EUROCONTROL

U.S. Department of Transportation
Federal Aviation Administration

2012 Comparison of Air Traffic Management-Related Operational Performance: U.S./Europe

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

November 2013

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 Air Traffic Management performance between the US and Europe. 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.

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

Final report – November 2013

ABSTRACT

This report provides a high-level comparison of operational ATM performance between the US and Europe. Building on established operational key performance indicators, the goal of the joint study between the Federal Aviation Administration (FAA) and EUROCONTROL is to understand differences between the two ATM systems in order to further optimise ATM performance and to identify best practices for the benefit of the overall air transport system. The analysis is based on a comparable population of data and harmonised assessment techniques for developing reference conditions for assessing ATM performance.

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

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

This report builds on the well-established and accepted elements of the previous studies in order to provide a high-level comparison of operational ATM performance between the US and Europe. The analysis in this report is current through calendar year 2012 and the geographical scope of the comparison is limited to continental airspace.

Where possible, performance measures were improved in order to consider new data flows and input received over the past years. The framework applied in this report will continue to be refined as more advanced methodologies are being developed and initiatives are underway to better consider external factors that could influence ATM performance (i.e. differences in weather conditions, airline schedules, aerodrome capacity, etc.).

The analysis described in this report does not address all eleven ICAO Key Performance (KPAs). While the primacy of Safety is fully recognised, the scope of this report is limited to operational ATM performance. Hence, the ICAO KPAs mainly addressed in this report are efficiency, predictability and indirectly environmental sustainability when evaluating the additional fuel burn.

The work has also now been introduced to ICAO at the Air Navigation Conference (AN-Conf./12) in November 2012. FAA and EUROCONTROL are prepared to support ICAO efforts to update its guidance on performance measures using the demonstrated implementation of common measures utilised in these benchmarking studies.

SETTING THE SCENE

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

The total surface of continental airspace analysed in the report is similar for Europe and the US. However, the US controls approximately 59% more flights operating under instrumental flight rules (IFR) with less Air Traffic Controllers (ATCOs) and fewer facilities.

Calendar Year 2012	Europe	USA	US vs. Europe
Geographic Area (million km^2)	11.5	10.4	≈ -10%
Nr. of civil en route Air Navigation Service Providers	37	1	
Number of Air Traffic Controllers (ATCOs in Ops.)	≈17 200	≈13 300	≈ -23%
Total staff	≈58 000	≈35 500	≈ -39%
Controlled flights (IFR) (million)	9.5	15.2	≈ +59%
Flight hours controlled (million)	14.2	22.4	≈ +59%
Relative density (flight hours per km^2)	1.2	2.2	≈ x1.8
Share of flights to or from top 34 airports	67%	66%	
Share of General Aviation	3.9%	21%	
Average length of flight (within respective airspace)	559 NM	511 NM	≈ -11%
Number of en route centres	63	20	-42
Nr. of APP units (Europe) and terminal facilities (US)	260	162	-98
Number of airports with ATC services	≈ 433	≈ 514	+81
Of which are slot controlled	> 90	4	
ATM/CNS provision costs (in billion €2011)	8.4	7.8	-12%
Source	EUROCONTROL	FAA/ATO	

TABLE I: US/EUROPE KEY ATM SYSTEM FIGURES (2012)

Reported full-time Air Traffic Controllers (ATCOs) (CANSO international reporting definition) are 23% less in the US. This range narrows to 10% when US "developmental" controllers are considered. Although "developmentals" do not meet the "ATCO in OPS" ACE and CANSO definition, they have an active role in controlling traffic and the category does not directly compare to the European "on the job trainee" which has a much more limited role.

The organisation of the ATM system is fundamentally different. Europe comprises 37 ANSPs (and a similar number of different regulators) and 63 Area Control Centres (ACC). In contrast, the US has one ANSP and 20 Air Route Traffic Control Centres (ARTCC). The US has 162 Terminal Radar Approach Control Facilities (TRACONs) and Combined Facilities servicing a number of airports each, compared to Europe's 260 Approach control units (APPs). Some TRACONs in the US are so large in terms of size of airspace and service provided that they could be compared to some of the lower airspace ACCs in Europe.

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

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

Moreover, all States in Europe have their individual military needs and requirements that need to be accommodated within their respective national airspace (see Figure I). This contrasts with the ATM system in the US where only one single service provider (FAA) is responsible for the organisation, coordination, and development of one contiguous airspace.

As a consequence, there is a notable difference in the number and locations of Special Use Airspace (SUA). In Europe, the number of restricted and segregated areas is higher and they are more scattered which potentially affects the level of flight inefficiency and capacity from the system point of view.

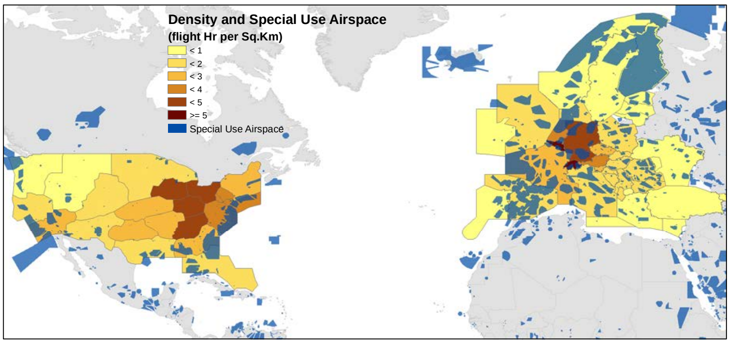


FIGURE I: COMPARISON OF SPECIAL USE AIRSPACE

In terms of traffic growth, there was a notable decoupling in 2004 when the traffic in Europe continued to grow while US traffic started to decline.

At system level, European traffic continued to grow by 13.9% between 2004 and 2008 but declined by 5.3% between 2008 and 2012, as a consequence of the economic crisis. During the same period (2004-2012) traffic in the US declined by almost 16%.

However, the system level averages 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 East.

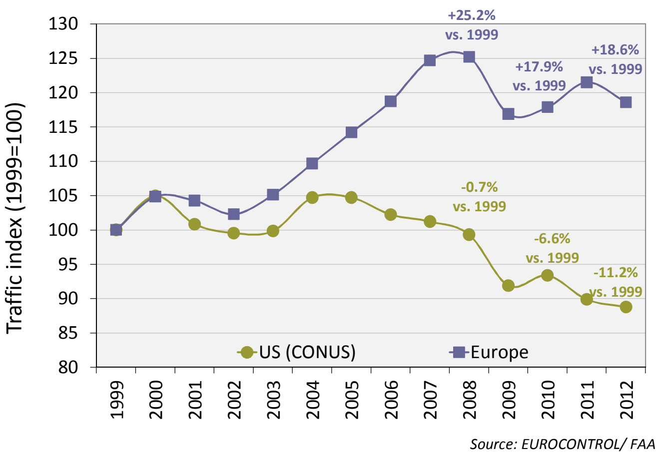


FIGURE II: EVOLUTION OF IFR TRAFFIC IN THE US AND IN EUROPE

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

OPERATIONAL SERVICE QUALITY

The industry standard for "service quality" in air transport is usually on-time performance (i.e. share of flights within 15 minutes of published airline schedules).

Although performance evolved differently over the past years, arrival punctuality is at a similar level (≈83%) in the US and in Europe in 2012.

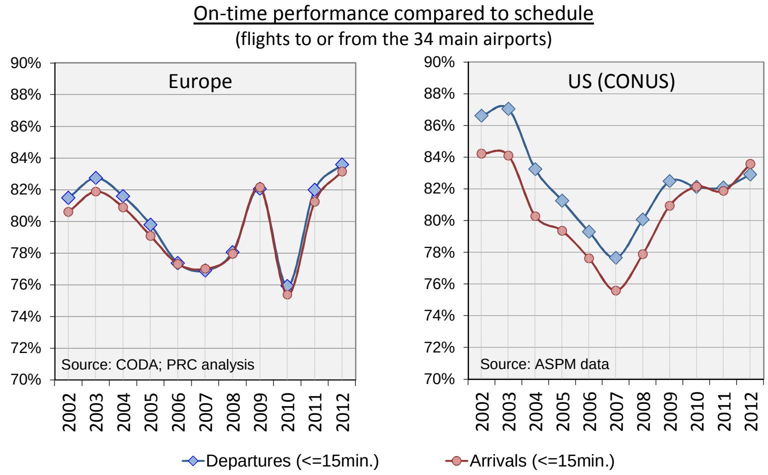


FIGURE III: ON-TIME PERFORMANCE

The US experienced a significant deterioration of on-time performance between 2003 and 2007, followed by a continuous improvement between 2007 and 2012. In general, changes at the large airports such as Atlanta (ATL) and Chicago (ORD) as well as in the New York area (JFK, EWR, and LGA) contributed the most to the observed improvements.

