay 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 from 2008 to 2010.

2.3.11 Overall, scheduled departures declined by 6% from 2008-2010. However, departures in IMC conditions dropped by over 20% suggesting that weather conditions in the US were more favourable in 2010 than in 2008. Figure 16 below shows how the 20% decrease in operations in IMC is broken down by airport. Note these changes reflect both changing demand levels and changing weather condition.

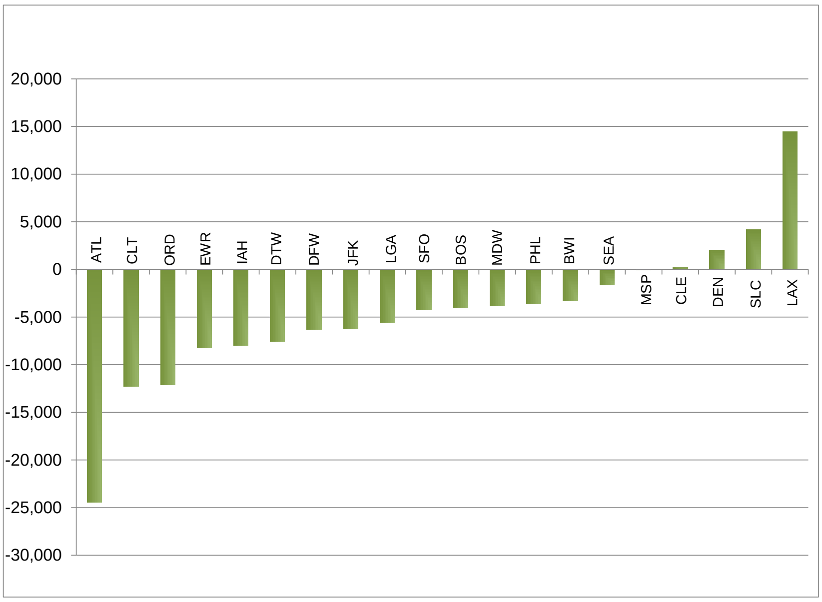


Figure 16: Difference in IMC Flights [2008-2010]

2.3.12 In addition to ceiling and visibility limitations, convective weather/thunderstorms in the summer are quite severe and widespread in the US (mostly eastern half) and may require ground holds and continent-wide reroutings of entire traffic flows. In the data reported by airlines in the US, delays related to non-extreme weather situations are predominantly attributed to the ATM system (see also Chapter 4.4).

DEMAND LEVELS AND SCHEDULING OF OPERATIONS

2.3.13 Demand levels and airlines schedules can have a significant impact on ANSP performance. Several of the performance measures addressed in this report are also influenced by the airline schedule. Namely, concentrated demand that exceeds capacity will degrade system performance. Also, increases in scheduled block time (i.e. time airlines announce as the travel time between city pairs) will mask system inefficiencies.

2.3.14 The two systems also differ considerably in terms of scheduling of operations at airports.

2.3.15 In Europe, traffic at major airports is usually controlled (in terms of volume and concentration) in the strategic phase through the airport capacity declaration process, and the subsequent allocation of airport slots to aircraft operators months before the actual day of operation. This is the case for 30 of the 34 airports analysed in this report which are fully coordinated (IATA Level 3).

2.3.16 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.

2.3.17 The few schedule constrained airports in the US are typically served by a wide range of carriers. In 2007, schedule constraints existed only at New York LaGuardia (LGA), Chicago O'Hare (ORD), and Washington National (DCA). During fiscal year 2008, additional scheduled capacity constraints were established at New York (JFK) and Newark (EWR) airports while the constraint at Chicago O'Hare was removed with the addition of the new runway.

2.3.18 The airport capacity declaration process at European airports could arguably result in schedule limitations or peaks closer to IMC capacity while in the US, where demand levels are controlled by airlines and VMC is more prominent, the airports are scheduled closer to VMC capacity [Ref. 9].

2.3.19 While the unrestricted scheduling at US airports encourages high airport throughput levels, it also results in a higher level of variability when there is a mismatch between scheduled demand and available capacity.

2.3.20 More work is needed to relate ATM performance to the demand/capacity ratios observed in both Europe and the US. Follow-on research would develop comparable capacity definitions for both systems and would develop a better understanding of the impact of:

- Capacity variations;
- Schedule practices;
- Air traffic management and peak throughput; and,
- Capacity utilisation.

CAPACITY AND AIRPORT INFRASTRUCTURE

2.3.21 The available capacity of the airports in the two systems directly affects performance. Capacity as a measure of the number of operations that may be handled by the facility will change for a multitude of reasons. Increased aircraft separation requirements during different weather conditions or due to the operation of a larger percentage of heavy aircraft will decrease throughput.

2.3.22 Simulation models are often used to estimate capacity and how it varies by weather or fleet mix. This analysis is used to guide the process that sets capacity limits at airports. These published limits may be used as an indicator of the capacity of the airport.

2.3.23 An estimation of the capacity may also be derived from the analysis of the maximum throughput over different time periods. The 95th or 98th percentile observed throughput is often used in this context. However, maximum throughput as an indicator of capacity is not useful when demand is below capacity and recent reductions in demand complicate the use of this measure.

2.3.24 There were several airport development projects in the US over 2008-2010. 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.

3 APPROACH TO COMPARING ANS SERVICE QUALITY

This chapter provides a brief description of differences in Air Traffic Flow Management (ATFM) techniques between the US and Europe and outlines the approach for assessing Air Navigation Services (ANS) related service quality.

3.1 Differences in air traffic flow management techniques

3.1.1 The two ATFM systems differ notably in the timing (when) and the phase of flight (where) ATFM measures are applied.

3.1.2 In Europe, demand management measures are applied months in advance through strategic agreements on airport capacities and slots. In addition, the focus in Europe is to anticipate demand/capacity imbalance and if necessary to solve them by delaying aircraft on the ground (allocation of ATFM take-off slots, normally 3 hours before departure). The European system operates airport streaming on a local and distributed basis with the CFMU mainly protecting the en route segments from overload.

3.1.3 In the US, demand management mainly takes place on the day of operation when necessary. The US system appears to have less en route capacity problems and is geared towards maximising airport throughput. With less en route capacity restrictions, the US has the capability to absorb large amounts of time through speed control and path stretching in en route airspace to achieve the metering required by TMAs and airports.

3.1.4 The comparison of operational performance has the potential to provide interesting insights from a fuel efficiency point of view as Europe applies more delay at the gate. However, as both systems try to optimise the use of available capacity, this needs to be put in context for a complete picture.

GROUND BASED FLOW MANAGEMENT

3.1.5 In Europe when traffic demand is anticipated to exceed the available capacity in en route control centres or at an airport, ATC units may call for “ATFM regulations.” Aircraft subject to ATFM regulations are held at the departure airport according to “ATFM slots” allocated by the Central Flow Management Unit (CFMU).

3.1.6 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). The CFMU was initially created in the 1990s to manage the lack of en route capacity of a fragmented ATC system.

3.1.7 In the US, ground delay programmes are mostly used in case of severe capacity restrictions at airports when other ATFM measures, such as Time Based Metering (TBM) or Miles in Trail (MIT) are not sufficient. The Air Traffic Control System Command Centre (ATCSCC) applies Estimated Departure Clearance Times (EDCT) to delay flights prior to departure. Most of these delays are taken at the gate.

AIRBORNE FLOW MANAGEMENT

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

3.1.9 In the US, traffic flows are controlled through MIT and TBM. Flow restrictions are passed back from the arrival airport to surrounding centres and so on as far as necessary. Ultimately MIT can also affect aircraft on the ground. En route-caused restrictions are small compared to airport driven flow restrictions in the US.

3.1.10 If an aircraft is about to take off from an airport to join a traffic flow on which en route spacing or an 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. These Traffic Management System (TMS) delays are taken on the ground either at the gate or in the taxi-out phase. Better data collection and more analysis are needed to understand the real distribution of these delays between the gate and taxi phase.

TERMINAL MANAGEMENT AREA

3.1.11 In both the US and the European system, the terminal area around a congested airport is used to absorb delay and keep pressure on the runways. Traffic Management initiatives generally recognize maximising the airport throughput as paramount. With 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. With MIT and TBM, delays can be absorbed further back at more fuel efficient altitudes.

3.2 Conceptual framework for assessing ANS-related service quality

3.2.1 The FAA/ATO and EUROCONTROL have been sharing approaches to performance measurement informally over the past five-plus years. Both have developed similar sets of Key Performance Areas and Indicators. The specific key performance indicators (KPIs) used in this paper were developed using common procedures on comparable data from both the FAA/ATO and EUROCONTROL.

3.2.2 The objective of the report is the high-level evaluation of the ATM-related service quality in the US and in Europe. Quality of service can be expressed in terms of:

- Performance compared to airline schedule times; and,
- Predictability (variability) and Efficiency (fuel, time) of actual operations.

3.2.3 Figure 17 outlines the conceptual framework for assessing ANS-related service quality.

3.2.4 As a first step, Chapter 4 analyses the performance compared to scheduled airline block times including some of the underlying delay reasons as reported by airlines through airline data collections (see also Chapter 1.3).

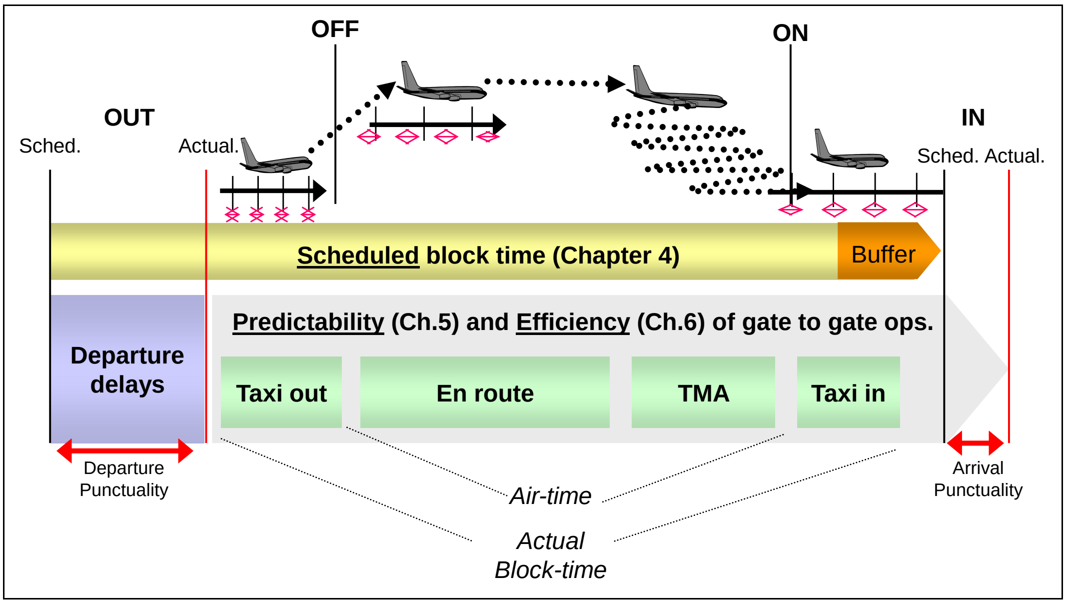


Figure 17: Conceptual framework to measuring ATM-related service quality

3.2.5 Although the analysis of performance compared to airline schedules is valid from a passenger point of view and provides first valuable insights, the masking of expected travel time variations through the inclusion of strategic time buffers in scheduled block times makes a more detailed analysis of actual operations necessary.

3.2.6 Chapters 5 and 6 focus on the predictability and efficiency of the actual operations by phase of flight (departure, taxi-out, en route, terminal area, taxi-in, arrival) in order to better understand the ATM contribution and differences in traffic management techniques.

3.2.7 In this context, it is important to describe the interrelation between the delay compared to the scheduled times as reported by airlines (on-time performance/punctuality), and the predictability and efficiency of actual operations as outlined in Figure 18.

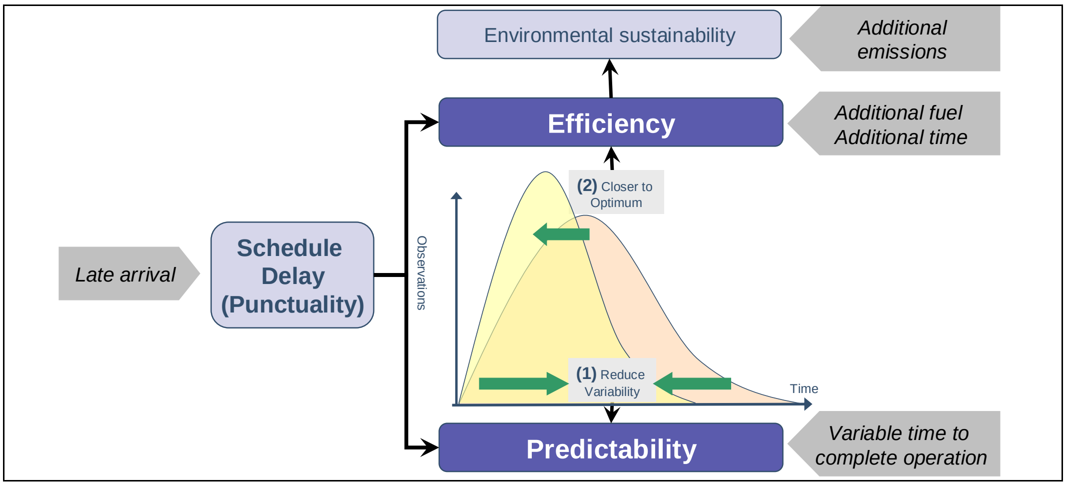


Figure 18: Schedule delay, predictability and efficiency

3.2.8 From a scheduling/planning point of view, the predictability of operations months before the day of operations has a major impact to which extent the use of available resources (aircraft, crew, etc.) can be maximised. The lower the predictability of operations in the scheduling phase, the more time buffer is required to maintain a satisfactory level of punctuality[16] and hence the higher the strategic costs to airspace users.

3.2.9 Predictability measures the variation in air transport operations as experienced by the airspace users. It consequently focuses on the variance (distribution widths) associated with the individual phases of flight (see (1) in Figure 18). 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.

3.2.10 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 US jet stream winds in the winter and convective weather in the summer impact overall predictability statistics.

3.2.11 In addition to predictability, the efficiency of operations is of major importance to airspace users. Efficiency generally relates to fuel efficiency or reductions in flight times of a given flight and can be expressed in terms of fuel and/or time. It consequently focuses on the difference between mean travel times from a predefined (schedule) or unimpeded optimum time (see (2) in Figure 18).

3.2.12 Additional fuel burn also has an environmental impact through gaseous emissions (mainly CO_2) which is illustrated by the link between efficiency and environmental sustainability in Figure 18.

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

3.2.14 While this report does not directly address capacity, measures focused directly on capacity improvements, as opposed to the resulting delay, are extremely valuable in assessing ATM progress.

3.3 <u>**Interpretation of the results**</u>

3.3.1 For the interpretation of the results in the next chapters, the following points should be borne in mind:

a) 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.

b) 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 in the US and Europe. There are lessons however to be learned from both sides.

[16] The level of "schedule padding" is subject to airline policy and depends on the targeted level of on-time performance.

c) A clear-cut allocation between ATM and non-ATM related causes is 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 performance (i.e. distribution of delay between air and ground) and thus on costs to airspace users.

d) The approach measures performance from a single airspace user perspective without considering inevitable operational trade-offs, environmental or political restrictions, or other performance affecting factors such as weather conditions.

e) ANSP performance is inevitably affected by airline operational trade-offs on each flight. The measures 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.).

f) 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 measures 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.