Although starting already from a lower level of punctuality than in the US, service quality in Europe deteriorated further between 2003 and 2007. The steep improvement between 2007 and 2009 was interrupted in 2010 when punctuality in Europe degraded to the worst level recorded since 2001.

The main factors for this deterioration in Europe were a large number of industrial actions and higher than usual weather-related delays during the winters of 2009 and 2010. In 2011 and 2012 punctuality in Europe improved again reaching a similar level as the US (83%) in 2012.

Figure IV provides an analysis of how the duration of the individual flight phases (departure, taxi-out, airborne, taxi-in, total) have evolved over the years compared to the long term average.

The analysis compares actual times for each city pair with the long-term average for that city pair over the full period.

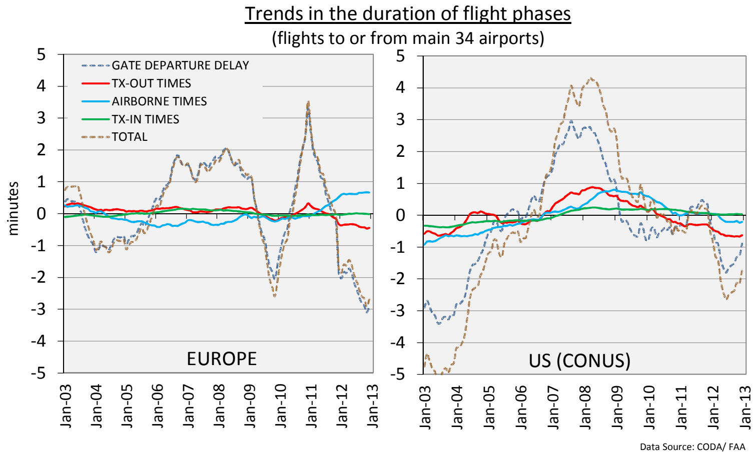


FIGURE IV: TRENDS IN THE DURATION OF FLIGHT PHASES

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

In the US, performance appears to be largely driven by the capacity variation that occurs at key airports where demand is near capacity. Capacity is measured by the tactical capacities that are used for traffic flow management with variation measured as the per cent difference between the most favourable and least favourable rates. For 2012, San Francisco (SFO) and Newark (EWR) were rated as the most impacted airports when capacity variation is weighted by demand. Historically, the New York Area airports have been rated as most impacted due to the effect of a demand/capacity imbalance. As of 2008, all three New York Area airports (JFK, LGA and EWR) are subject to schedule limitations.

In the US, the trailing 12-month average began to decline at the beginning of 2008 which coincided with several FAA initiatives to improve performance in the New York area including schedule limitations at all three airports. Similar to Europe, gate departure delay was the largest component associated with the change in average flight time. Between 2008 and 2010, most flight components went back to their long-term average and improved even further between 2010 and 2012. A substantial improvement is also visible for taxi-out times as a result of the initiatives to improve performance in this area.

The operational improvements observed in recent years on both sides of the Atlantic have to be seen in the context of declining traffic levels (see Figure II).

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

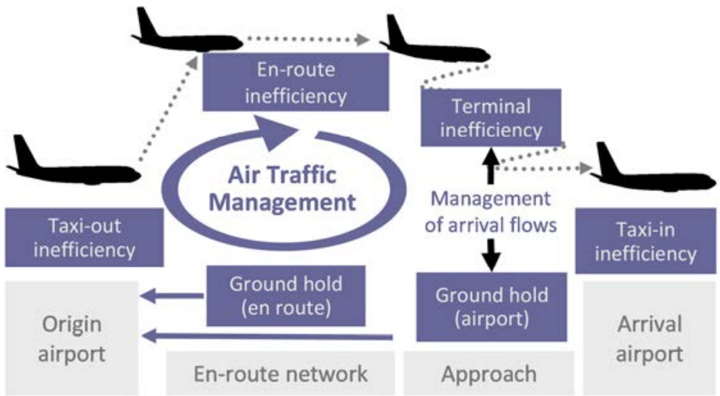


FIGURE V: CONCEPTUAL FRAMEWORK FOR MEASURING OPERATIONAL ANS-RELATED PERFORMANCE

For this reason, the evaluation of ATM-related operational service quality is broken down by phase of flight which enables a better understanding of the ATM contribution and differences in traffic management techniques between the US and Europe.

Inefficiencies have a different impact on airspace users (fuel burn, time), depending on the phase of flight (terminal area, cruise, or ground) and the level of predictability (strategic or tactical). Figure VI provides an overview of the ATM-related impact on airspace users' operations in terms of time, fuel burn and associated costs.

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

ATM-related impact on airspace users' operations			Impact on punctuality	Engine status	Impact on fuel burn/ CO_2 emissions	Impact on airspace users' costs
ATM related inefficiencies	At stand	Airport ATFM/ EDCT	High	OFF	Quasi nil	Time
		En route ATFM/ EDCT				
	Gate-to-gate	Taxi-out phase	Low/ moderate	ON	High	Time + fuel
		En route phase				
		Terminal area				

FIGURE VI: IMPACT OF ATM-RELATED INEFFICIENCIES ON AIRSPACE USERS' OPERATIONS

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

ATM-related ground holdings can be applied at departure airports when aircraft are anticipated to arrive during a period of capacity shortfall en route or at the destination airport.

Table II compares ATM-related departure restrictions imposed in the two ATM systems due to en route and airport constraints. For comparability reasons, only EDCT and ATFM delays larger than 15 minutes were included in the calculation.

TABLE II: ATM-RELATED DEPARTURE HOLDINGS AT GATE

Only delays > 15 min. are included.		EUR			US		
		2008	2010	2012	2008	2010	2012
	IFR flights (M)	5.5	5.0	4.9	9.2	8.6	8.4
En route related delays >15min. (EDCT/ATFM)	% of flights delayed >15 min.	5.0%	5.8%	1.9%	0.1%	0.1%	0.1%
	delay per flight (min.)	1.4	1.9	0.5	0.1	0.1	0.1
	delay per delayed flight (min.)	28	32	28	63	48	62
Airport related delays >15min. (EDCT/ATFM)	% of flights delayed >15 min.	2.8%	3.1%	2.0%	2.4%	1.5%	1.4%
	delay per flight (min.)	0.9	1.1	0.6	1.9	1.1	1.0
	delay per delayed flight (min.)	32	36	32	76	71	69

On average, en route related delays at the gate are much lower in the US whereas airport related ground holdings are – despite a considerable improvement between 2008 and 2012 – slightly higher in the US.

The share of flights affected by departure restrictions at origin airports also differs considerably between the US and Europe. Despite a reduction from 5% in 2008 to 1.9% in 2012, flights in Europe are still almost 20 times more likely to be held at the gate for en route constraints than in the US where the percentage remained constant at 0.1%. The significant improvement in Europe in 2012 is partly due to lower traffic levels than in 2008 but also due to an increased focus on the average en route ATFM delay indicator in the first reference period of the Single European Sky performance scheme (2012-2014).

Although slightly higher, for airport related delays the percentage of delayed flights at the gate is more comparable in both ATM systems (2.0% in Europe vs. 1.4% in US in 2012).

At the same time, both the airport and en route related ground holding per delayed flight in the US are more than twice as high as in Europe. The reason for this is that in the US, ground delays due to en route constraints are rarely required and airport related ground delays are only applied after Time Based Metering or Miles In Trail (MIT) restrictions are used which consequently leads to a lower share of flights affected by EDCT delays but higher delays per delayed flight than in Europe.

In the US, the airport related EDCT delay is largely attributed to 5 airports with a comparatively high average delay per arrival: Newark (EWR), San Francisco (SFO), Philadelphia (PHL), New York (LGA), and Chicago (ORD). Traffic to these airports is also highly susceptible to the impact of variations in airport capacity.

In Europe, (ATFM) ground delays are used much more frequently for balancing demand with en route and airport capacity, which consequently leads to a higher share of traffic affected but with a lower average delay per delayed flight.

The **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 departure and MIT restrictions, aircraft type, and remote de-icing, to name a few. Of these aforementioned causal factors, the take-off queue size is considered to be the most important one for taxi-out inefficiencies.

The analysis of taxi-out efficiency refers to the period between the time when the aircraft leaves the stand and the take-off time. The additional time shown in Figure VII is measured as the average additional time beyond an "unimpeded" reference time.

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

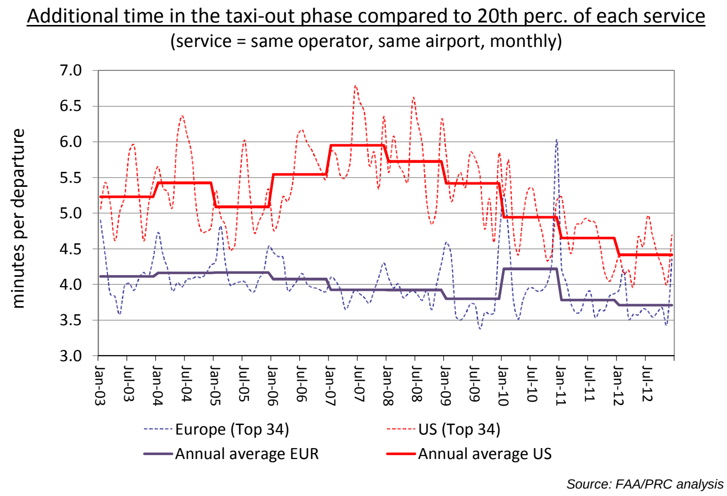


FIGURE VII: EVOLUTION OF ADDITIONAL TAXI-OUT TIME

In Europe, the additional time might also include a small share of ATFM delay which is not taken at the departure gate, or some delays imposed by local restriction, such as Minimum Departure Interval (MDI).

In 2008, average taxi-out additional time per departure was much higher in the US (6.5 min.) than in Europe (4.6 min.). The differences between the US and Europe at that time were largely driven by different flow control policies and the absence of scheduling caps at most US airports.

Due to a number of initiatives aimed at improving taxi-out efficiency (mainly at the New York airports), average additional taxi-out time decreased by more than one minute in the US between 2008 and 2012 with a positive effect on fuel burn and the environment. In Europe, taxi-out performance also improved but not at the same scale as in the US.

In Europe Airport Collaborative Decision Making (A-CDM) initiatives try to optimise the departure queue by managing the pushback times. The aim is to keep aircraft at the stand to keep additional time and fuel burn in the taxi-out phase to a minimum and to maintain sufficient queuing time at the threshold to maximise runway throughput. However the impact on total time is limited as delay is moved from taxi-out to the gate.

En route flight efficiency has a horizontal (distance) and a vertical (altitude) component. Within the scope of the report, only the horizontal component was analysed. Although the horizontal component is generally of higher economic and environmental importance, it is acknowledged that the inclusion of the vertical component would provide a more complete picture.

The planned improvement of surveillance data in the European Flow Management System (envisaged radar update rate of 30 seconds) could help with the development of a commonly agreed indicator for the assessment of vertical flight efficiency in the future.

In 2012, compared to previous editions, the methodology has been improved and more accurate data became available in Europe which limits the possibility to compare the horizontal en route flight efficiency results to the results in previous editions of this report.

As shown in Figure VIII, the level of total horizontal en route flight inefficiency for flights to or from the main 34 airports in Europe in 2012 was 2.98% compared to 2.73% in the US.

An "inefficiency of 5% for a flight of 1000NM means for instance that the extra distance was 50NM (Alternatively, this could be expressed as a flight "efficiency" of 95%).

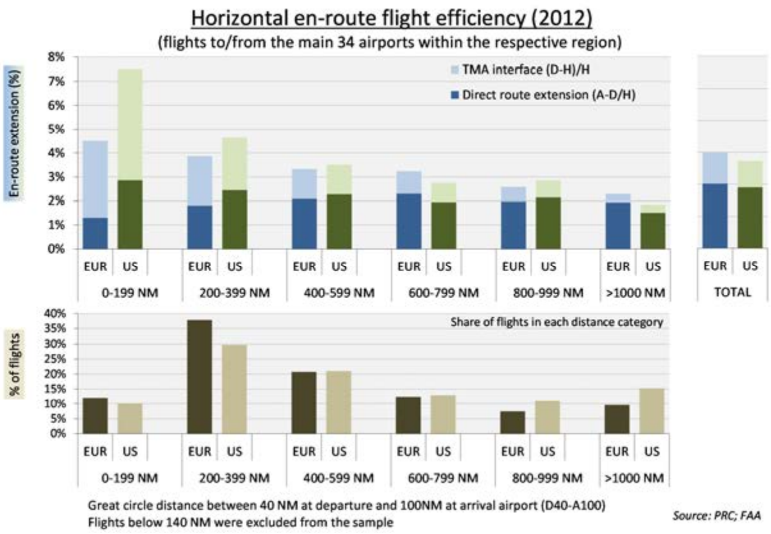


FIGURE VIII: HORIZONTAL EN ROUTE FLIGHT INEFFICIENCY

Overall, horizontal en route flight inefficiency on flights to or from the main 34 airports in Europe is 0.25% higher than in the US in 2012 with corresponding fuel burn benefits in the US. En route flight efficiency is further broken down into terminal effects and en route extension.

Direct en route extension is predominantly driven by (1) route network design (2) route availability, (3) route utilisation (route selection by airspace users) and (4) ATC measures such as MIT and reroutes in the US (but also more direct routings).

Due to inherent safety and capacity limitations, a certain level of "inefficiency" is inevitable. However there is scope for further improvement in both ATM systems.

Different from the US where the Federal Aviation Administration (FAA) is responsible for airspace management and route design, in the amalgamated European ATM system airspace design remains the prerogative of the individual States and the development of a European Route Network Improvement Plan relies on a cooperative decision making process between involved stakeholders.

In Europe, the fragmentation of airspace appears to be an issue which affects overall flight efficiency and which also 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 however expected to help improve this.

Further work is needed to better understand the impact of fragmentation and the number, location, and coordination of restricted and segregated areas on ATM performance in general and on horizontal en route flight efficiency and capacity in particular.

The **average additional time within the last 100 NM** is measured as the average additional time beyond an unimpeded reference time. Actual transit times within the 100 NM radius are affected by a number of ATM and non-ATM-related parameters including, inter alia, flow management measures (holdings, etc.), airspace design, airports configuration, aircraft type, environmental restrictions, and in Europe, to some extent the objectives agreed by the airport scheduling committee when declaring the airport capacity.

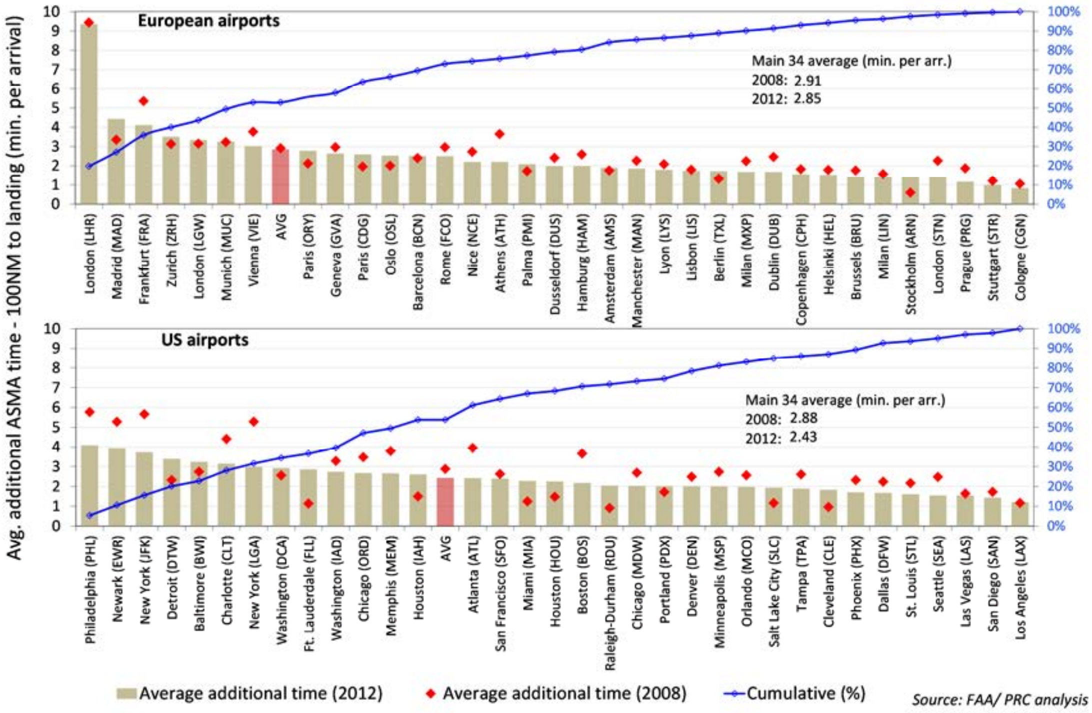


FIGURE IX: AVERAGE ADDITIONAL TIME WITHIN THE LAST 100NM

At system level, the additional time within the last 100 NM was similar in 2008 but is lower in the US in 2012. 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 Madrid (MAD) and Frankfurt (FRA) which shows less than half the level observed at London Heathrow. Although consistent with decisions taken during the airport capacity declaration process regarding average holding in stack, it is remarkable that London (LHR) alone accounted for 20% of all the additional time observed at the main 34 airports in 2012.