4 PUNCTUALITY OF AIR TRANSPORT OPERATIONS

From a passenger viewpoint, safety, price, convenience of schedule, and on-time performance are among the most important selection criteria when choosing an airline.

4.1 On-time performance

4.1.1 This chapter evaluates operational air transport performance compared to airline schedules in the US and in Europe. It furthermore analyses trends in the evolution of scheduled block times. The last section aims at identifying the main delay drivers by analysing the delay information reported by airlines (see Chapter 1.3) in order to get a first estimate of the ATM contribution towards overall air transport performance.

4.1.2 On-time performance is the end product of complex interactions between airlines, airport operators, and Air Navigation Service Providers (ANSPs) from the planning and scheduling phases up to the day of operation. Strong network effects are expected in air transport performance.

Figure 19: Punctuality of operations

4.2 Evolution of on-time performance

4.2.1 Figure 20 compares the industry-standard indicators for punctuality, i.e. arrivals or departures delayed by more than 15 minutes versus schedule.

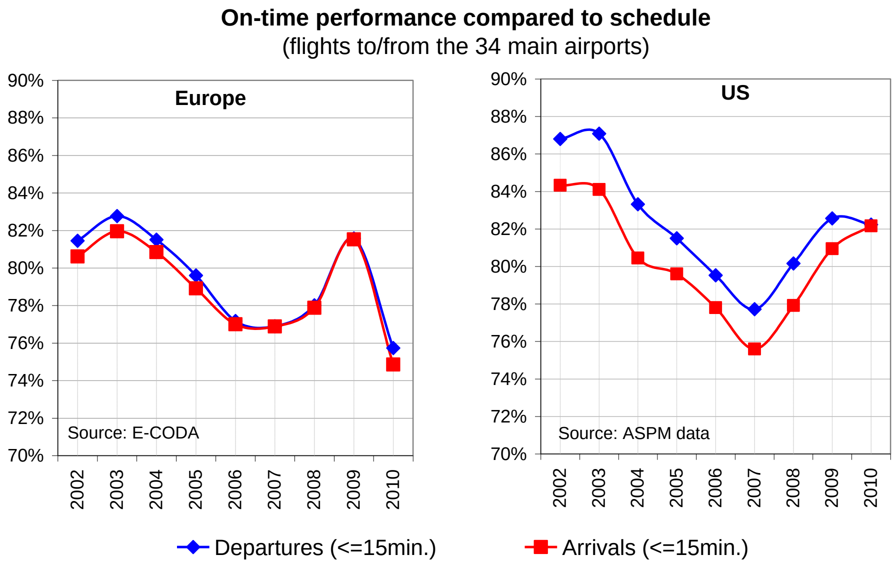


Figure 20: On-time performance [2002-2010]

4.2.2 After a continuous decrease between 2004 and 2007, on-time performance in Europe and in the US shows an improvement in 2008, as shown in Figure 20. However, this improvement needs to be seen in the context of lower traffic growth (and in the case of the US, lower overall traffic) as a result of the global financial and economic crisis, and increased schedule padding in the US (see Figure 24).

4.2.3 In the US, both arrival and departure on-time performance have increased relative to 2008. While arrival on-time continued to improve from 2009 to 2010, departure on-time slightly declined from 82.6% to 82.2%. Figure 21 shows the facilities that contribute the most to the change in the system-wide arrival or departure trend. The improvement at Chicago O'Hare, especially from 2008 to 2009 largely dominates the trends, followed by improvements at Newark (EWR) and Atlanta (ATL). The reasons behind the improvement in on-time performance are a mix of improved Air Traffic Service (ATS), infrastructure investment, policy, and airline practice.

4.2.4 The Chicago O'Hare Modernization Programme includes new runways and extensions at the airport. The opening of Runway 9L-27R in November 2008 created a third parallel runway, which allows for three independent arrival streams even in IMC conditions. The New York airports are now all schedule-limited, which reduced congestion at these airports. A more detailed discussion on how increasing block time can lead to an apparent improvement in performance is included in the next section.

4.2.5 In Europe, the unprecedented drop in traffic reduced demand far below planned capacity levels in 2009. The resulting spare capacity in most areas (airlines, airports, ATC) translated in a significant improved on-time performance in 2009. Air transport punctuality in Europe in 2010 was the worst recorded since 2001 although traffic was still below 2007 levels and traffic growth was modest. Some of the main causes contributing to this poor performance were ANS-related delays, primarily due to industrial actions, and higher than usual weather related delays (snow, freezing conditions) during winter 2009 and in December 2010. The volcanic ash cloud in April/May 2010 had a limited impact on punctuality, as the majority of the flights were cancelled.

4.2.6 From 2004 to 2009, the level of arrival punctuality was similar in the US and in Europe. This changed radically in 2010 as arrival on-time degraded in Europe but improved in the US. Prior to 2010, the gap between departure and arrival punctuality has been significant in the US and quasi nil in Europe. This was most likely due to differences in flow management techniques as outlined in Chapter 3.1.

4.2.7 In Europe, flights are usually delayed at the departure gate according to ATFM slots while in the US, flow management techniques focus more on the gate-to-gate phase. Additionally, the airport slot coordination in Europe may play a role in smoothing departure and arrival punctuality. The change in the departure-arrival gap in 2010 for the US is driven heavily by improvement in on-time performance at Atlanta (ATL).

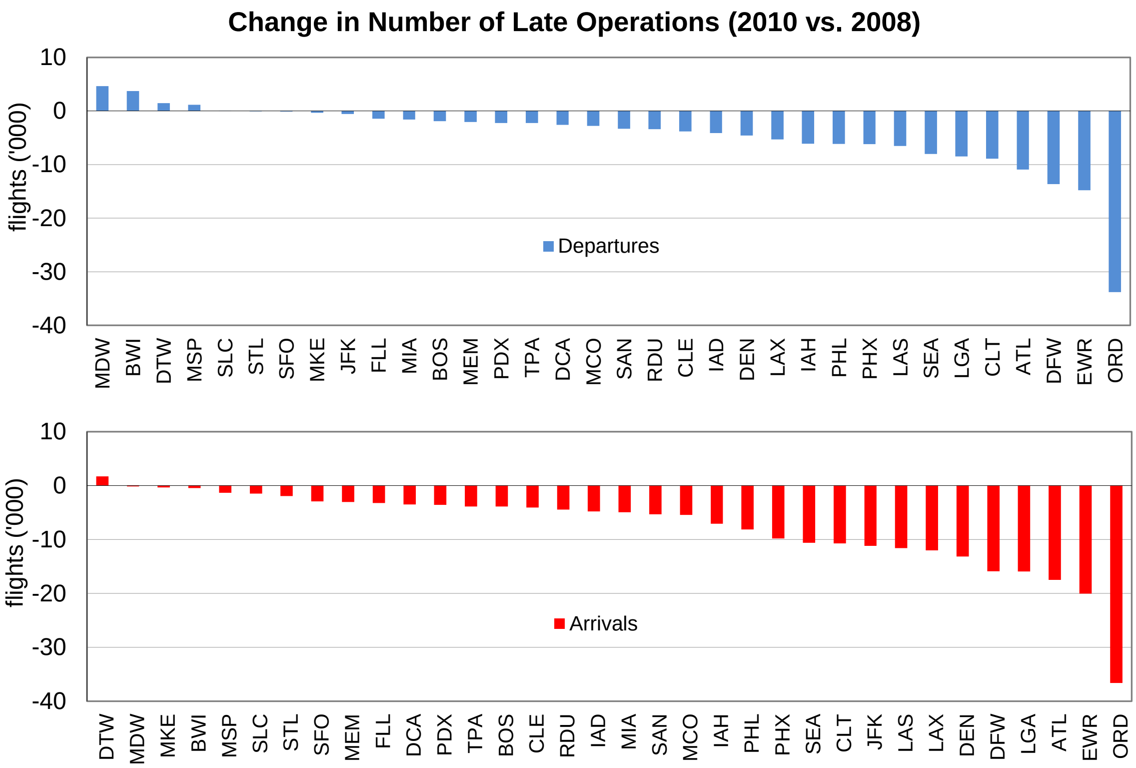


Figure 21: Change in number of late operations [2008-2010]

4.2.8 The system-wide on-time performance is the result of contrasted situations among airports. Figure 22 shows the share of arrivals delayed by more than 15 minutes compared to schedule for the 20 most penalising airports in Europe and the US in 2010. The results are significantly different than those reported in the 2008 benchmark report.

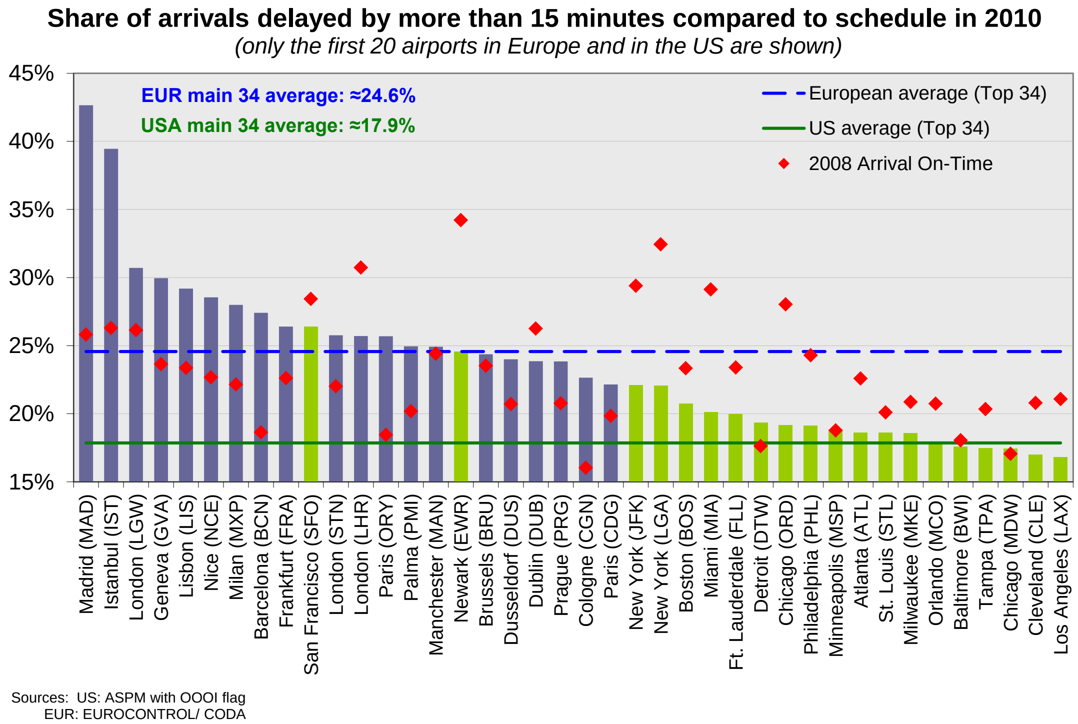


Figure 22: Arrival punctuality (airport level)

4.2.9 In the US, San Francisco has the lowest on-time percentage followed by the airports in the New York area. However, San Francisco (SFO) does not have as significant effect on the system level on-time shown in Figure 20. Atlanta (ATL) leads the US with double the number of delayed flights as San Francisco (SFO), followed by Chicago (ORD) and Dallas (DFW). Larger airports with their larger volume of flights tend to have a greater effect on the NAS-wide percentage shown in Figure 20 than SFO. In Europe for 2010, Madrid (MAD) and Istanbul (IST) largely outpaced other European airports and surpassed London Heathrow (LHR), which was the most penalising airport in 2008.

4.2.10 The impact and the importance of performance at individual airports on the air traffic management network and vice versa needs to be better understood. On-time performance at each airport is influenced by performance at departure airports and previous flight legs. A US study showed that for Miami airport in 2000, when traffic dropped considerably, on-time performance decreases were clearly a function of the performance at the linked airports in the OEP 35 [Ref. 10].

4.3 **Evolution of scheduled block times**

4.3.1 Airlines often include strategic time buffers in their schedules to account for a certain level of variation in travel times on the day of operations and to provide a sufficient level of punctuality to their customers. The level of "schedule padding" is subject to airline policy and depends on the targeted level of on-time performance.

4.3.2 Airlines build their schedules for the next season by applying a quality of service/ punctuality 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 wider the distribution (and hence the higher the level of variation) of historic block-to-block times, the more difficult it is to build reliable schedules resulting in higher utilisation of resources (e.g. aircraft, crews) and higher overall costs.

4.3.3 The impact of a shift in block time variability is outlined in the right graph of Figure 23.

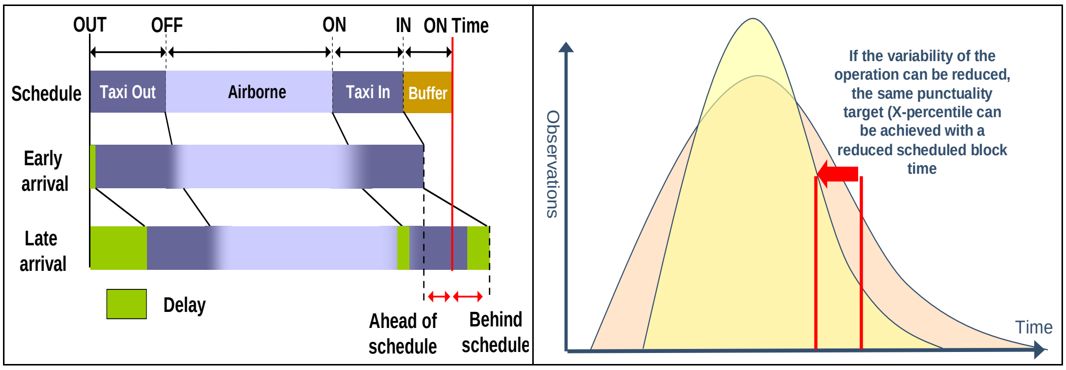


Figure 23: Scheduling of airline operations

4.3.4 Nevertheless, it should be pointed out that improvements in block time distributions does not automatically result in higher punctuality levels, as the scheduled times for the new season will be reduced automatically by applying the punctuality target to the set of improved block times (block times are cut to improve utilisation of aircraft and crews).

4.3.5 Figure 24 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[17]).

4.3.6 Europe shows only a slight increase in scheduled block times between 2008 and 2010 while in the US, average block times have increased by some 3 minutes between 2005 and 2010. These increases may result from adding block time to improve on-time performance or could be tied to a tightening of turnaround times. The US has seen a redistribution of demand in already congested airports (e.g. JFK) which is believed to be responsible for the growth of actual and scheduled block times (see also paragraph 6.1.6 ff.).

[17] 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.

4.3.7 Seasonal effects are visible, scheduled block times being on average longer in winter than in summer. US studies by the former Free Flight Office have shown that the majority of increase is explained by stronger winds on average during the winter period [Ref. 11].