The US shows a less contrasted picture with many airports improving between 2008 and 2012. Similar to taxi-out performance, there is still a notable difference for the airports in the greater New York area, which show the highest level of additional time within the last 100 NM.

ESTIMATED "BENEFIT POOL" ACTIONABLE BY ATM

By combining the analyses for individual phases of flight, an estimate of the "improvement pool" actionable by ANS can be derived. It is important to stress that the results represent a theoretical optimum which is – due to inherent safety and capacity limitations - not achievable at system level.

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

While ATM is often not the root cause for imbalances between capacity and demand, the aim should be to optimise how the additional time is distributed while maximising the use of capacity. The predictability of the different flight phases and fuel costs will help determine how much and where delay needs to be absorbed.

As the two ATM systems differ in terms of average flight lengths and aircraft mix, for comparability reasons, the estimated benefit pool actionable by ATM for each system in Table III below was determined by assuming that a "standard" aircraft performs a flight of 450NM in the US and the European ATM system.

TABLE III: ESTIMATED "BENEFIT POOL" ACTIONABLE BY ATM

Estimated benefit pool actionable by ATM for a typical flight (flights to or from the main 34 airports)		**Estimated average additional time (min.)**						**Fuel burn**	**Estimated excess fuel burn (kg)**[1]			
		EUR			US			engines	EUR		US	
		2008	**2012**		**2008**	**2012**			**2008**	**2012**	**2008**	**2012**
Holding at gate per departure (only delays >15min. included)	en route-related (% of flights)	1.4 (5.0%)	0.5 (1.9%)	↓	0.07 (0.1%)	0.08 (0.1%)	↗	OFF	≈0	≈0	≈0	≈0
	airport-related (% of flights)	0.9 (2.8%)	0.6 (2.0%)	↓	1.9 (2.4%)	1.0 (1.4%)	↓	OFF	≈0	≈0	≈0	≈0
Taxi-out phase (min. per departure)		4.6	4.3	↓	6.5	4.9	↓	ON	68	64	98	73
Horizontal en route flight efficiency		2.4[2]	1.9	↓	1.9	1.7	↓	ON	108	86	87	79
Terminal areas (min. per arrival)		2.91	2.85	↓	2.88	2.43	↓	ON	119	117	118	100
Total estimated benefit pool		12.1	10.1	↓	13.3	10.1	↓		296	266	303	252

The analysis of ATM-related service quality by phase of flight shows a similar "benefit pool" and associated fuel burn in the US and Europe but with differences in the distribution by phase of flight which correspond with the observed differences in flow management strategies.

Although in a context of declining traffic, system wide ATM performance improved considerably in the US and in Europe over the past five years. The resulting savings in terms of

1 Fuel burn calculations are based on averages representing a "standard" aircraft in the system.
2 The EUR 2008 figure is based on an estimate as the radar data was not yet available at system level in 2008.

time and fuel in both ATM systems had a positive effect for airspace users and the environment.

The improvement in Europe over the past five years was mainly driven by a reduction of en route ATFM (gate) delay and improvements in horizontal flight efficiency.

For the US, a remarkable improvement of taxi-out efficiency and a substantial reduction of airport related EDCT (gate) delays can be observed between 2008 and 2012. The notable reduction in the gate to gate phase (mainly taxi-out efficiency) not only reduced the additional time but also additional fuel burn. Overall, ATM performance in the US improved at a higher rate than in Europe over the past five years making the two ATM systems comparable in terms of total estimated average additional time in 2012.

Although the US saw an overall improvement in operational performance, this can be expected given the favourable conditions that have occurred from 2008-2012. Ceiling and visibility weather indicators point to less impact from weather and this is largely reflected in the higher capacity rates observed. Overall demand is also down putting less stress on the system than in 2008. It is therefore not clear if the improved performance levels will be sustained if traffic begins to increase or if weather degrades.

While technologies, concepts, and procedures have helped to further optimise safety, add some capacity, and increase efficiency over the past years, it will remain challenging to maintain the same level of efficiency while absorbing projected demand increases over the next 20 years

Conclusions

Overall, the differences in ATM related operational service quality between the two systems appear to originate from a number of different reasons, including, inter alia, regulatory and operational differences, 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 ATM-related service quality would also need to address safety, capacity, and other relevant performance affecting factors. A better understanding of trade-offs, such as maximizing capacity and throughput against maximising predictability, would be needed to identify best practices and policies.

1 INTRODUCTION

1.1 Background and objectives

The EUROCONTROL Performance Review Commission (PRC) and the US Air Traffic Organization[3] (FAA-ATO) have produced a series of joint performance studies using commonly agreed metrics and definitions to compare, understand, and improve air traffic management (ATM) performance.

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

In 2003, a comparison of economic performance (productivity and cost effectiveness) in selected US and European en route centers [Ref. 1] was carried out to measure economic performance in a homogenous way and to identify systemic differences which would explain the significant higher level of unit costs observed in Europe. The methodology applied for the economic comparison at that time has been adopted by the International Civil Aviation Organization (ICAO) in the ICAO Manual on Air Navigation Economics [Ref. 2]. In 2013, FAA and EUROCONTROL collaborated on an assessment of cost-effectiveness indicators [Ref. 3] that examined cost trends using the EUROCONTROL ATM cost-effectiveness (ACE) [Ref. 4] and CANSO[4] reporting definitions [Ref. 5].

In 2009, the PRC and the FAA-ATO produced a joint report on operational performance of air traffic management (ATM) using data from the top 34 airports in each region. In order to understand the impact of ATM and differences in ATM techniques and to estimate the amount of inefficiency that can be addressed by improvement in the ATM system, the analysis was broken down by phase of flight. This approach also supports better measurement of fuel efficiency. The first report, comparing operational performance in 2008, was published in 2009 [Ref. 6] and an updated edition comparing performance in 2010 was released in 2012 [Ref. 7].

In developing the joint reports, EUROCONTROL and the FAA identified common databases and common indicators that could be used to evaluate and compare ATM-related performance. The indicators are based on PRC and FAA-ATO best practices with a focus on comparability of measures that identify areas where performance differs between Europe and the US and to encourage and stimulate more detailed research for the overall benefit of both ATM systems.

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

---

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

4 The Civil Air Navigation Services Organization.

The work from the joint US/ Europe comparison reports has now also been introduced to ICAO at the Air Navigation Conference (AN-Conf/12) in November 2012. FAA and EUROCONTROL are prepared to support ICAO efforts to update its guidance on performance measures using the demonstrated implementation of common measures utilised in these benchmarking studies.

This report builds on the well-established and commonly accepted elements of the previous studies in order to provide a high-level comparison of operational ATM performance between the US and Europe.

Where possible, performance measures were improved in order to consider new data flows and input received over the last two years. The framework applied in this report will continue to be refined as more advanced methodologies are being developed and initiatives are underway to better consider external factors that could influence ATM performance (i.e. differences in weather conditions, airline schedules, aerodrome capacity etc.).

1.2 Study scope

Comparisons and benchmarking require common definitions and understanding. Hence the work in this report draws from commonly accepted elements of previous work from ICAO, the FAA, EUROCONTROL and CANSO. The key performance indicators (KPIs) used in this report are developed using procedures on best available data from both the FAA-ATO and the PRC.

PERFORMANCE AREAS

In its Manual on Global Performance of the Air Navigation System [Ref. 9], ICAO identified eleven Key Performance Areas (KPAs) of interest in understanding overall ATM system performance: Access and Equity, Capacity, Cost Effectiveness, Efficiency, Environmental sustainability, Flexibility, Global Interoperability, Predictability, Participation, Safety, and Security.

The analysis described in this report does not address all eleven ICAO performance KPAs. While the primacy of Safety is fully recognised, the scope of this report is limited to the operational efficiency of ATM performance. Hence, the ICAO KPAs mainly addressed in this report are Efficiency, Predictability and indirectly Environmental Sustainability when evaluating the additional fuel burn.

A number of performance indicators in this report are also used for target setting or monitoring purposes within the Single European Sky (SES) performance scheme (see grey box). In the first reference period (RP1) from 2012-2014, EU-wide targets were set on cost-efficiency, en route delay per flight, and horizontal flight efficiency.

Single European Sky Performance Scheme

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

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

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

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

The first reference period (RP1) runs for three years from 2012 to 2014. The 2nd reference period (RP2) will be from 2015-2019.

The relationship between variations in capacity and ATM efficiency performance – especially related to weather conditions at airports - is only partially addressed in this report. Nevertheless, knowledge and appreciation of this relationship and interdependency are important for the reader to understand and to interpret the underlying causes behind ATM inefficiency.