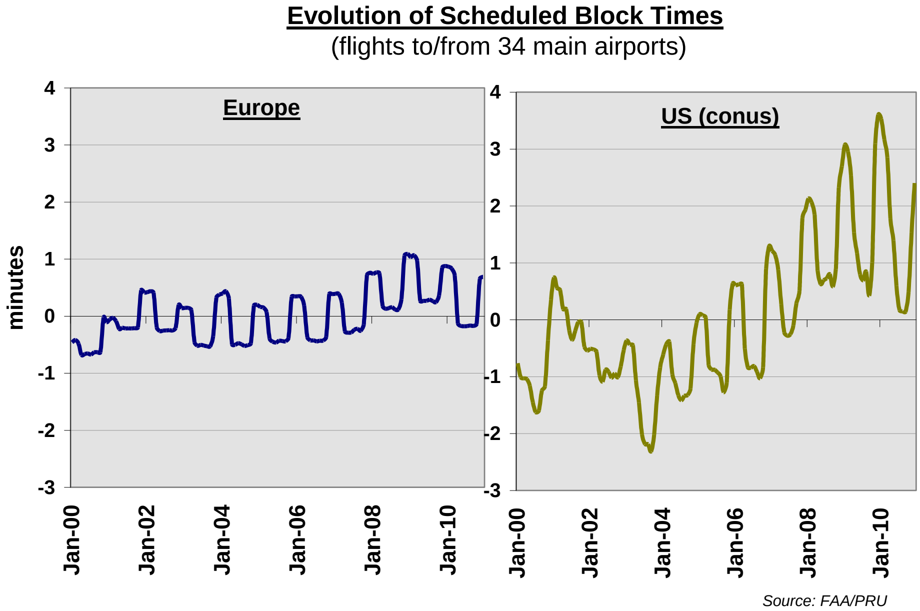


Figure 24: Scheduling of air transport operations [2000-2010]

4.3.8 Figure 24 should be seen in combination with Figure 20. From 2004 to 2008, not only has on-time performance decreased but scheduled flight times have also increased in the US due to congestion, meaning that delay costs are understated because airlines are padding schedules. 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. 12 and Ref. 13].

4.4 Drivers of air transport performance – as reported by airlines

4.4.1 This section aims at identifying underlying delay drivers as reported by airlines[18] in the US and in Europe (see also Chapter 1.3). The reported delays relate to the schedules published by the airlines.

4.4.2 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.

4.4.3 Hence, for the US the reported data also includes further delays or improvements in the en route and taxi phase, which is not the case in Europe.

4.4.4 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).

18 The analysis of predictability and efficiency in Chapters 5 and 6 is based on ANSP data.

- Air Carrier + 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.
- 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, reboarding of aircraft because of security breach, inoperative screening equipment, and/or other security related causes.
- ATM System (NAS)/ATFM: Delays attributable to the national aviation system that refer to a broad set of conditions, such as non-extreme weather conditions[19], airport operations, heavy traffic volume, and air traffic control. In Europe, aircraft are held at their origin through ATFM slots which may cause delays to the concerned flights. The ATFM delay of a given flight is attributed to the most constraining ATC unit, either en route (en route ATFM delay) or departure/arrival airport (airport ATFM delay).

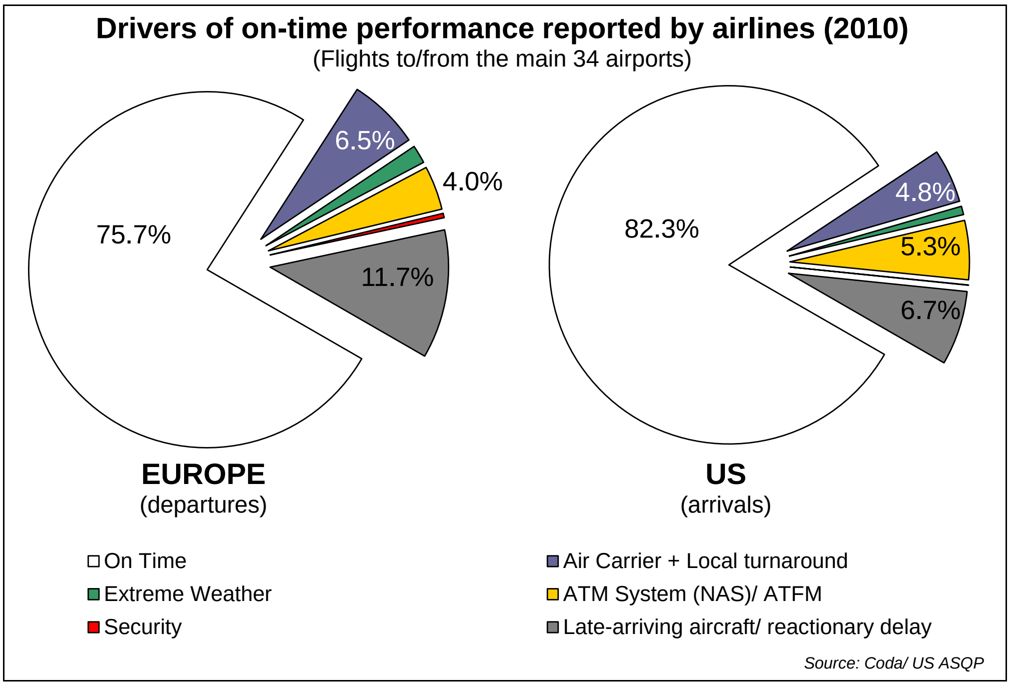


Figure 25: Drivers of on-time performance in Europe and the US [2010]

19 According to a more detailed study of the FAA, weather conditions are the main driver of delays attributed to the NAS system.

4.4.5 Figure 25 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.

4.4.6 In Europe, according to airline reporting much of the primary delay at departure is not attributable to the ANS system but more to local turnaround delays caused by airlines, airports, and ground handlers.

4.4.7 In the US, the distribution relates to the scheduled arrival times and the higher share of ANS-related delay at arrival is partly due to the fact that this figure is impacted by ATM delays accrued after departure.

4.4.8 The share of delay due to reactionary delay is considerably higher in Europe, which might be due to the fact that the delays refer to scheduled departure times and therefore do not consider possible improvements in the gate-to-gate phase. More work to better understand the propagation of primary delay through the respective air transport networks would be required.

4.4.9 It should be noted that the ANS system related delays in Figure 25 result from not only en route and airport capacity shortfalls but to weather effects which ATM and aircraft systems are not currently able to fully mitigate (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. 14].

4.4.10 Figure 26 and Figure 27 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 are shown for the US and for Europe.

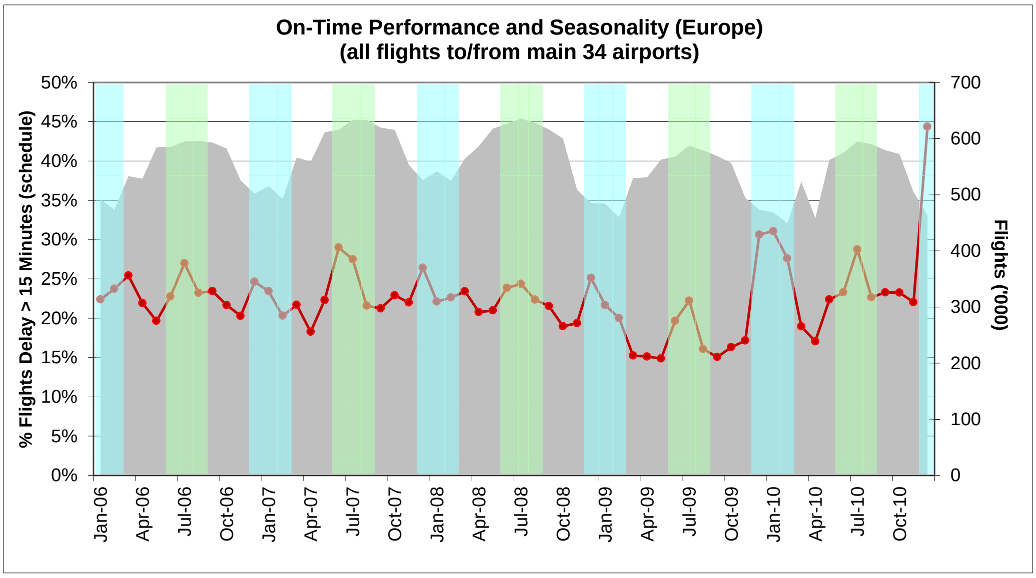


Figure 26: Seasonality of delays [Europe]

4.4.11 The red line in Figure 26 and Figure 27 shows the seasonality of delay for flights between the top 34 airports in Europe and the US. In Europe and the US, a clear pattern of summer and winter peaks is visible.

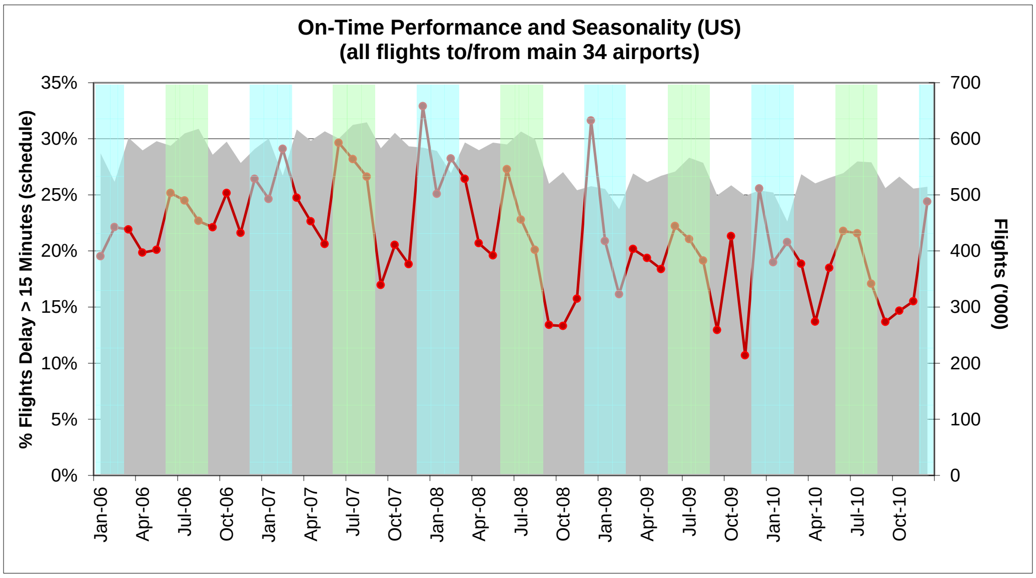


Figure 27: Seasonality of delays [US]

4.4.12 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.

4.4.13 In contrast to this chapter which evaluates performance compared to the airline schedules, the following two chapters are based on the statistical analysis of actual travel times and segregated by phase of flight. They provide a first order of magnitude in terms of air transport predictability (Chapter 5) and efficiency (Chapter 6). Both chapters break performance down to a flight segment level to give more visibility into causal factors.

5 PREDICTABILITY OF AIR TRANSPORT OPERATIONS

This chapter looks at predictability 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.

5.1 Predictability by phase of flight

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

5.1.2 Predictability evaluates the level of variability in each phase of flight as experienced by the airspace users[20]. In order to limit the impact from outliers, variability is measured as the difference between the 80th and the 20th percentile for each flight phase.

5.1.3 ANS contributes though the application of various flow management measures as described in Chapter 3.1.

5.1.4 In the departure phase, ANS contributes to the departure time variability through ANS-related departure holdings and subsequent reactionary delays on the next flight legs. The ANS-related departure delays are analysed in more detail in Chapter 6.3.

5.1.5 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 ANS (see Chapter 3.1).

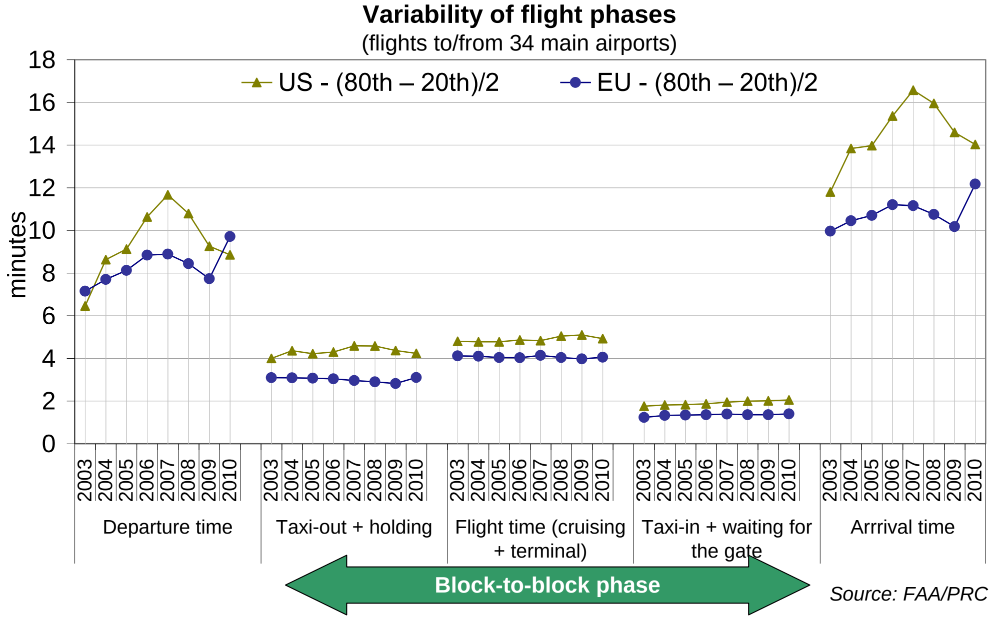


Figure 28: Variability of flight phases [2003-2010]

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

5.1.6 Figure 28 shows that in both Europe and the US, arrival predictability is mainly driven by 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.

5.1.7 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 surface both at the gate and in taxi-out.

5.1.8 Between 2003 and 2007, departure time variability continuously increased on both sides of the Atlantic. Contrary to Europe, variability increased also in the taxi-out and flight phase in the US, which appears to be driven by the different approaches in both scheduling operations and absorbing necessary delay (see Chapter 3.1).

5.1.9 As demand increases in congested areas, the variability in times in all flight phases also increases. Over the last five years, the US has seen demand increases at congested major airports, driving the variability of the overall ATM system [Ref. 15].

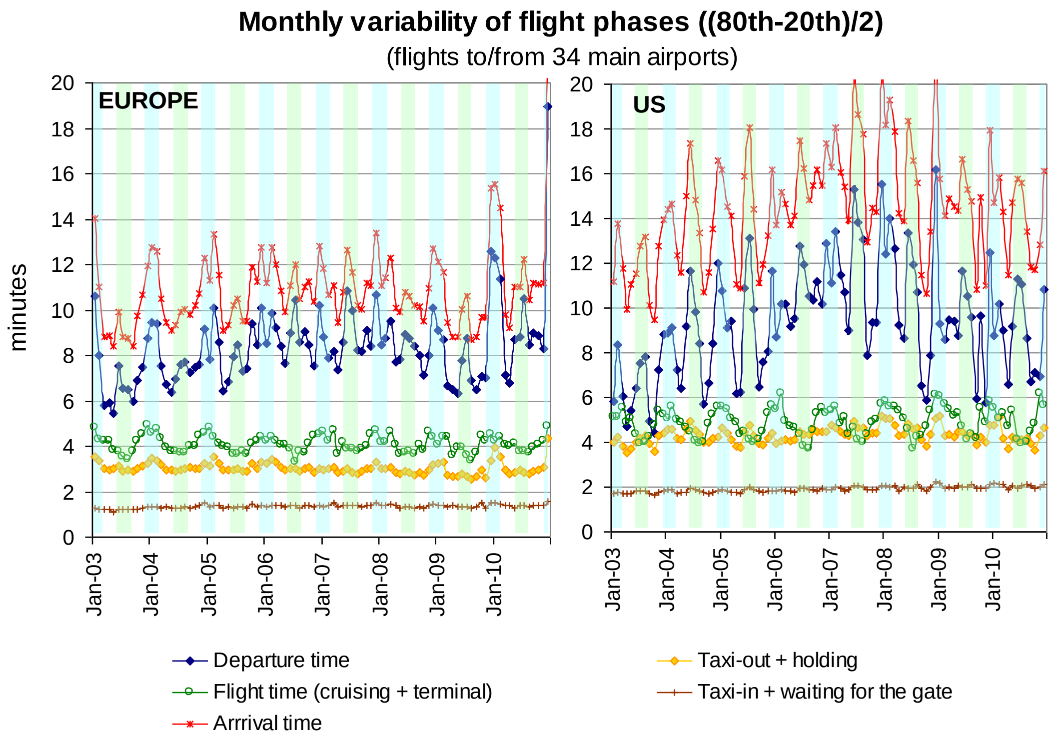


Figure 29: Monthly variability of flight phases [2003-10]

5.1.10 At US airports, winter delays are believed to be driven by higher frequency of instrument meteorological conditions (IMC) combined with scheduling closer to visual meteorological conditions (VMC) (see paragraph 2.3.18). 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.

5.1.11 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.

5.1.12 Figure 29 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 24).

5.1.13 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.

6 EFFICIENCY OF AIR TRANSPORT OPERATIONS

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 mean travel times and an optimum time (see also Figure 18 on page 24).

6.1 High-level trend analysis

6.1.1 Figure 30 provides a first analysis of how the duration of the individual flight phases (departure, taxi-out, airborne, taxi-in, total) has evolved over the years in Europe and the US. The analysis is based on the DLTA Metric (see footnote 17 on page 31) and compares actual times for each city pair with the long-term average for that city pair over the full period (2003-2010). 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 5.5 minutes above the long-term average.

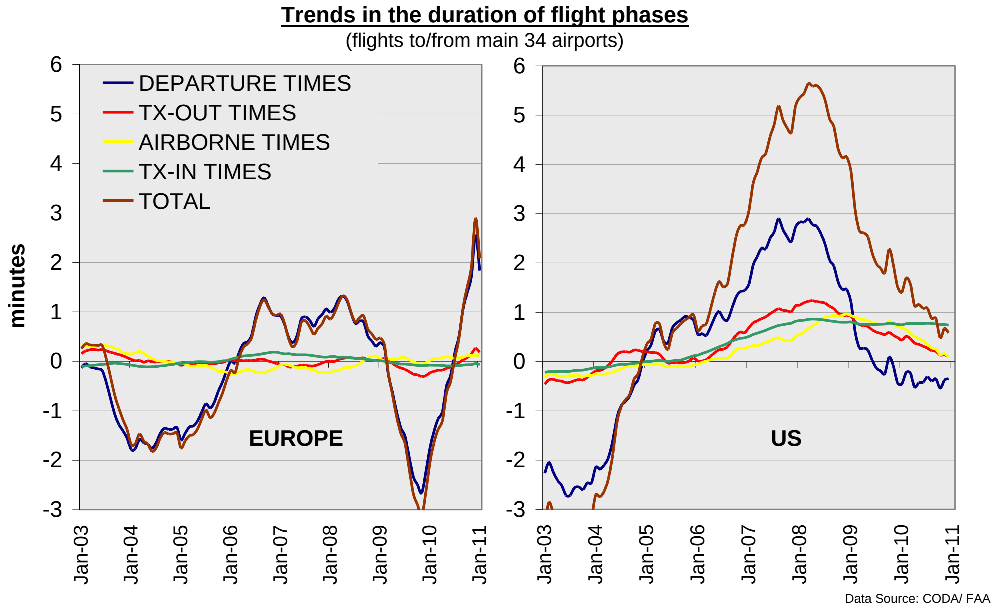


Figure 30: Trends in the duration of flight phases [2003-2010]

6.1.2 In Europe, performance is clearly driven by departure delays with only very small changes in the gate-to-gate phase. The drop in 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, departure delays increased again significantly mainly due to exceptional events (industrial actions, extreme weather) and a notable increase in taxi-out times.

6.1.3 In the US, the trailing 12-month average began to decline at the beginning of 2008. Until 2008, departure delay was the largest component associated with the change in average flight time, which contrasts with Europe. From 2008 through 2010, most flight components are back to their long-term average with the exception of taxi-in time. Taxi-in times may have increased over the long-term due to operations on new runways farther from the terminal or gate constraints becoming more important relative to the other components.

6.1.4 It is notable how the decrease in actual travel time that begins in 2008 compares with the smaller decrease in schedule block time that begins in 2009 (see Figure 24). This indicates a larger relative schedule buffer in the US from 2008 to 2010. The difference or potential "lag" in these two measures may be one of the contributing factors to the improved NAS on-time performance shown in Figure 20 in Chapter 4.

6.1.5 The trends shown in Figure 30 are consistent with the analysis of the level of variability in the individual phases of flight in Figure 28 in Chapter 5. The block time trends in Figure 24 are also similar.

6.1.6 The decline in average block time is consistent with improving performance and the overall decline in traffic in the US. For events leading up to 2008, despite the overall decrease in traffic, there was an increase in traffic in the already congested area of New York. This largely explains the increase in US system delay while overall traffic was falling. Figure 31 shows how traffic increases in the New York and Philadelphia areas are driving much of the delay though 2007.

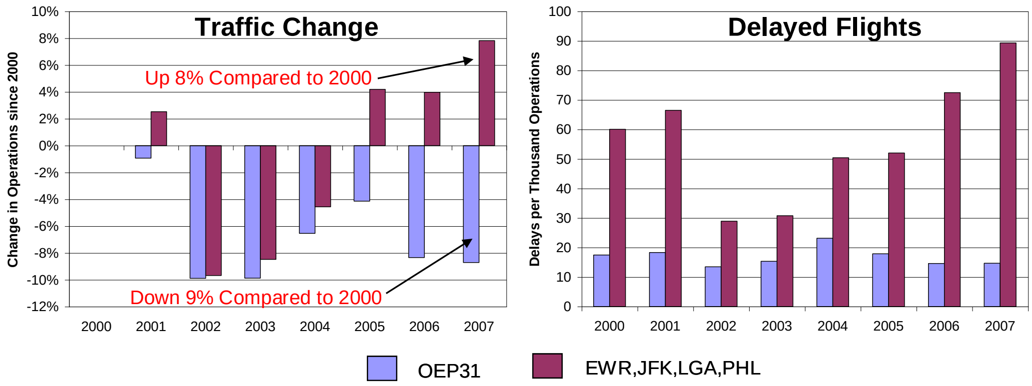


Figure 31: Growth in congested airports drives delay in the US [2000-2007]

6.1.7 The next sections in this chapter provide a more detailed analysis of efficiency indicators by phase of flight (Figure 32). In order to better understand the impact of ATM and differences in traffic management techniques, the analysis is broken down by phase of flight (i.e. pre-departure delay, taxi-out, en route, terminal arrival, taxi-in and arrival delay).

6.2 Conceptual framework for the more detailed analysis of efficiency

6.2.1 Inefficiencies in the different flight phases have different impacts on aircraft operators and the environment. Whereas ANS-related holdings (ATFM/EDCT delay) result in departure delays mainly experienced at the stands, inefficiencies in the gate-to-gate phase also generate additional fuel burn. The additional fuel burn has an environmental impact through gaseous emissions (mainly CO_2), which generates a link to the "Environmental Sustainability" KPA as shown in Figure 18.

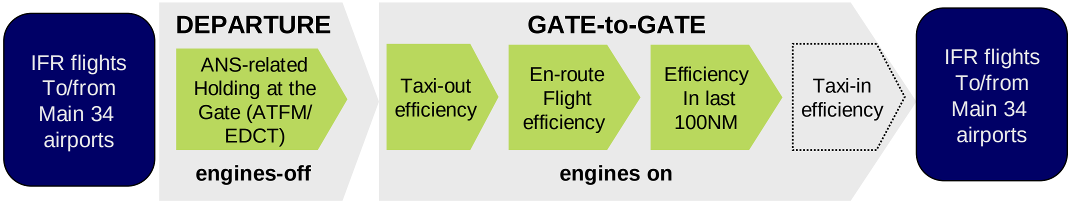


Figure 32: Measurement of efficiency by phase of flight

6.2.2 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.

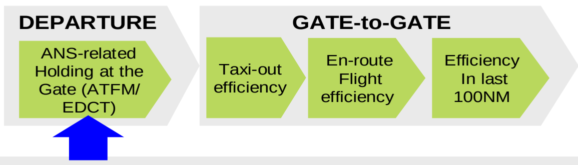
6.2.3 The taxi-in and the TMA departure phase (40 NM ring around departure airport) were not analysed in more detail as they are generally not considered to be large contributors to ANS-related inefficiencies. However, it is acknowledged that at some select airports, the efficiency of the taxi-in phase can be an issue due to apron and stand limitations. Other restrictions at individual airports may also need further study to quantify improvement opportunities.

6.3 ANS-related departure holdings

6.3.1 This section reviews ANS-related departure delays in the US and in Europe (EDCT versus ATFM).

6.3.2 The US (EDCT) and Europe (ATFM) currently use different strategies for absorbing necessary delay in the various flight phases (see also Chapter 3.1). Reducing gate/surface 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 gate/surface delays risks underutilisation of capacity and thus, increases overall delay.

6.3.3 In 2010, flights to and from the main 34 airports account for 66% (Europe) and 63% (US) of the controlled flights but experience 79% and 98.6% of total ATFM/EDCT delay, respectively.



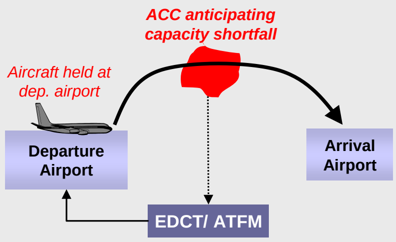
ANS-related departure holdings

Aircraft that are expected to arrive during a period of capacity shortfall en route or at the destination airport are held on the ground at their various origin airports.

The delays are calculated with reference to the times in the last submitted flight plan (not the published departure times in airline schedules). Most of these delays are taken at the gate but some occur also during the taxi phase.

ATFM/EDCT departure delays can have various ATM-related (ATC capacity, staffing, etc.) and non-ATM related (weather, accident, etc.) reasons.

While ATM is not always the root cause of the ATFM/EDCT departure holdings, the way the situation is handled can have a considerable impact on costs to airspace users and the utilisation of scarce capacity.



6.3.4 Table 5 compares ANS-related departure delays attributable to en route and airport constraints. For comparability reasons, only EDCT and ATFM delays larger than 15 minutes were included in the calculation.

6.3.5 The change between 2008 and 2010 is consistent with overall trends between the US and Europe. In the US, delay declined with traffic whereas in Europe, delay increased largely due to off nominal events (mainly due to industrial actions and extreme weather in winter).

Table 5: ANS-related departure delays (flights to/from main 34 airports within region)

Only delays > 15 min. are included.			**En route related delays >15min. (EDCT/ATFM)**			**Airport related delays >15min. (EDCT/ATFM)**		
		IFR flights (M)	***% of flights delayed >15 min.***	***delay per flight (min.)***	***delay per delayed flight (min.)***	***% of flights delayed >15 min.***	***delay per flight (min.)***	***delay per delayed flight (min.)***
US	**2008**	9.2	0.1%	0.1	57	2.6%	1.8	70
	2010	8.6	0.1%	0.05	44	1.6%	1.0	66
Europe	**2008**	5.6	5.0%	1.4	28	3.0%	0.9	32
	2010	5.0	5.7%	1.8	32	3.3%	1.2	36

6.3.6 For the US, TMS delays (see 3.1.10) due to local en route departure and MIT restrictions are considered in the taxi time efficiency section (see Chapter 6.4).

6.3.7 The share of flights affected by ATFM/EDCT delays due to en route constraints differs considerable between the US and Europe. In Europe, flights are as much as 50 times more likely to be held at the gate for en route constraints (see Table 5).

6.3.8 For airport related delays, the percentage of delayed flights at the gate is similar in the US and in Europe.

6.3.9 In the US, ground delays (mainly due to airport constraints) are applied only after Time Based Metering or Miles In Trail options are used which consequently leads to a lower share of flights affected by EDCT delays but higher delays per delayed flight than in Europe. More analysis is needed to see how higher delays per delayed flight are related to moderating demand with “airport slots” in Europe.

6.3.10 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 (see Table 5). The results in Table 5 are consistent with the differences in the application of flow management techniques described in Chapter 3.1.

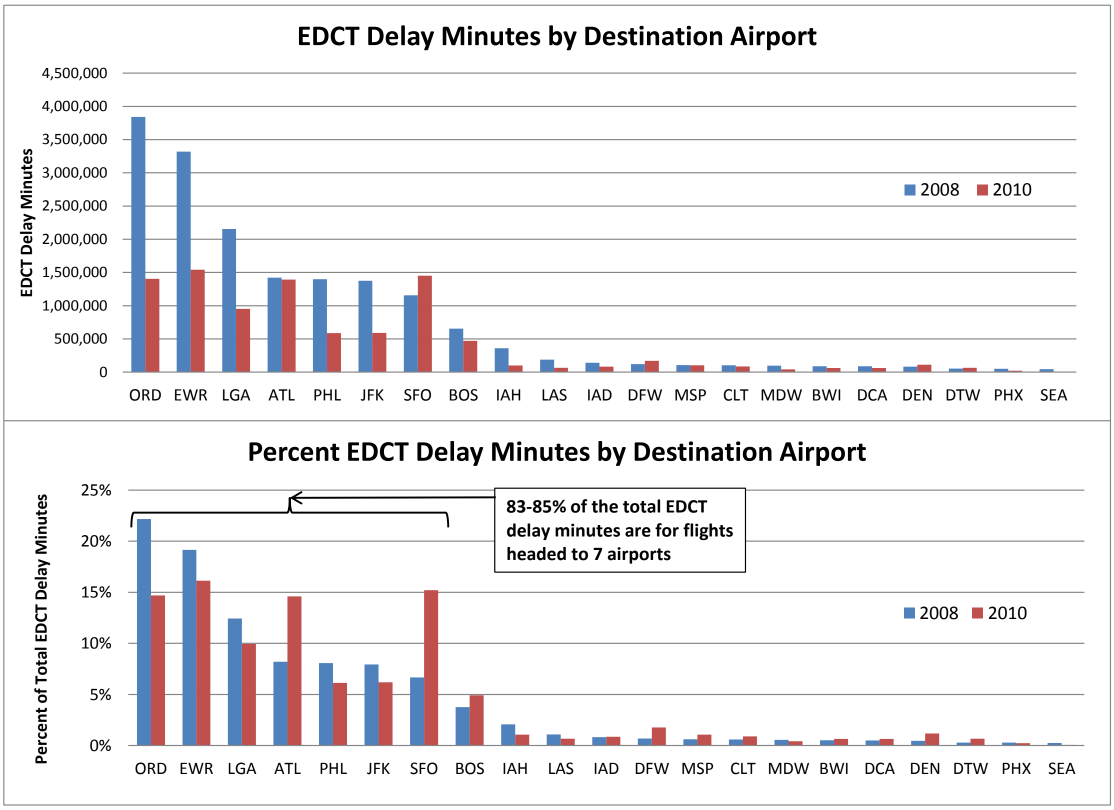


Figure 33: Comparison of EDCT delay minutes in US

6.3.11 Figure 33 compares EDCT delays greater than 15 minutes for flights destined to the main 34 airports in the US for 2008 and 2010. Although approximately 83-85% of the total EDCT delay minutes are concentrated at seven destination airports (ORD, EWR, LGA, ATL, PHL, JFK, and SFO), flights headed to these seven airports make up only 20-21% of the total operations in the US, indicating that many of the flights headed to these airports experience high EDCT delays. Despite the seven airports continuing to make up a large percentage of EDCT delay from 2008 to 2010, the total EDCT delay minutes in the US decreased by 45% as is illustrated in the top part of Figure 33.