While distinct, the KPAs are not independent. For example, improvements to capacity through new runways will also lead to improvements in predictability and flight efficiency. However, other efforts that maximise the use of available capacity by maximising throughput can lead to a decrease in flight efficiency and predictability. Due to the complex and interrelated nature of the ATM system, the exact interrelations among KPAs, performance affecting factors and their magnitude in influencing the ATM system are not fully understood. The findings of the joint studies could help to further understand those interdependencies.

It is acknowledged, that for a comprehensive comparison of ATM service performance, Safety performance would need to be considered.

GEOGRAPHICAL SCOPE

Unless stated otherwise, for the purpose of this report, "Europe" is defined as Air Navigation Services (ANS) provided by the EUROCONTROL States[5] and Estonia, excluding Oceanic areas and the Canary Islands.

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

Figure 1.1 shows the geographical scope with the US CONUS sub-divided into 20 Air Route Traffic Control Centers (ARTCCs) and the European area subdivided into 63 en route centres[6].

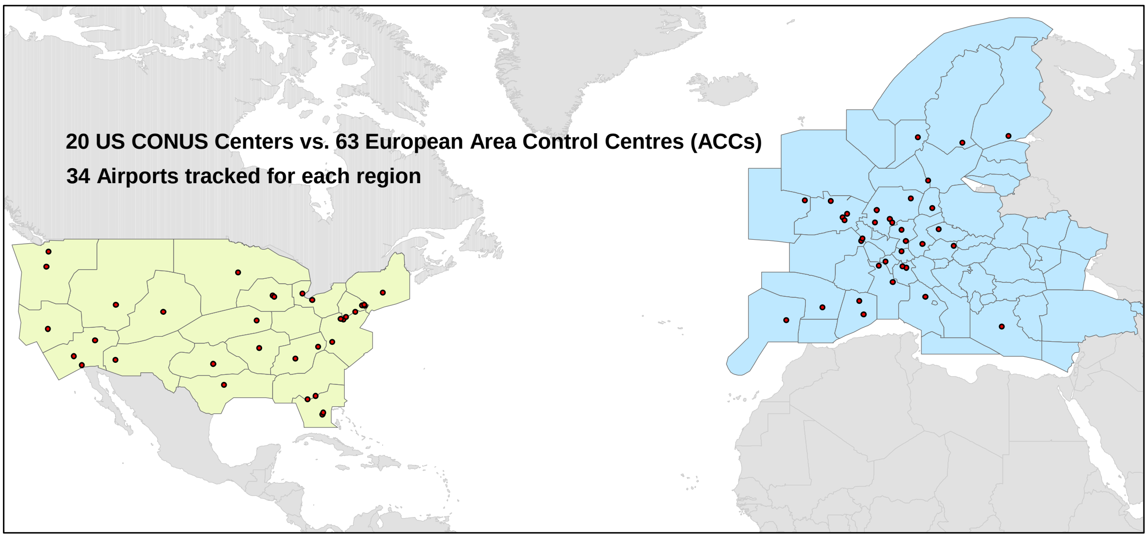


Figure 1.1: Geographical scope of the comparison in the report

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

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

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

As shown in Table 1-1, the total surface of continental airspace analysed in the report is similar for Europe and the US. However, the US controls approximately 59% more flights operating under Instrumental Flight Rules (IFR) [7] with less Air Traffic Controllers (ATCOs)[8] and fewer en route and terminal facilities.

Table 1-1: US/Europe ATM key system figures at a glance (2012)

Calendar Year 2012	Europe[9]	USA[10]	US vs. Europe
Geographic Area (million km^2)	11.5	10.4	≈ -10%
Nr. of civil en route Air Navigation Service Providers	37	1	
Number of Air Traffic Controllers (ATCOs in Ops.)	≈17 200	≈13 300[11]	≈ -23%
Total staff	≈58 000	≈35 500	≈ -39%
Controlled flights (IFR) (million)	9.5	15.2	≈ +59%
Flight hours controlled (million)	14.2	22.4	≈ +59%
Relative density (flight hours per km^2)	1.2	2.2	≈ x1.8
Share of flights to or from top 34 airports	67%	66%	
Share of General Aviation	3.9%	21%	
Average length of flight (within respective airspace)	559 NM	511 NM	≈ -11%
Number of en route centres	63	20	-42
Number of APP units (Europe) and terminal facilities (US)	260	162	-98
Number of airports with ATC services	≈ 433	≈ 514[12]	+81
Of which are slot controlled	> 90	4 [13]	
ATM/CNS provision costs (in billion €2011)	8.4	7.8	-12%
Source	EUROCONTROL	FAA/ATO	

The method of reporting controller counts has changed over the assessment period as both groups learn more about the different classifications and how best to make the comparison.

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

8 The ATCO figures in this report only refer to civil ATCOs – military ATCOs with a civil license were not considered in the report.

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

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

11 This value reflects the CANSO reporting definition of a fully trained ATCO. It is lower than the total controller headcount from the FAA controller workforce plan which also includes developmental controllers. The number of ATCOs in OPS does not include 1375 controllers reported for contract towers.

12 Total of 514 facilities of which 263 are FAA staffed and 251 contract towers.

13 LGA, JFK, EWR, and DCA.

One key point in making this comparison is to use the ATCOs in operation definition employed by the ACE and CANSO benchmarking reports. Under this definition, full time equivalent (FTE) ATCOs are defined as participating in an activity that is either directly related to the control of traffic or is a necessary requirement for ATCOs to be able to control traffic. Such activities include manning a position, refresher training and supervising on the job trainee controllers, but do not include participating in special projects, teaching at a training academy, or providing instruction in a simulator. This count does not include controllers designated as in "on-the-job training" in Europe or as a "developmental" at the FAA. Using this definition, full time ATCO's grew for both Europe and the US from 2008-2012 and the US tends to operate with some 23 percent less full time ATCOs than Europe for both 2008 and 2012.

This percentage narrows to 10% less controllers when FAA developmental controllers are considered. According to the FAA controller workforce plan, a "developmental" controls live traffic with an ability to staff a limited subset of the positions at a facility. FAA Controller Workforce Staffing levels make adjustments based on planned retirements and training requirements for developmentals which can range from 2-3 years. More work is needed to compare European "on-the-job training" controllers with FAA developmentals in order to draw firmer conclusions on the staffing comparisons in both systems.

For the ATM system, Europe continues to operate with more physical facilities than the US. The European study region comprises 37 ANSPs (and a similar number of different regulators) and 63 Area Control Centres (ACC). In contrast, the US has one ANSP and 20 Air Route Traffic Control Centres (ARTCC). The US has 162 Terminal Radar Approach Control Facilities (TRACONs) and Combined Facilities servicing a number of airports each, compared to Europe's 260 Approach control units (APPs). Some TRACONs in the US are so large in terms of size of airspace and service provided that they could be compared to some of the lower airspace ACCs in Europe.

The fragmentation and differences in regulatory environment in Europe potentially affect ATM performance in certain areas.

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

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

In order to ensure the comparability of operational ATM performance, the analysis scope of this report was influenced by the need to identify a common set of data sources with a sufficient level of detail and coverage. Therefore - unless stated otherwise - the detailed analyses of ATM-related operational performance by phase of flight in Chapter 3 are limited to flights to or from the main 34 airports for commercial (IFR) traffic in both the US and in Europe. A detailed list of the airports included in this report can be found in Annex I.

TEMPORAL SCOPE

The operational analyses in this report were carried out for the calendar year 2012 and, where applicable, comparisons to previous years were made to track changes over time.

1.3 Data sources

The report examines several operational key performance indicators derived from comparable databases for both EUROCONTROL and the Federal Aviation Administration (FAA). There are many different data sources for the analysis of ATM performance. For consistency reasons, most of the data in this study were drawn from a combination of centralised third party interfaces (airline, airport operator) and ATM operational systems.

Data from air traffic management systems

Both US and Europe obtain key data from their respective air traffic flow management (ATFM) 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 European Network Manager. This source provides the total IFR traffic picture and is used to determine the "main" airports in terms of IFR traffic and the flight hour counts used to determine traffic density.

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

The data set also provides flight trajectories which are used for the calculation of flight efficiency in terms of planned routes and actual flown routing. 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 flights, thus allowing for performance comparisons in the terminal area.

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

Data from airlines

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

In the US, most performance measures are derived from the Aviation System Performance Metrics (ASPM) database which fuses detailed airline data with data from the traffic flow system. ASPM coverage in 2012 is approximately 94% of the IFR traffic at the main 34 airports with 87% of the total IFR traffic reported as scheduled operations.

Air carriers are required to report performance data if they have at least 1% of total domestic scheduled-service passenger revenues (plus other carriers that report voluntarily). Airline reported performance data for scheduled flights at the main 34 airports represent only 66% of all main 34 IFR flights. The air carrier reported data cover non-stop scheduled-service flights between points within the United States (including territories). Data include what is referred to as OOOI (Out of the gate, On the runway, Off the runway, and Into the gate). OOOI data along with airline schedules allow for the calculation of gate delay, taxi times, en route times, and gate arrival time delay on a flight by flight basis.