6.3.12 The same seven destination airports that make up a large percentage of EDCT delay are also the top seven airports having the highest capacity variation impact (right side of Figure 15). Since flights are typically scheduled to VMC capacity at US airports, when weather conditions deteriorate, capacity at the airport is reduced while demand levels remain the same. EDCT delay is applied to flights usually as a result of reduced capacity at the destination airport due to constraints arising from poor weather conditions among other factors.

6.3.13 Figure 34 shows the share of flights with ANS-related departure holdings for airport and en route constraints (ATFM/EDCT) larger than 15 minutes by month and cause for the US and Europe.

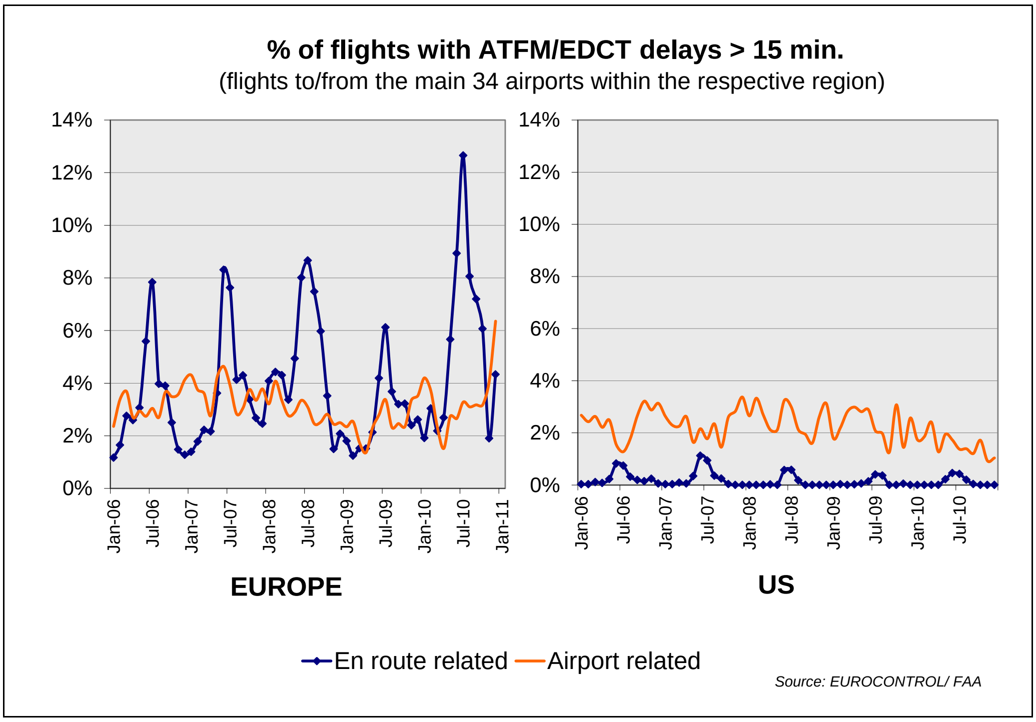


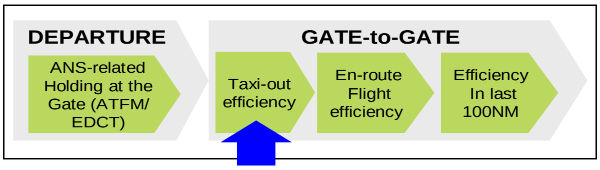
Figure 34: Evolution of EDCT/ATFM delays [2006-10]

6.3.14 Similar to the arrival punctuality (see also Figure 26 and Figure 27), a pattern of summer and winter peaks is visible for ANS-related departure holdings in the US and in Europe.

6.3.15 The en route related delays are much lower in the US than in Europe, but show similar summer peaks on both sides of the Atlantic due to completely different reasons. Whereas in the US, en route delays are mostly driven by convective weather, in Europe they are mainly the result of capacity and staffing constraints (and industrial actions in 2010) driven by variations in peak demand (large differences between summer and winter). More analysis of en route delay and capacities in the US and Europe is needed.

6.4 Taxi-out efficiency

6.4.1 This section aims at evaluating the level of inefficiencies in the taxi-out phase.



6.4.2 The analysis of taxi-out efficiency in the next sections 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.

6.4.3 The taxi-out phase and hence the performance measure 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 restrictions, aircraft type, and remote de-icing, to name a few. Of these aforementioned causal factors, the take-off queue size[21] is considered to be the most important one [Ref. 16].

6.4.4 In the US, the additional time observed in the taxi-out phase also includes TMS delays (see 3.1.10) 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).

6.4.5 In order to get a better understanding, two different methodologies were applied. 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.

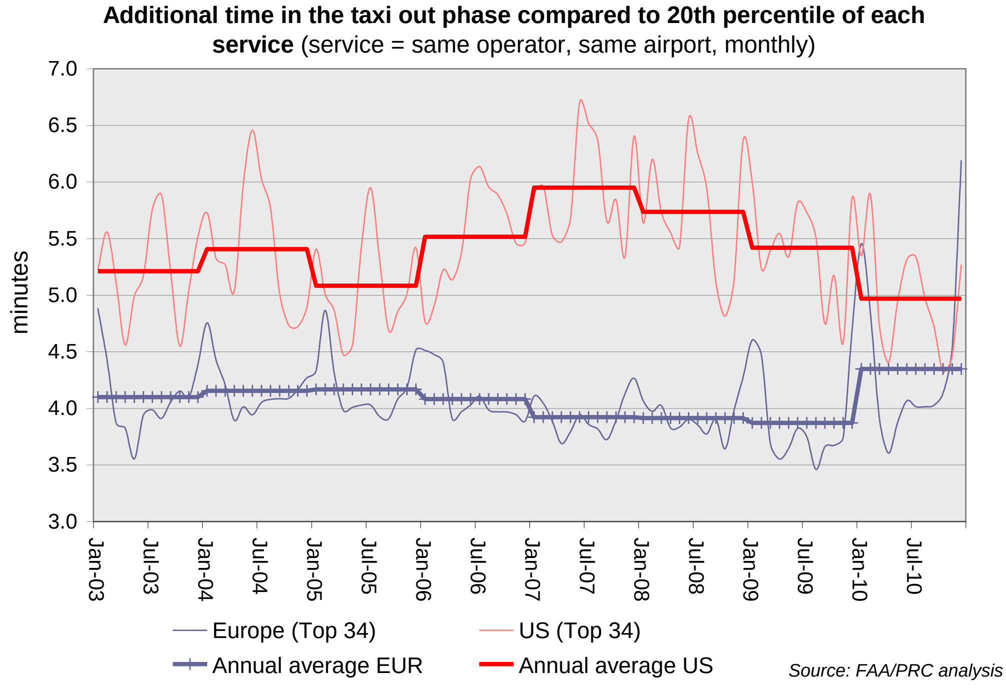


Figure 35: Additional times in the taxi-out phase (system level) [2003-2010]

6.4.6 Two interesting points can be drawn from Figure 35:

- 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 2010, US performance improved continuously which narrowed the gap. In Europe, performance remained relatively stable but showed a notable deterioration in 2010, which was mainly due to severe weather conditions in winter.
- Seasonal patterns emerge, but with different cycles in the US and in Europe. Whereas in Europe the additional times peak during the winter months are most likely due to weather conditions, in the US the peak is in the summer which is most likely linked to congestion.

---

[21] 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.

6.4.7 The high-level result in Figure 35 is driven by contrasted situations among airports. Figure 36 shows a more detailed comparison of additional time in the taxi-out phase at the major airports in Europe and the US.

6.4.8 The comparison of additional times by airport in Figure 36 is based on the respective official methodologies for the evaluation of inefficiencies in the taxi-out phase as described in Annexes III and IV.

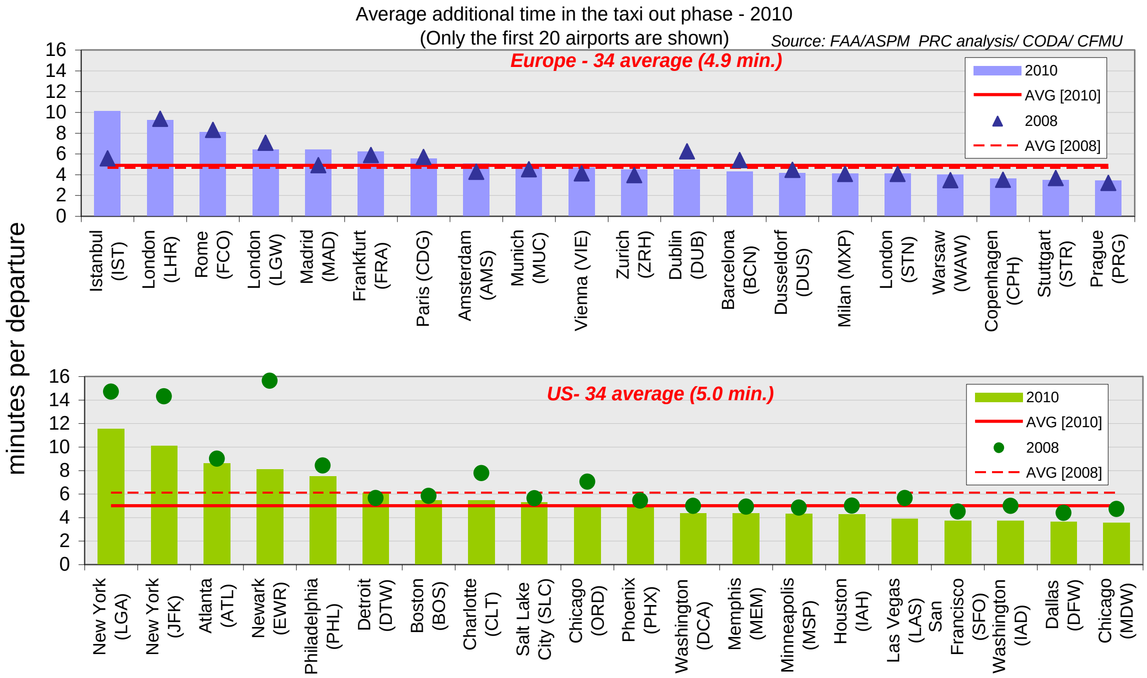


Figure 36: Comparison of additional time in the taxi-out phase

6.4.9 Although some care should be taken when comparing the two indicators due to differing methodologies, Figure 36 tends to confirm the trends seen in Figure 35. Historically, there have been higher average additional times in the taxi-out phase in the US than in Europe (6.2 minutes per departure in US compared to 4.3 minutes per departure in Europe in 2008); however, the difference is much smaller for 2010. For reasons of clarity, only the 20 most penalising airports of the 34 main airports are shown.

6.4.10 The observed differences in inefficiencies between the US and Europe reflect the different flow control policies (see also 3.1) 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 adds to the focus of getting off-gate on time.

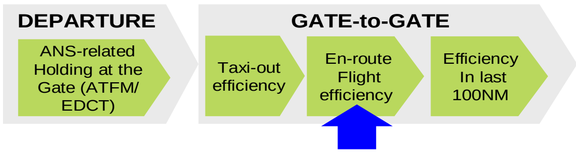
6.4.11 The impact of ANSPs on taxi times is marginal when runway capacities are constraining departures. However, the data on taxi delays is useful in developing policies and procedures geared towards keeping aircraft at the gate longer, in the same way that Europe does with Airport Collaborative Decision Making (A-CDM).

6.4.12 A-CDM initiatives in Europe try to optimise the departure queue while minimising costs to aircraft operators. Departing aircraft are sequenced by managing the pushback times and the taxi-out phase to provide minimal queues and improved sequencing at the runway.

6.4.13 The aim is to keep aircraft at the gate in order to minimise fuel burn due to departure holdings at the runway. These departure delays at the gate are reflected in the departure punctuality measures (see Chapter 4). However, the ANS part due to congestion in the taxiway system is presently difficult to isolate with the available data set.

6.5 En route flight efficiency

6.5.1 This section aims at approximating the level of ANS related inefficiencies in the en route phase.



6.5.2 Deviations from the optimum trajectory generate additional flight time, fuel burn and costs to airspace users. En route flight efficiency has a horizontal (distance) and a vertical (altitude) component.

6.5.3 The focus of this section is on horizontal en route flight efficiency, which is of much higher economic and environmental importance than the vertical component [Ref. 17].

6.5.4 Nevertheless, there is scope for improvement, and more work on vertical flight inefficiencies and potential benefits of implementing Continuous Descent Approach (CDA) would form a more complete picture.

6.5.5 The flight efficiency within the last 100 NM before arrival is addressed in Chapter 6.6.

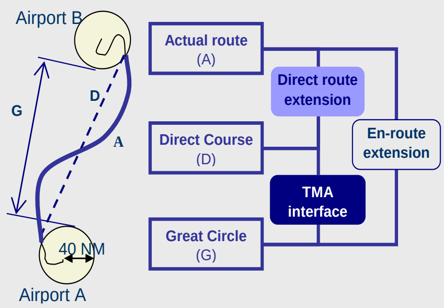
6.5.6 The horizontal en route flight efficiency indicator takes a single flight perspective. It relates observed performance to the great circle distance, which is a theoretical (and unachievable) situation where each aircraft would be alone in the system with zero wind and will not be subject to any constraints. In high-density areas, flow separation is essential for safety and capacity reasons with a consequent impact on flight efficiency.

Horizontal flight efficiency

The KPI for horizontal en route flight efficiency is en route extension. En route extension is defined as the difference between the length of the actual trajectory[22] (A) and the Great Circle Distance (G) between the departure and arrival terminal areas (radius of 40 NM around airports). Where a flight departs or arrives outside the respective airspace, only that part inside the airspace is considered. Flights with a great circle distance (G) shorter than 60 NM between terminal areas were excluded from the analysis. En route extension can be further broken down into:

- direct route extension, which is the difference between the actual flown route (A) and the direct course (D), and
- the TMA interface, which is the difference between the direct course between the two terminal entry points (D) and the great circle distance (G).

Whereas the TMA interface is more concerned with the location of the TMA entry points, the direct route extension relates more to the actual flight path.



[22] Differences in ground distances (irrespective of wind). The actual route distance is computed for all IFR flights based on ETFMS data, i.e. quasi radar data.

6.5.7 While the great circle distance used for the calculation of the indicator is the shortest route, it should be noted that it may not always correspond to the economic preferences of airspace users[23].

6.5.8 Figure 37 depicts the en route extension for flights to/from the main 34 airports within the respective region (Intra Europe, US CONUS) and the respective share of flights (bottom of Figure 37).

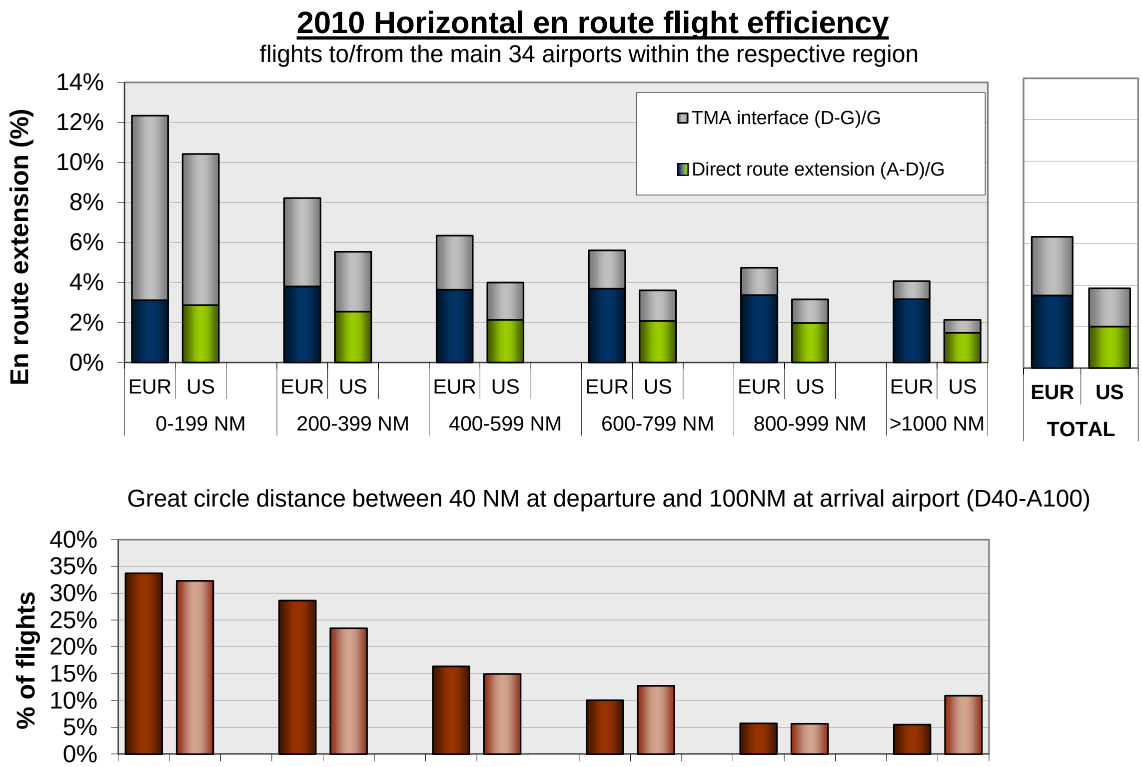


Figure 37: Comparison of en route extension [2010]

6.5.9 "Direct route extension" 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 (prevailing route network). Overall, it is approximately 1% lower in the US for flights of comparable length.

6.5.10 In Europe, en route flight efficiency is mainly affected by the fragmentation of airspace (airspace design remains under the auspices of the States) [Ref. 18]. For the US, the indicator additionally includes some path stretching due to MIT restrictions.

LIMITATIONS TO IMPROVING HORIZONTAL FLIGHT-EFFICIENCY

6.5.11 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) or other reasons (differences in route charges[24], avoid congested areas) need to be considered.

23 Which may be influenced by factors such as wind, route charges and congested airspace.

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

6.5.12 The horizontal flight efficiency measure takes a single flight perspective as it relates actual performance to the great circle distance, which is a theoretical (and unachievable) situation where each aircraft would be alone in the system and not be subject to any constraints.

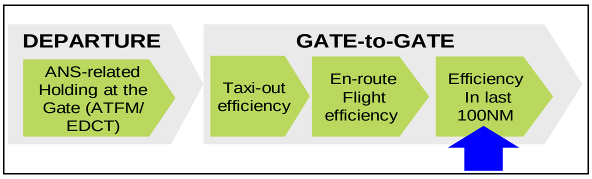
6.5.13 From a system point of view, flow separation is essential for safety and capacity reasons with a consequent negative impact on flight efficiency. Consequently, the aim is not the unachievable target of direct routing for all flights at any time, but to achieve an acceptable level of flight efficiency which balances safety and capacity requirements.

6.5.14 A certain level of inefficiency is inevitable and the following limiting factors should be borne in mind for the interpretation of the horizontal flight efficiency results:

- Basic rules of sectorisation and route design. For safety reasons, a minimum separation has to be applied between aircrafts;
- Systematisation of traffic flows to reduce complexity and to generate more capacity;
- Strategic constraints on route/airspace utilisation (rules that govern the utilisation of the network, restricted areas, shared civil/military airspace);
- Interactions with major airports; and
- Lastly, ideal cruise speeds or altitudes are not discerned from radar databases and may require detailed performance modelling or information on airline intent.

6.6 Flight efficiency within the last 100 NM

6.6.1 This section aims at estimating the level of inefficiencies due to airborne holding, metering, and sequencing of arrivals.

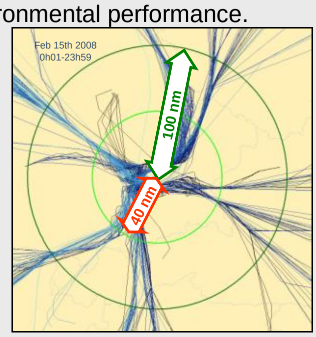


6.6.2 For this exercise, the locally defined terminal manoeuvring area (TMA) is not suitable for comparisons due to considerable variations in shape and size and ATM strategies. Hence, in order to capture tactical arrival control measures (sequencing, flow integration, speed control, spacing, stretching, etc.) irrespective of local ATM strategies, a standard Arrival Sequencing and Metering Area (ASMA) was defined.

6.6.3 The actual transit times within the 100 NM ASMA ring are affected by a number of ANS and non-ANS-related parameters including flow management measures (holdings, etc.), airspace design, airports configuration, aircraft type, pilot performance, 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.



6.6.4 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 for each airport.

6.6.5 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 (Annex II and IV) and the results should be interpreted with a note of caution.

6.6.6 Figure 38 shows the average additional time within the last 100 NM for the US and Europe in 2008 and 2010. For clarity reasons only the 20 most penalising airports of the 34 main airports are shown.

6.6.7 At system level, the additional time within the last 100 NM is similar in the US (2.45 minutes) and in Europe (2.5 minutes). However, the picture is contrasted across airports.

6.6.8 In Europe, London Heathrow (LHR) is a clear outlier[25], having by far the highest level of additional time within the last 100 NM, followed by Frankfurt (FRA) which shows only half the level observed at London Heathrow.

6.6.9 The US shows a less contrasted picture, but there is still a notable difference for the airports in the greater New York area, which show the highest level of inefficiencies within the last 100 NM in 2008.

6.6.10 Due to the large number of variables involved (see also paragraph 6.6.2), the direct ANS 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.

6.6.11 In Europe, the support of the en route function is limited and rarely extends beyond the national boundaries (see also paragraph 3.1.8). Hence, most of the sequencing 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.

---

25 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.

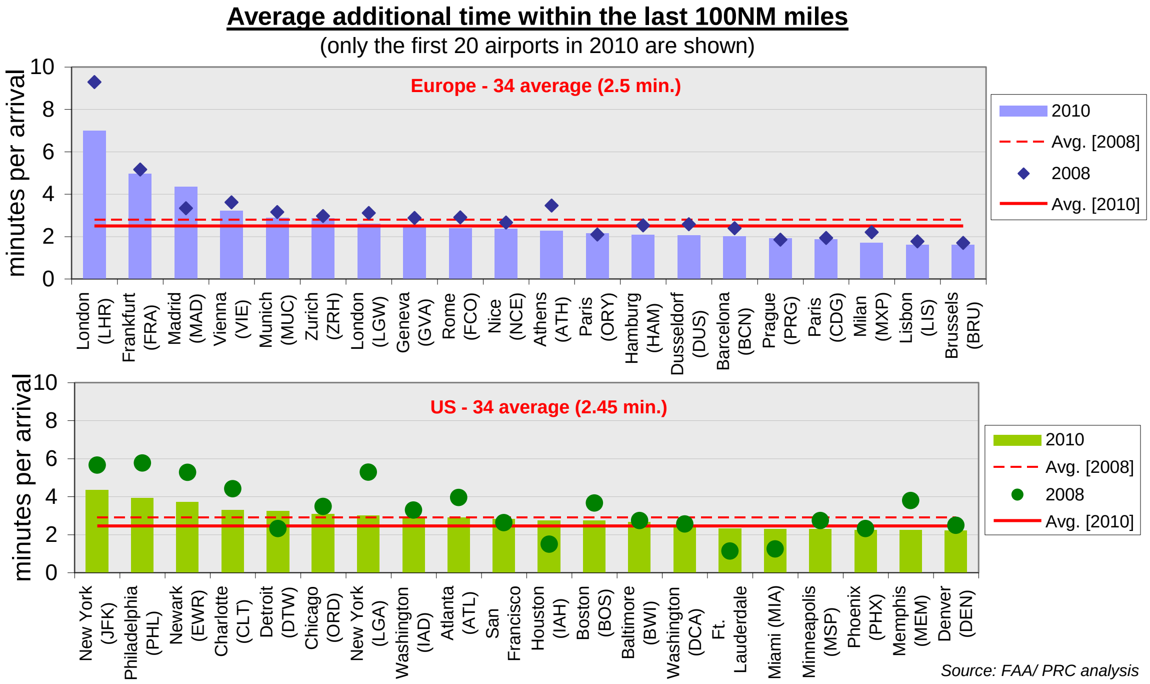


Figure 38: Estimated average additional time within the last 100 NM

6.6.12 On both sides of the Atlantic, the operations at those airports operating close to VMC capacity are vulnerable to adverse weather conditions and cause high levels of delay to airspace users.

6.6.13 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 is declared for comparable airports.

7 ESTIMATED BENEFIT POOL ACTIONABLE BY ANS

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

7.1.2 This chapter 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.

7.1.3 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 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[26], as described in Chapters 3.3 and 6.5.

7.1.4 Table 6 summarises the estimated level of inefficiency actionable by ANS in the individual flight phases, as analysed in the respective chapters.

Table 6: Estimated benefit pool actionable by ANS [2010]

Estimated benefit pool actionable by ANS for a typical flight [2010] (flights to/from the main 34 airports)		Estimated additional time (avg. per flight in min.)		Predictability (% of flights affected)		Fuel burn	Est. excess fuel burn (kg)[27]	
		EUR	US	EUR	US	engines	EUR	US
Holding at gate per departure (only delays >15min. included)	en route-related	1.8	0.05	5.7%	0.1%	OFF	≈0	≈0
	airport-related	1.2	1.0	3.3%	1.6%	OFF	≈0	≈0
Taxi-out phase (min. per departure)[28]		4.9	5.0	100%		ON	73 kg	75kg
Horizontal en route flight efficiency[29]		2.1-3.8	1.3-2.5	100%		ON	176kg	114kg
Terminal areas (min. per arrival)[30]		2.5	2.45	100%		ON	103kg	100kg
Estimated benefit pool actionable by ANS		≈12.5-14.2	≈9.8-11.0				352kg	289kg

26 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.

27 Fuel burn calculations are based on averages representing a "standard" aircraft in the system. (Taxi ≈ 15kg/min., Cruise.≈ 46kg/min., TMA holding 41kg/min.).

28 The estimated inefficiencies in the taxi-out phase refer only to departures from the main 34 airports. If all flights to/from the main 34 airports were considered, the "inefficiency" per flight would be lower because departures from less congested airports to the main 34 airports were included.

29 The horizontal flight efficiency figures relate to the distance between the 40 NM radius at the departure and the 100 NM radius at the arrival airport. The range in horizontal en route flight efficiency relates to direct route extension (A-D)/G which assumes the need to maintain a route structure in the TMA area and the en route extension (A-G)/G which assumes that all the route structure including TMA can be improved. Europe/US differences in the average distance would lead to different results, as the "inefficiency" is measured as a percentage of the great circle distance. For comparability reasons, the estimated additional time calculation was based on an average great circle distance of 450 NM for the US and Europe.

30 The estimated inefficiencies in the last 100 NM refer only to arrivals at the main 34 airports. If all flights to/from the main 34 airports were considered, the "inefficiency" per flight would be lower because arrivals at less congested airports from the main 34 airports were included.

7.1.5 Although Table 6 shows an estimated total to provide an order of magnitude, the interpretation requires a note of caution as 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).

7.1.6 Whereas for ANS-related holdings at the gate (see Chapter 6.3) the fuel burn is quasi nil, those delays are not evenly spread among flights (small percentage of flights but high delays) and hence difficult to predict.

7.1.7 The estimated "inefficiencies" in the gate-to-gate phase are generally more predictable for airspace users (more evenly spread but smaller delays) but generate higher fuel burn.

7.1.8 Actual fuel burn depends on the respective aircraft mix and therefore varies for different traffic samples. For comparability reasons, the fuel burn shown in Table 6 is based on typical average fuel burn, which was equally applied to the US and Europe figures (main 34 airports).

7.1.9 At system level, the total estimated inefficiency pool actionable by ANS and associated fuel burn are of the same order of magnitude in the US and Europe (estimated to be 6-8% of the total fuel burn).

7.1.10 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.

7.1.11 Inefficiencies in the vertical flight profile for en route and in the taxi-in phase are assumed to be of lower magnitude [Ref. 17] and were therefore not included in Table 6. The magnitude can change by region or airport and it is acknowledged that there is also scope for 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.

7.1.12 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.

8 CONCLUSIONS

8.1.1 The paper provides a high-level comparison of operational performance between the US and Europe Air Navigation systems based on a set of commonly agreed indicators from the FAA/ATO and EUROCONTROL. It provides an update to a previous report that benchmarked performance using 2008 operations.

8.1.2 The initial focus has been to develop a set of comparable performance measures in order to create a sound basis for high-level comparisons between countries and world regions.

8.1.3 Overall, the FAA controls approximately 67% more IFR flights with fewer controllers and fewer en route facilities.

8.1.4 Performance evolved differently in Europe than the US between 2008 and 2010. Europe experienced a series of atypical events in 2010 including industrial actions and higher than usual weather related delays (snow, freezing conditions) during winter 2009 and in December 2010.

8.1.5 The US saw large improvements to system-wide performance over the same time period. In general, changes at the large airports such as Atlanta and Chicago as well as in the New York area contribute the most to system-wide performance trends. The decline in demand is thought to be the primary driver for the improved performance. However there are other contributing factors. Airlines may be operating more efficiently and weather conditions appear better based on ceiling/visibility measures.

8.1.6 The analysis of schedule adherence reveals a similar level of arrival punctuality in the US and Europe, albeit with the US experiencing increasing time buffers in airline schedules and a higher level of variability, part of which is assumed to be the result of airports scheduling closer to VMC capacity and resulting weather effects.

8.1.7 Although the analysis of performance compared to airline schedules is valid from a passenger point of view and provides first valuable insights, the “masking” of expected travel time variations through the inclusion of strategic time buffers in scheduled block times makes a more detailed analysis of actual operations necessary to better understand the impact of ATM and differences in traffic management techniques.

8.1.8 The analysis of actual operations is broken down by phase of flight (i.e. pre-departure delay, taxi-out, en route, terminal arrival, taxi-in, and arrival delay). This reveals strong and weak points on both sides.