The US data also included flight itineraries for the domestic operations through tail number tracking of aircraft (international legs are not reported). This allows for a 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.

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

In Europe, the Central Office for Delay Analysis (CODA) collects data from airlines each month. The data collection started in 2002 and the reporting was voluntary until the end of 2010. As of January 2011, airlines which operate more than 35 000 flights per year[14] within the European Union airspace are required to submit the data on a monthly basis according to Regulation (EU) No 691/2010 [Ref. 10].

In 2012, the CODA coverage was approximately 63% of total scheduled commercial IFR flights and approximately 76% of flights at the 34 main airports. The data reported are similar to the US and include OOOI data, schedule information and causes of delay, according to the IATA delay codes. However the European data provides greater coverage (76% vs 66%) for the 34 main airports.

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

ADDITIONAL DATA ON CONDITIONS

Post-operational analyses 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.

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

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

---

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

1.4 Organisation of this report

As outlined in Figure 1.2, the report is organised in five chapters:

- Chapter 1 contains the introduction and provides some background on report objectives, scope and data sources used for the analyses for ATM performance in this report.

- Chapter 2 provides some essential background information on the two ATM systems to set the scene for the more detailed analyses of ATM performance carried out in Chapter 3. The comparison of key traffic characteristics in Section 2.1 is followed by an evaluation of air transport service quality in the US and in Europe in Section 2.2 before the main features and flow management techniques of the two ATM systems including key differences are discussed in Section 2.3.

- Chapter 3 provides a detailed comparison of operational ATM performance in the two systems with a focus on the predictability and efficiency of actual operations by phase of flight.

- Chapter 4 concludes with a summary of findings before Chapter 5 highlights areas for further analysis and potential improvements in data and methods for ATM performance assessment.

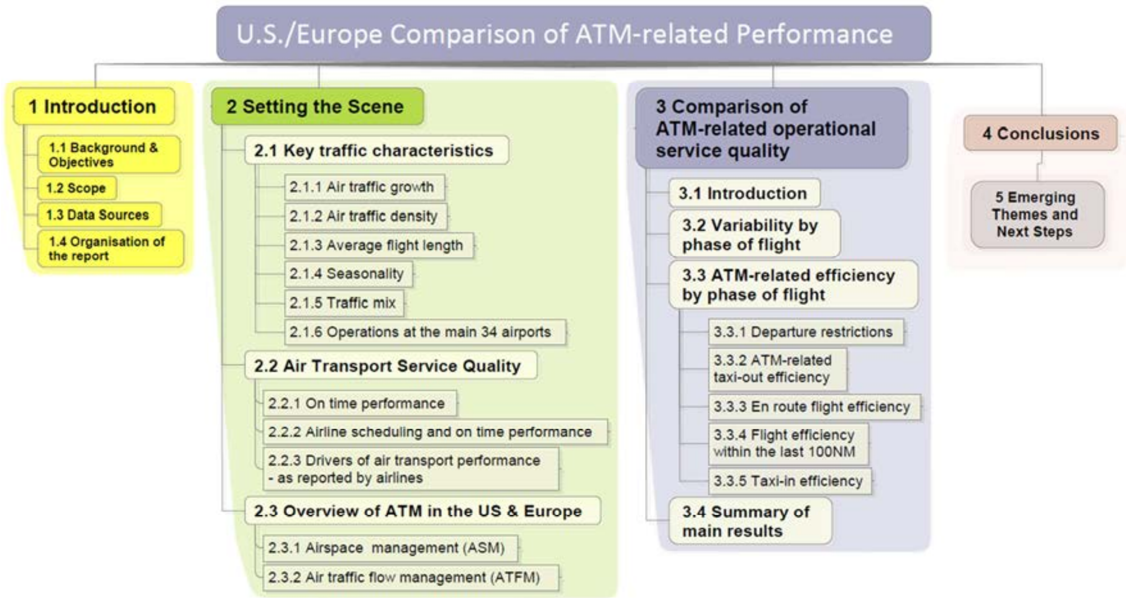


Figure 1.2: Organisation of the report

2 SETTING THE SCENE

This chapter provides some essential background information on the two ATM systems to set the scene for the more detailed analyses of ATM performance carried out in Chapter 3.

The comparison of key traffic characteristics in the first section is followed by an evaluation of air transport service quality in the US and in Europe in Section 2.2.

Section 2.3 provides an overview of the two ATM systems highlighting similarities and the main differences in the application of air traffic flow management techniques.

2.1 Key traffic characteristics in the US and in Europe

This section provides some key air traffic characteristics of the ATM system in the US and in Europe. The purpose is to provide some background information and to ensure comparability of traffic samples for the more detailed analysis in Chapter 3.

2.1.1 AIR TRAFFIC GROWTH

Figure 2.1 depicts the evolution of IFR traffic in the US and in Europe between 1999 and 2012.

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

Whereas traffic in Europe grew by almost 19% between 1999 and 2012, the traffic in the US declined by 11% during the same period.

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

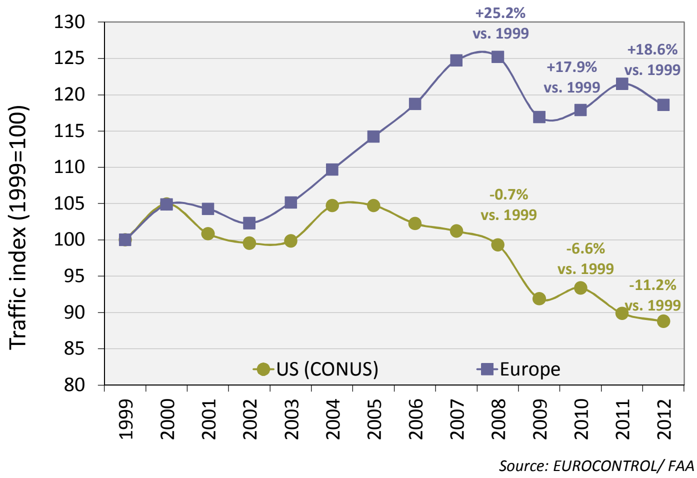


Figure 2.1: Evolution of IFR traffic in the US and in Europe

However, the system level averages mask contrasted growth rates within the US and Europe as illustrated in the map in Figure 2.2.

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

The US is a more homogenous and mature market which shows a different behaviour. Compared to 2008, traffic levels in the US declined in all centres, with a strong decline on the entire West coast. The traffic growth at the main airports in the US and Europe is shown in Figure 2.10 and Figure 2.11 on page 17 respectively.

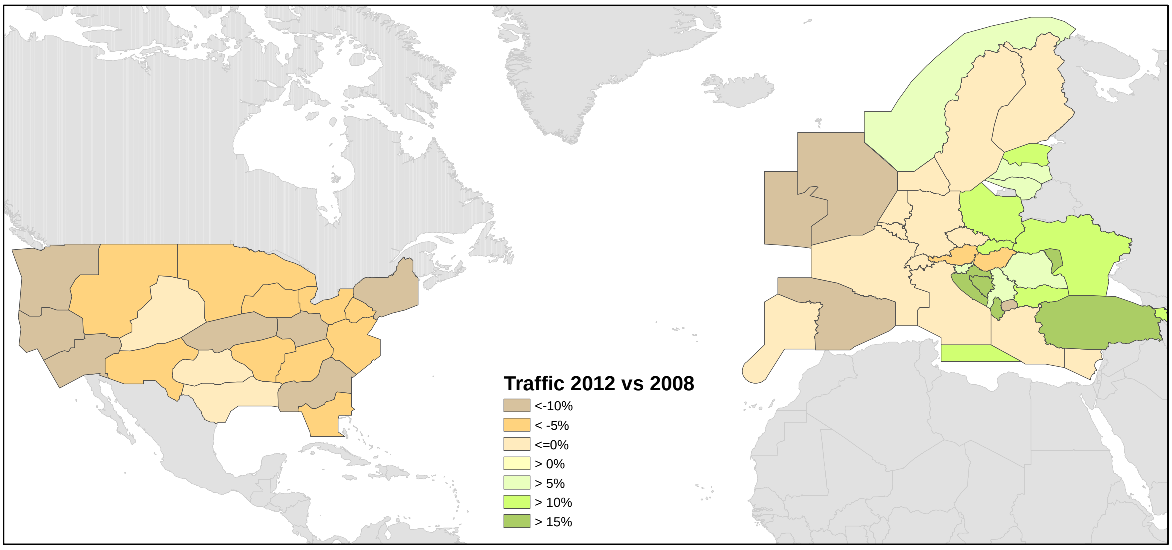


Figure 2.2: Evolution of IFR traffic in the US and in Europe (2012 vs. 2008)

2.1.2 Air traffic density

Figure 2.3 shows the traffic density in US and European en route centres measured in annual flight hours per square kilometre for all altitudes in 2012. For Europe, the map is shown at State level because the display by en route centre would hide the centres in lower airspace.