- In the US, departure punctuality has improved and taxi-out delays are now comparable with Europe. This was not the case in 2008, but it should be noted that Europe was affected by exceptional events in 2010.
- Horizontal en route flight efficiency is higher in the US with corresponding fuel burn benefits through more direct routing. The fragmentation of European airspace appears to be an issue which affects overall flight efficiency and limits the ability of the en route function to support airport throughput. The development of Functional Airspace

Block (FAB) within the Single European Sky Initiative (SES) is expected to help improve this.

- On average, the additional time within the last 100 NM is comparable. London and Frankfurt on the European side and the airports in the New York area on the US side show significantly higher arrival transit times on average.

8.1.9 Although safety and capacity constraints limit the practicality of ever fully eliminating these “inefficiencies,” there is value in developing a systematic approach to aggregating a benefit pool which is actionable by ANS.

8.1.10 Inefficiencies have a different impact (fuel burn, time) on airspace users, depending on the phase of flight (terminal area, cruise, or ground) and the level of predictability (strategic or tactical).

8.1.11 While ANS is often not the root cause of a delay, the aim should be to optimise how the delay is taken. The predictability of the different flight phases and fuel costs will help determine how much and where delay needs to be absorbed. Further work is needed to assess the impact of ATM performance on airspace users, the utilisation of capacity, and the environment.

8.1.12 The estimated inefficiency pool actionable by ANS and associated fuel burn is similar in the US and Europe (estimated to be 6-8% of the total fuel burn) but with notable differences in the distribution by phase of flight. There is also a wide range by destination airport as both the EU and the US have airports with large number of operations and congestion that influence the system-wide trend.

8.1.13 These differences possibly originate from different policies in allocation of airport slots and flow management, as well as different weather conditions. The impact on the environment, predictability, and flexibility in accommodating unforeseen changes may be different. In addition to weather and airport congestion management policy, a more comprehensive comparison of service performance would also need to address safety, capacity, and other relevant performance affecting factors. A better understanding of trade-offs would be needed to identify best practices and policies.

8.1.14 There is high value in global comparisons and benchmarking in order to drive performance and identify best practices. Moving forward, the conceptual framework enables operational performance to be measured in a consistent way and ATM best practices to be better understood. Identification and application of today’s best practices, with existing technology and operational concepts, could possibly help in raising the level of performance on both sides of the Atlantic in the relative short term and may have wider applicability.

9 EMERGING THEMES AND NEXT STEPS

9.1.1 The report provides a high-level comparison of operational performance between the US and Europe. The findings raise many questions to what extent performance differences are driven by scheduling policies, airline performance, ATM operating strategies, and/or differences in weather conditions.

9.1.2 This report utilises radar and key events times reported by airlines to develop the primary key performance indicators for efficiency. However, it is recognized that these performance databases may not capture the full benefit pool. There may be additional fuel savings from advances in ATM that make more use of the aircraft's Flight Management System (FMS). This level of efficiency calculation would require more detailed information on aircraft performance and airline intent.

9.1.3 Many research questions involve the ATM application of delay along the various flight phases, the subsequent environmental and economic impact, and the ability to maximise the use of scarce capacity. Recent research indicates there may be additional benefit pools available if operators could optimise their speed profiles [Ref. 19 and Ref. 20]. However, ascribing this inefficiency to ATM or airline cost-index operating practice is difficult.

9.1.4 For the US, the application of policies similar to those in Europe could improve delay statistics but at what economic cost? How much are US scheduling and ATM policies driven by the predominant weather conditions in the US? This report provided a first look at weather trends over time and how delay increases as meteorological conditions worsen. More detailed performance analysis would quantify the recoverable efficiency gains if more advanced ATM could mitigate the effects of weather.

9.1.5 For Europe, the questions revolve around the level and the use of capacities. Are capacities too low and over-constraining demand and efficient scheduling? Is the number of ANSPs impacting en route throughput, and does IMC weather and wind impact airport throughput?

9.1.6 This high level study raises questions and more in-depth study is needed to better understand what changes could be made now and in the future. There may be good reason for different focuses in the future ATM systems in Europe and the US.

9.1.7 Below are several specific research topics for further joint study with a view to identifying best practices (taking weather and other appropriate constraints into account) to further improve ATM performance on both sides of the Atlantic and possibly world-wide.

1) <u>Refinement of benefit pool actionable by ANS:</u> In order to establish a more complete understanding of the benefit pool actionable by ANS, it will be necessary to include other phases of flight in the benefit pool such as the initial departure phase and the taxi-in phase. There has also been recent work by both groups to improve the assessment of vertical flight efficiency in context with the current phase of flight calculation. Working with stakeholders, it may be possible to improve fuel benefit calculations to cover efficiencies not easily calculated from radar data.

2) Propagated/reactionary delay: Performance databases that contain delay cause codes and tail number tracking allow for a more detailed assessment of a facility's impact on overall performance. Aircraft arriving late to one airport may be delayed due to flight legs occurring earlier in the flights itinerary. More detailed measures assessing propagated delay would allow for improved assessment of a facility's impact on overall system performance.

3) En route capacity/airspace complexity: Many of the measures in this report show changes in performance by airport. Airspace capacity/airspace complexity and the subsequent impact on performance are not addressed. Benchmark updates could be improved by highlighting work performed in the EU and US on quantifying complexity as well as airspace constraints.

4) ATM performance, environmental impact and fuel burn: While ANS is often not the root cause of delay, the way the delay is managed and distributed along the various phases of flight has an impact on airspace users (predictability, fuel burn), the utilisation of capacity (en route and airport), and the environment (gaseous emissions).

   Three interesting questions to be addressed and also relevant for NextGen and SESAR are:

   - What level of "delay" is necessary to maximise the use of capacity?
   - How should delay be distributed along the various phases of flight in order to minimise impact on airspace users and the environment?
   - How can flexibility be improved to allow users to choose the best options?

   More research is required to determine the relation of optimised trajectories to the performance indicators. This would require more detailed aircraft performance modelling that could establish benchmark times according to weather, aircraft weight, and user preferences.

   Although not in the scope of the report, the potential benefit pool for intercontinental flights on Oceanic routes should be explored in order to identify scope for improvement.

5) ATM and airport capacity utilisation: More work is needed to better understand the impact of differences in airport scheduling practices and air traffic flow management on peak airport throughput in the US and in Europe.

6) Provision of en route capacity in Europe: Compared to the US, a large share of the delay in Europe is due to en route constraints. More work to understand the drivers of en route constraints in Europe (i.e. traffic growths, staffing, seasonality, fragmentation, complexity, etc.) and differences compared to the US could help reducing en route-related constraints in the European ATM system.

7) ATM and weather: Both groups have access to METAR weather data that can be linked to the performance databases used in this report. Airline reported delays have weather as a causal code, but in the US this is limited to extreme weather. This report provided a first look using US data on how delay and capacity vary by ceiling and visibility conditions. Future work would provide more detailed EU-US comparisons to quantify the degree to which weather is responsible for changes in ANSP performance.

8) Specific study on taxi delay: Since 2008, US taxi-out delay declined sharply and is now comparable to Europe. In terms of phase of flight, there are indications that taxi-in times have not decreased in proportion with other flight phases. This may be

due to gate constraints or other factors. Future work would look to establish more causal reasons for change in taxi-out delay and identify the main drivers of ATM performance.

9) Aircraft sizes: Considerable differences in average aircraft size between the US and Europe were observed. Are policy differences regarding pre-coordinated airport slots impacting aircraft size or is it more a factor of priority on frequency of flights and the hub-and-spoke model in the US? A more detailed analysis would help to better understand the factors driving the differing trends in average aircraft size.

10) Impact of shared airspace on ATM: In Europe, there is a high density of civil and military activity in the core area. More study is needed to evaluate the impact of ATM civil/military arrangements on flight efficiency and capacity in the US and Europe.

11) Consistent approach to ANS performance measurement: In addition to operational performance measures, there would be value in extending the scope to other performance areas such as safety or cost-effectiveness in order to develop a consistent and systematic approach for high level comparisons between countries and world regions.

ANNEX I - LIST OF AIRPORTS INCLUDED IN THIS STUDY

Table 7: Top 34 European airports included in the study [2010]

EUROPE	ICAO	IATA	COUNTRY	Avg. daily IFR departures in 2010	2010 vs. 2008
Amsterdam (AMS)	EHAM	AMS	NETHERLANDS	544	-10%
Athens (ATH)	LGAV	ATH	GREECE	257	-3%
Barcelona (BCN)	LEBL	BCN	SPAIN	381	-13%
Berlin (TXL)	EDDT	TXL	GERMANY	214	-1%
Brussels (BRU)	EBBR	BRU	BELGIUM	300	-13%
Cologne (CGN)	EDDK	CGN	GERMANY	179	-6%
Copenhagen (CPH)	EKCH	CPH	DENMARK	337	-7%
Dublin (DUB)	EIDW	DUB	IRELAND	218	-23%
Dusseldorf (DUS)	EDDL	DUS	GERMANY	294	-5%
Frankfurt (FRA)	EDDF	FRA	GERMANY	636	-4%
Geneva (GVA)	LSGG	GVA	SWITZERLAND	225	-6%
Hamburg (HAM)	EDDH	HAM	GERMANY	204	-8%
Helsinki (HEL)	EFHK	HEL	FINLAND	234	-8%
Istanbul (IST)	LTBA	IST	TURKEY	381	7%
Lisbon (LIS)	LPPT	LIS	PORTUGAL	195	-1%
London (LGW)	EGKK	LGW	UNITED KINGDOM	330	-8%
London (LHR)	EGLL	LHR	UNITED KINGDOM	624	-5%
London (STN)	EGSS	STN	UNITED KINGDOM	211	-19%
Madrid (MAD)	LEMD	MAD	SPAIN	594	-7%
Manchester (MAN)	EGCC	MAN	UNITED KINGDOM	217	-22%
Milan (MXP)	LIMC	MXP	ITALY	266	-11%
Munich (MUC)	EDDM	MUC	GERMANY	530	-10%
Nice (NCE)	LFMN	NCE	FRANCE	178	-9%
Oslo (OSL)	ENGM	OSL	NORWAY	298	-8%
Palma (PMI)	LEPA	PMI	SPAIN	239	-9%
Paris (CDG)	LFPG	CDG	FRANCE	685	-10%
Paris (ORY)	LFPO	ORY	FRANCE	301	-6%
Prague (PRG)	LKPR	PRG	CZECH REPUBLIC	208	-12%
Rome (FCO)	LIRF	FCO	ITALY	451	-5%
Stockholm (ARN)	ESSA	ARN	SWEDEN	262	-14%
Stuttgart (STR)	EDDS	STR	GERMANY	169	-16%
Vienna (VIE)	LOWW	VIE	AUSTRIA	362	-9%
Warsaw (WAW)	EPWA	WAW	POLAND	187	-8%
Zurich (ZRH)	LSZH	ZRH	SWITZERLAND	352	-2%
				325	-8%

Table 8: US main 34 airports included in the study

USA	ICAO	IATA	COUNTRY	Avg. daily IFR departures in 2010	2010 vs. 2008
Atlanta (ATL)	KATL	ATL	United States	1294	-3%
Baltimore (BWI)	KBWI	BWI	United States	367	0%
Boston (BOS)	KBOS	BOS	United States	500	-2%
Charlotte (CLT)	KCLT	CLT	United States	714	-1%
Chicago (MDW)	KMDW	MDW	United States	318	-9%
Chicago (ORD)	KORD	ORD	United States	1202	0%
Cleveland (CLE)	KCLE	CLE	United States	266	-17%
Dallas (DFW)	KDFW	DFW	United States	891	-1%
Denver (DEN)	KDEN	DEN	United States	871	1%
Detroit (DTW)	KDTW	DTW	United States	621	-2%
Ft. Lauderdale (FLL)	KFLL	FLL	United States	351	-7%
Houston (IAH)	KIAH	IAH	United States	736	-8%
Las Vegas (LAS)	KLAS	LAS	United States	554	-14%
Los Angeles (LAX)	KLAX	LAX	United States	772	-8%
Memphis (MEM)	KMEM	MEM	United States	462	-7%
Miami (MIA)	KMIA	MIA	United States	512	2%
Milwaukee (MKE)	KMKE	MKE	United States	256	5%
Minneapolis (MSP)	KMSP	MSP	United States	596	-3%
New York (JFK)	KJFK	JFK	United States	549	-9%
New York (LGA)	KLGA	LGA	United States	500	-4%
Newark (EWR)	KEWR	EWR	United States	554	-7%
Orlando (MCO)	KMCO	MCO	United States	429	-8%
Philadelphia (PHL)	KPHL	PHL	United States	614	-7%
Phoenix (PHX)	KPHX	PHX	United States	614	-8%
Portland (PDX)	KPDX	PDX	United States	302	-9%
Raleigh-Durham (RDU)	KRDU	RDU	United States	245	-16%
Salt Lake City (SLC)	KSLC	SLC	United States	447	-6%
San Diego (SAN)	KSAN	SAN	United States	257	-15%
San Francisco (SFO)	KSFO	SFO	United States	519	-1%
Seattle (SEA)	KSEA	SEA	United States	427	-9%
St. Louis (STL)	KSTL	STL	United States	252	-25%
Tampa (TPA)	KTPA	TPA	United States	255	-18%
Washington (DCA)	KDCA	DCA	United States	372	-2%
Washington (IAD)	KIAD	IAD	United States	497	-7%
				533	-6%

ANNEX II - US METHODOLOGY FOR TERMINAL ARRIVAL EFFICIENCY

This Annex describes the methodology for calculating the efficiency of individual flights in a defined terminal area. The efficiency is based on flight time inside of a 100 NM arc around the airport. The baseline or unimpeded time that actual flight times are compared to come from an existing FAA measure called the Terminal Arrival Efficiency Rating (TAER). The TAER is an official FAA performance metric used to assess throughput and the ETA used in its calculation serves as a benchmark of unimpeded time and indicator of flight efficiency. The benchmark times used in the subject terminal arrival efficiency measure are developed for unique combinations of:

(1) Approach Path
(2) Arrival Configuration - *From National Traffic Management Log (NTML) Database*
(3) Meteorological Condition - *Determined by ASPM*
(4) Aircraft Class - *Physical Class & Weight Class*

The sections below describe how radar-based databases are processed to determine a representative approach path and aircraft class for each runway used at an airport.

Data Requirements

The following table describes data extracted from radar sources in combination with data from ASPM that reports the runway used. For each flight that crosses the 40 NM circle from the arrival airport, the following data fields are needed to generate unimpeded benchmark ETAs:

Field	Description
ARR_APRT	Arrival airport
ARR_RUNWAY_CONFIGURATION	Runway configuration in use for arrivals
ARR_MC	Meteorological conditions at the airport at time of arrival
PHYSICAL_CLASS	Physical class: Jet, Turboprop, Piston, Other
WEIGHT_CLASS	Weight class: Heavy, 757, Large Jet, Commuter, Medium and Light
CROSS_100	Boolean value whether or not the flight crossed the 100 NM circle from the airport (flight may be less than 100 NM in Great Circle Distance)
TIME_CROSS_100	Time at the 100 NM crossing (if crossed)
TIME_CROSS_40	Time at the 40 NM crossing
TIME_ON	The On Time for the flight
BEARING_CROSS_100	The bearing from the airport (0 is due North, 90 is due East) of the 100 NM crossing point (if crossed)
BEARING_CROSS_40	The bearing from the airport of the 40 NM crossing point
DISTANCE_FLOWN_100_40	The distance flown (NM) between the 100 NM circle and the 40 NM circle (if the 100 NM circle is crossed)
DISTANCE_FLOWN_40_ON	The distance flown (NM) between the 40 NM circle and the airport

Process 1: Assigning Approach Paths (Creation of Fix Regions)

When generating the TAER ETAs, one of the grouping variables that used is an "assigned fix" based on the direction that the flight is approaching the airport. The process does not use the specific arrival fixes according to the airspace configuration data. Instead, it examines the data to see where flights actually cross the 40 NM circle from the airport and applies a peak finding algorithm to approximate locations for arrival fixes. Benchmark times are then developed for this clustered group of flight paths depending on their eventual arrival runway and their specific aircraft class.

For each airport, we count how many flights crossed the 40 NM circle in each degree bin:

SELECT ARR_APRT, ROUND(BEARING_CROSS_40,0), COUNT(*) FROM ASPM_TAER_DATA GROUP BY ARR_APRT, ROUND(BEARING_CROSS_40);

This creates an airport by airport histogram of the flight counts binned by the degree from which the flight approached the airport. This is the process for creating the fix regions for a specific airport:

1. Create a rolling five degree centred count of flights at each degree bin. That is, the rolling count $r(n) = \sum_{n-2}^{n+2} c(n)$ where $c(n)$ is the original histogram count and the bins are assumed to go through 0/360 degrees (that is, for example, $r(0) = c(358) + c(359) + c(0) + c(1) + c(2)$)
2. Find the maximum $r(n)$ that is at least 2% of the total number of flights at that airport and not within 20 degrees (inclusive) of another previously determined fix. If such a value exists, add it to the fix list and repeat step 2, else go on to step 3.
3. Sort the fix list and assign cut off values for the fix regions as the average value between two adjacent fixes (including the last fix and the first fix).

This creates the list of fixes and the ranges for which to assign flights to a clustered set of approach paths.

Process 2: Calculate Benchmark Times by Group

For each flight, read in all of the required data. Using the BEARING_CROSS_100 if the CROSS_100 value is true, or the BEARING_CROSS_40 if the CROSS_100 is false, find the assigned fix value by using the fix bin ranges calculated in Process 1. Then group the flights which crossed the 100 NM circle (where CROSS_100 is true) by the following category data:

1. Arrival Airport
2. Assigned Approach Path (Fix Region)
3. Arrival Configuration
4. Meteorological Condition
5. Physical Class
6. Weight Class

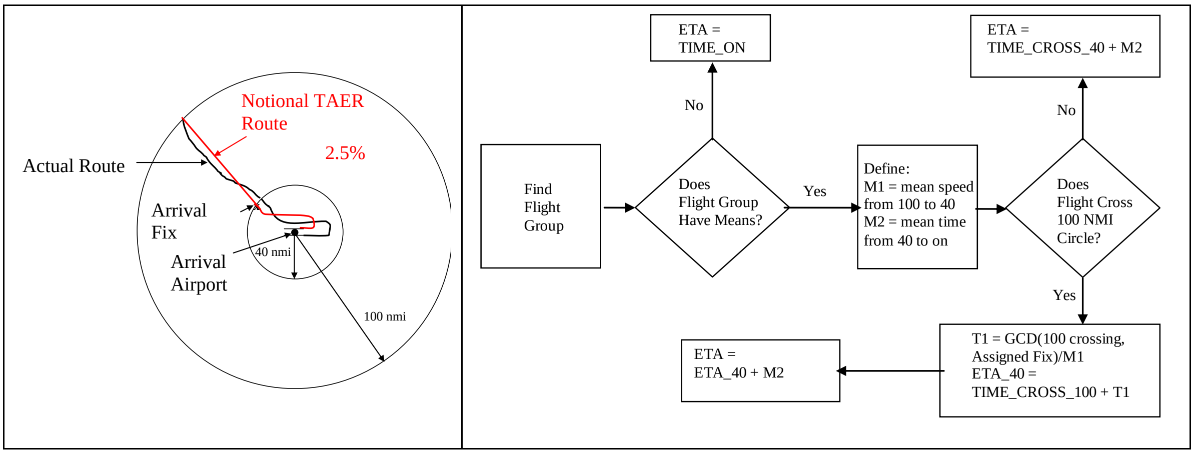
For each group that had at least 50 flights during the year, we sort the flights by the total distance flown from the 100 NM circle crossing to the arrival airport, DISTANCE_FLOWN_100_40 + DISTANCE_FLOWN_40_ON. From that, we take the flights between the 5^{th} and 15^{th} percentiles… those flights that are short, but not the extreme shortest flights. We then use those flights (the 5^{th} to 15^{th} percentile flights by distance) to calculate an average ground speed flown between the 100 NM circle and the 40 NM circle (DISTANCE_FLOWN_100_40/(TIME_CROSS_40-TIME_CROSS_100), and the average time from the 40 NM circle to the airport (TIME_ON-TIME_CROSS_40).

To reiterate, for each group of flights, we now have an average speed from the 100 to 40 NM circles and an average time from the 40 NM circle to the runway. These averages are based on the flights that are relatively short in distance flown and thus are more likely to be unimpeded.

Process 3: Find Flight by Flight ETAs

Now that we have the grouped means, we can calculate the flight by flight ETAs. For each flight:

1. Find the grouping for the flight as in Process 2 above. Do this even if the flight did not cross the 100 NM circle.
2. Find the two means calculated in Process 2 above. If the grouping for the flight did not have enough flights to use to calculate the means in Process 2, assign the ETA to be the TIME_ON and finish. If there were enough flights and the means exist for this grouping, proceed to Step 3.
3. If the flight did not cross the 100 NM circle, that is CROSS_100 is false, assign the ETA to be the TIME_CROSS_40 + mean time from 40 NM to the airport and finish. Else, proceed to Step 4.
4. If the flight did cross the 100 NM circle, use the BEARING_CROSS_100 and the Assigned Fix Bearing to find the great circle distance from the 100 NM crossing position to the assigned fix. Calculate the estimated time from the 100 NM circle to the 40 NM circle by dividing the great circle distance by the mean speed from 100 to 40 calculated in Process 2. Add that time to the TIME_CROSS_100 to find an estimated time of crossing at the 40 NM assigned fix. To that 40 NM estimated time, add the mean time from 40 NM to the airport to generate the ETA.


Notional TAER
Route
2.5%
Actual Route
Arrival
Fix
Arrival
Airport
40 nmi
100 nmi
ETA =
TIME_ON
No
Find
Flight
Group
Does
Flight Group
Have Means?
Yes
Define:
M1 = mean speed
from 100 to 40
M2 = mean time
from 40 to on
ETA =
TIME_CROSS_40 + M2
No
Does
Flight Cross
100 NMI
Circle?
Yes
T1 = GCD(100 crossing,
Assigned Fix)/M1
ETA_40 =
TIME_CROSS_100 + T1
ETA =
ETA_40 + M2

ANNEX III - US METHODOLOGY FOR UNIMPEDED TAXI-OUT TIMES

1. Start with a city pair flight with the data items: date (year, month, and day), departure and arrival airport, departure and arrival times (both scheduled and actual), OOOI times (out, off, on, and in). The season parameter is defined as follows: winter in (12, 01, 02), spring in (03, 04, 05), summer in (06, 07, 08), and fall in (09, 10, 11).
2. Split a flight into two parts: departure and arrival.
3. The departure part contains: Airport, Carrier, Season, Actual gate-out time (entry time into a departure queue), and Actual wheels-off time (exit time out of the departure queue).
4. The arrival part contains: Airport, Carrier, Season, Actual wheels-off time (entry time into an arrival queue), and Actual gate-in time (exit time out of the arrival queue).
5. Set up a bin for each minute of a single day and count how many aircraft (both departing and arriving) ahead of the flight at the queue entry time for the departure and arrival queues separately.
6. Compute for each group an upper quartile (75^{th} percentile) and exclude the upper 25% from the estimation computation. This is done to prevent extremely large values from exerting excessive effects on the estimates. After all, we are estimating an optimal taxi times, assuming there is no obstruction in the taxiways.
7. Run a regression for each subgroup determined by the airport, air carrier, and season, again, separately for the departure and arrival queues.

   $y_o = ax_o + bx_i + c$, where y_o is a taxi-out time and x_o and x_i are the number of aircraft taxing out and taxing in, respectively. a and b are regression coefficients with $a \geq 0$ and $b \geq 0$.

8. Adopt only results for which both regression coefficients are positive (the more aircraft, the longer taxi times).
9. For the subgroups with non-positive regression coefficients, do other things with boundary conditions set for the resulting coefficients to be positive. (SAS used has some regression or non-linear model fitting procedures in which one can specify the boundary conditions.)
10. Finally, to obtain the unimpeded taxi-out times, set the number of departing aircraft to be 1 and arriving aircraft to be 0 in the regression equation for the departure queue, meaning that my aircraft is only one moving. For the unimpeded taxi-in times, set the number of arriving aircraft to be 1 and departing aircraft to be 0 in the equation for the arrival queue.
11. The other statistics are for information only as a reference to see if the unimpeded times are reasonable.

ANNEX IV - EUROPEAN METHODOLOGY FOR UNIMPEDED TIME

This Annex describes the methodology used for the calculation of the additional time in the taxi-out phase and within the last 100 NM for Europe.

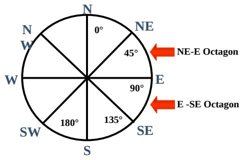
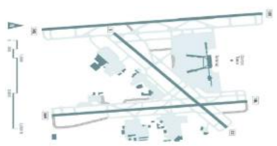
Data Requirements

For each flight, the following data fields were used for the calculation of the unimpeded times. Presently, the runway and stand information is not available in the central data collections accessible to EUROCONTROL. When this data was not available, the unimpeded times were calculated at a lower level of detail (i.e. without stand runway combination).

Field	Last 100 NM	Taxi-out	Description	Source
DEP_APRT		X	Departure airport	CFMU
ARR_APRT	X		Arrival airport	CFMU
DEP_RUNWAY		X	Departure runway	Airport
ARR_RUNWAY	X		Arrival runway	Airport
AIRCRAFT_CLASS	X	X	Physical class: Jet, Turboprop, Piston	CFMU
BEARING_CROSS_100	X		The bearing from the airport (0 is due North, 90 is due East) of the 100 NM crossing point (if crossed)	CFMU
TIME_CROSS_100	X		Time at the 100 NM crossing (if crossed)	CFMU
BEARING_CROSS_40	X		The bearing from the airport of the 40 NM crossing point	CFMU
TIME_CROSS_40	X		Time at the 40 NM crossing	CFMU
ALDT	X		Actual landing time	CFMU
AOBT		X	Actual off-block time	CODA
DEPARTURE GATE		X	Departure gate/stand	
ATOT		X	Actual take-off time	

Process 1: Grouping of flights

Each flight is categorised according to some key factors (as far as available) relevant for performance measurement:

• Aircraft class: grouping of aircraft type into Heavy, Medium, Small Jet or Turbo Prop in order to account for speed differences.	Physical class: Jet, Turboprop, Piston	Last 100 NM / Taxi-out
• ASMA entry sector: The ASMA (circle around airport with a radius of 100 NM) is divided into 8 sectors of 45° in order to capture the direction from which the flight entered into the ASMA.		Last 100 NM
• Runway use: The inclusion of the arrival/departure runway provides useful additional information for airport performance analyses.		Last 100 NM / Taxi-out

• Congestion index: The allocation of a congestion level to each flight is important to remove congestion effects in the calculation of the unimpeded transit times. • For the last 100 NM, it considers the number of landings by other aircraft between the analysed flight enters the 40 NM radius and its actual landing. • For taxi-out, it considers the number of take-offs and landings by other aircraft between the analysed flight goes off block and its take-off.		Last 100 NM / Taxi-out

Process 2: Calculation of unimpeded reference time

For each group with the same characteristics (aircraft class, entry sector, runway, stand, if available or applicable), an unimpeded reference time is calculated.

The unimpeded reference time is the truncated average (10^{th}-90^{th} percentile) of all flights equal to or below a predefined congestion index. The aim is not to capture the fastest times but to reference the average behaviour when no congestion is present.

In order to take the difference in airport throughput into account, the threshold for the congestion index to be used for the calculation of the unimpeded time is defined as 50% (or alternatively 25%) of the maximum airport throughput using the following formula (max = 25% * max. throughput *12/60). This assumes that the unimpeded transit time is around 12 min. For example, for an airport with a maximum throughput of 40, only the flights with a congestion index of 4 or less would be included in the calculation of the unimpeded transit time.

Process 3: Additional time calculation

For each group (same aircraft class, entry sector, runway, stand, if available and applicable), the additional time is calculated as the difference between the average transit time (of all flights in this group) and the unimpeded reference time for this group determined in the previous step.

In order to get high level results, the weighted average of all the individual groups (aircraft class, entry sector and runway, if available) is calculated in a final step.

The sensitivity analysis showed that the methodology appears to be robust for high-level performance measurement. Subject to data availability, the methodology can also be adjusted the level of detail (runway-entry point combination).

ANNEX V - 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)
Airside	The aircraft movement area (stands, apron, taxiway system, runways etc.) to which access is controlled.
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
ATAG	Air Transport Action Group
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	EUROCONTROL Central Flow Management Unit
CO_2	Carbon dioxide
CODA	EUROCONTROL Central Office for Delay Analysis

CTOT	Calculated take-off Time
EC	European Commission
ECAC	European Civil Aviation Conference.
E-CODA	Enhanced Central Office for Delay Analysis (EUROCONTROL)
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.
EU	European Union [Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom]
EUROCONTROL	The European Organisation for the Safety of Air Navigation. It comprises Member States and the Agency.
EUROCONTROL Member States	Thirty-eight Member States (31.12.2008): Albania, Armenia, Austria, Belgium, Bosnia & Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, 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.
FAA	US Federal Aviation Administration
FAB	Functional Airspace Blocks
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)
General Aviation	All civil aviation operations other than scheduled air services and non-scheduled air transport operations for remuneration or hire.
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.
IMC	Instrument Meteorological Conditions
KPA	Key Performance Area
KPI	Key Performance Indicator
M	Million
MET	Meteorological Services for Air Navigation
MIL	Military flights
MIT	Miles in Trail

MTOW	Maximum Take-off Weight
NAS	National Airspace System
NM	Nautical mile (1.852 km)
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.
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
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 VI - REFERENCES

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

2 "ATM Global Environment Efficiency Goals for 2050," CANSO, December 2008.

3 ICAO Manual on Global Performance of the Air Navigation System (ICAO Document 9883)

4 Enhancing Airline Passenger Protections, Final Rule, 74 Fed. Reg. 68983, December 30, 2009

5 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.

6 Algorithm to describe weather conditions at European Airports (ATAP 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

7 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.

8 US DOT, FAA, The MITRE Corp., Airport Capacity Benchmark Report 2004, September 2004

9 Amedeo Odoni and Thomas Morisset, "The declared capacity: A critical decision for major airports," May 2009.

10 Timothy Ayanla and Dave Knorr, FAA Brief: Analysis of Delays at Miami and Fort Lauderdale.

11 FAA Free Flight Performance Metrics Reports 1999-2001.

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

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

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

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

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

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

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

19 "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.

20 Lovegren, Jonathan A., Hansman, John, "Estimation of Potential Aircraft Fuel Burn Reduction in Cruise Via Speed and Altitude Optimization Strategies," MIT International Centre for Air Transportation (ICAT), Report No. ICAT-2011-03, February 2011

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

2012-AJR-018 — Produced by ATO Communications.