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

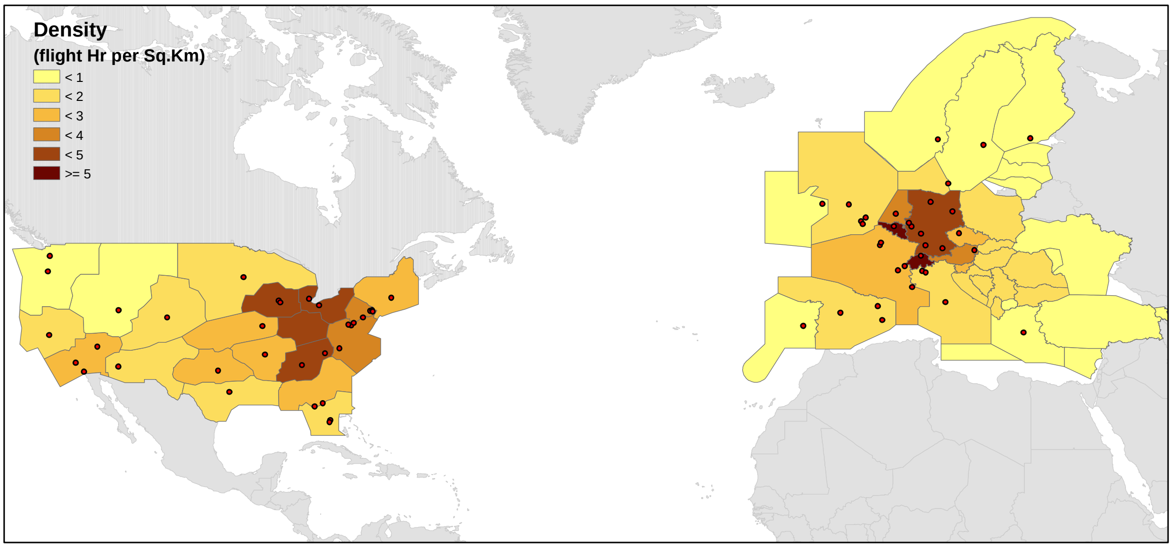


Figure 2.3: Traffic density in US and European en route centres (2012)

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

2.1.3 AVERAGE FLIGHT LENGTH

Table 2-1 provides a more detailed breakdown of IFR traffic for the US and Europe in 2012. The average great circle distances shown in Table 2-1 refer only to the distances flown within the respective airspace and not the length of the entire flight.

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

By far the largest share in both systems is due to traffic within the respective region. In the US this share is 84.8% which is notably higher than in Europe with 77.6%. Consequently the share of flights to or originating from outside the respective region is higher in Europe.

Table 2-1: Breakdown of IFR traffic (2012)

ALL IFR TRAFFIC	EUROPE (2012)			US CONUS (2012)		
	N	% of total	Avg. dist. (NM)	N	% of total	Avg. dist. (NM)
Within region	7.1 M	77.6%	467 NM	12.9 M	84.8%	511 NM
To/from outside region	1.9 M	21.0%	877 NM	2.0 M	13.3%	510 NM
Overflights	0.1 M	1.4%	875 NM	0.3 M	1.9%	500 NM
Total IFR traffic	9.2 M	100%	559 NM	15.2 M	100%	511 NM

Traffic to/from main 34 airports	EUROPE (2012)			US CONUS (2012)		
	N	% of total	Avg. dist. (NM)	N	% of total	Avg. dist. (NM)
Within region	4.9 M	79.6%	484 NM	8.4 M	84.2%	607 NM
To/from outside region	1.2 M	20.4%	956 NM	1.6 M	15.8%	539 NM
Total	6.1 M	100%	580 NM	10.0 M	100%	596 NM

When all IFR flights including overflights are taken into account, the average flight length is longer in Europe (559 NM) compared to the US (511 NM).

However, this changes when only "domestic" flights within the respective regions are considered. For example, en route efficiency measures shown later in Chapter 3 use "within region" traffic to or from the main 34 airports (lower part of Table 2-1).

For this population, the average flight length is much higher in the US (607 NM) compared to Europe (484 NM). This is due mainly to the large amount of transcontinental traffic in the US system. This gap would narrow considerably if outside region traffic were included (596 NM) US vs. (580 NM) Europe.

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

For Europe, the "Outside Region" traffic is less concentrated at coastal entry airports but more scattered with direct long haul flights to worldwide destinations from almost every capital city airport. For instance, a flight from London Heathrow (LHR) to the Middle East would traverse almost the entire European airspace before exiting the airspace. As a consequence, the average distance of those flights is considerably higher in Europe than in the US.

Another interesting aspect is the evolution of the average flight length shown for the traffic within the respective region in Figure 2.4.

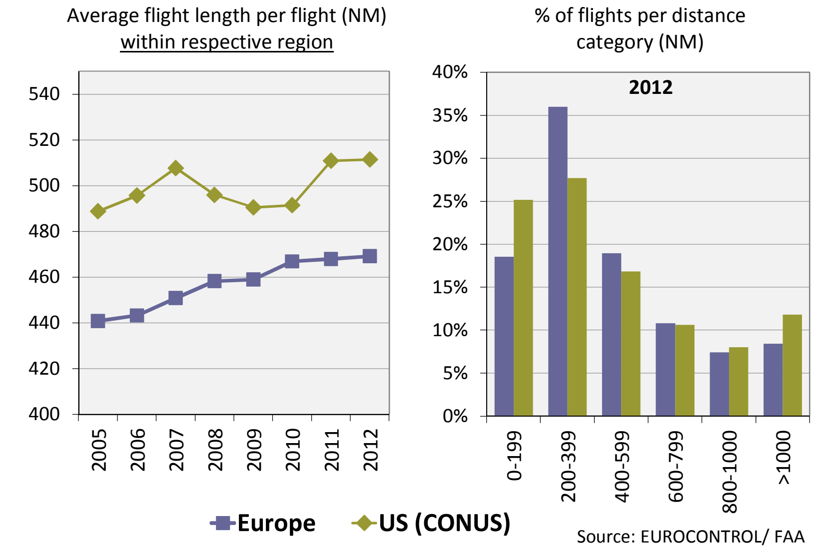


Figure 2.4: Evolution of average IFR flight lengths (within respective region)

Although average flight length in the US showed a decrease between 2007 and 2009, both systems show a notable increase in average flight length over time which is an interesting observation for the more detailed evaluation of ATM related operational service quality in Chapter 3.

2.1.4 Seasonality

Seasonality and variability of air traffic demand can be a factor affecting ATM performance. If traffic is highly variable, resources may be underutilised during off-peak times but scarce at peak times. Different types of variability require different types of management practices to ensure that ATM can operate efficiently in the face of variable demand.

Figure 2.5 compares the seasonal variability (relative difference in traffic levels with respect to the yearly averages) and the "within week" variability.

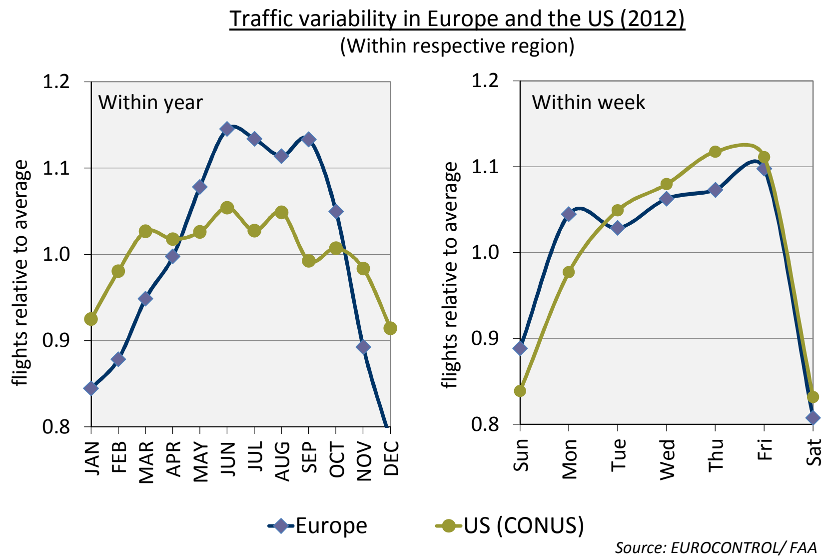


Figure 2.5: Seasonal traffic variability in the US and Europe (system level)

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

Figure 2.6 shows the seasonal traffic variability in the US and in Europe for 2012.

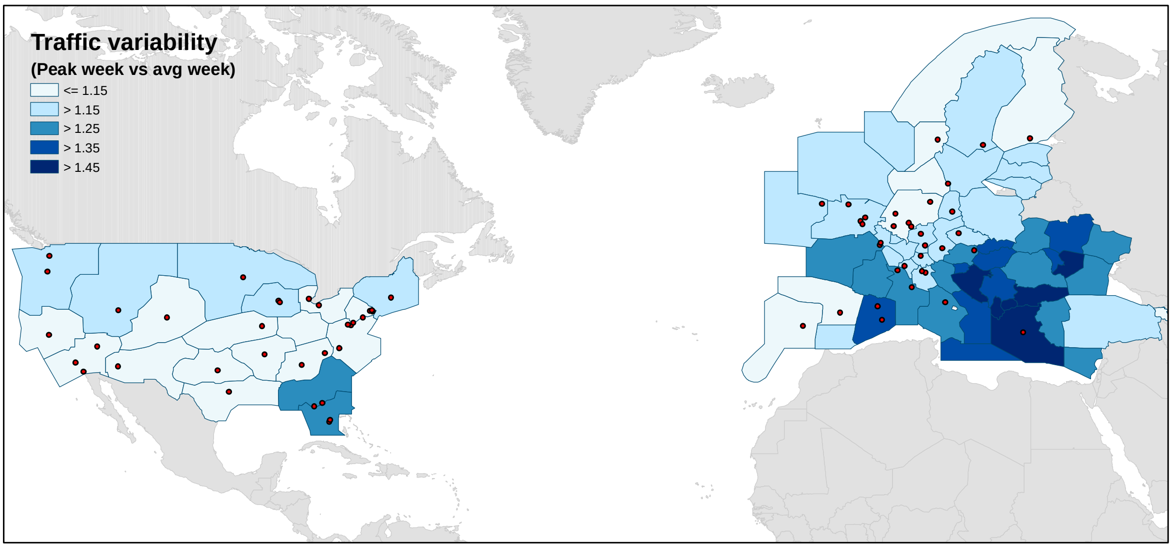


Figure 2.6: Seasonal traffic variability in US and European en route centres (2012)

In Europe, a very high level of seasonal variation is observed for the holiday destinations in South Eastern Europe where a comparatively low number of flights in winter contrasts sharply with high demand in summer.

In the US, the overall seasonality is skewed by the high summer traffic in northern en route centres (Boston and Minneapolis) offsetting the high winter traffic of southern centres (Miami and Jacksonville) (see Figure 2.6)

2.1.5 TRAFFIC MIX

A notable difference between the US and Europe is the share of general aviation which accounts for 21% and 3.9% of total traffic in 2012, respectively (see Table 1-1 on page 4). This is confirmed by the distribution of physical aircraft classes in Figure 2.7 which shows a large share of smaller aircraft in the US for all IFR traffic (left side of Figure 2.7).

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

In order to improve comparability of data sets, the more detailed analyses in Chapter 3 was limited to controlled IFR flights either originating from or arriving to the main 34 US and European airports (see Annex I). Traffic to or from the main 34 airports in 2012 represents some 67% of all IFR flights in Europe and 66% in the US.

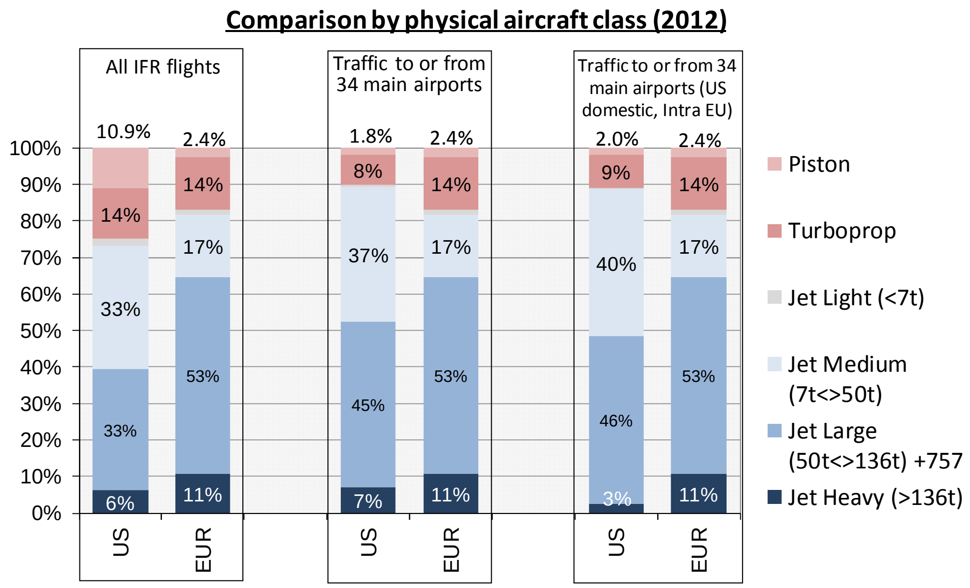
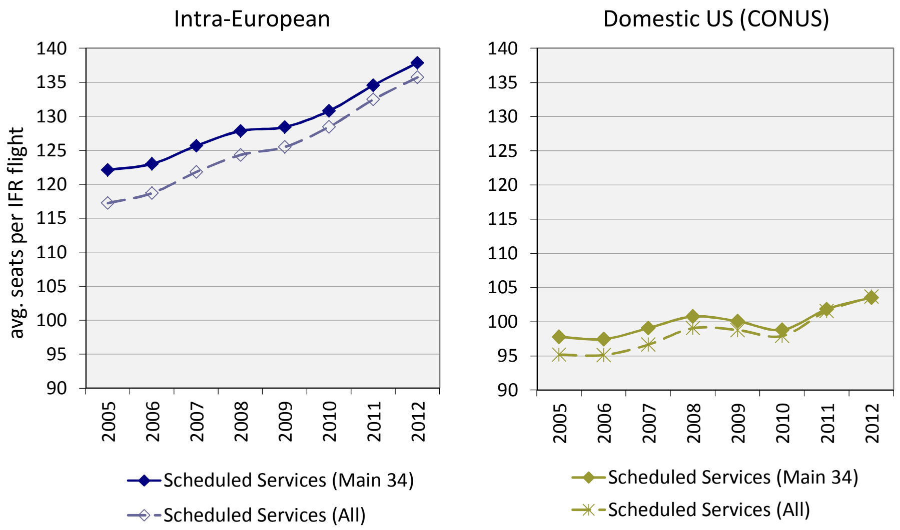


Figure 2.7: Comparison by physical aircraft class (2012)

Figure 2.8 shows the evolution of the number of average seats per scheduled flight in the US and in Europe, based on data for passenger aircraft. For 2012, the average number of seats per scheduled flight is 31% higher in Europe for traffic to or from the main 34 airports. This is consistent with the observation in Figure 2.7 showing a higher share of larger aircraft in Europe.

Whereas in Europe the average number of seats per flight increased continuously between 2005 and 2012, the number of seats per aircraft declined in the US between 2008 and 2010. However recent US trends since 2010 point to an increase in aircraft gauge. Figure 2.8 indicates the potential for US passenger growth to increase with relatively flat or modest growth in operations.



Source: FAA/ PRC analysis

Figure 2.8: Average seats per scheduled flight (2005-2012)

The different practices of airlines in the two regions are most likely tied to demand, market competition, and other factors [Ref. 11]. For example, it can be observed that for similar flight segment lengths such as Munich (MUC) to Hamburg (HAM) and San Francisco (SFO) to Los Angeles (LAX), an increasing number of European low cost carriers are utilising a high density one-class seat layout compared to a standard two-class configuration preferred by US carriers.

Also, since only a few US airports are slot restricted, this enables airlines to increase the frequency of service (with smaller aircraft) to win market share and to attract high yield business travellers. Further analysis and research will improve the understanding of the factors driving the differing trends between the US and Europe and the subsequent effect on performance.

2.1.6 OPERATIONS AT THE MAIN 34 AIRPORTS

The number of operations which can be safely accommodated at an airport not only depends on the number of runways but also to a large extent on runway layout and available configurations (many runways may not be operated independently). The choice of the configuration depends on a number of factors including weather conditions and wind direction, type of operation (arrival/ departure peak) and environmental considerations such as noise constraints. The configuration, combined with environmental restrictions, as well as apron and terminal airspace limitations affect the overall capacity of the airport.

Some of the key factors determining runway throughput are the distance between runways (dependent or independent[15]), the mode of operation (mixed[16] or segregated[17]), and geographical layout (intersecting runways, crossing taxiways).

Figure 2.9 shows the airport layouts of Boston Logan (BOS) and Chicago Midway (MDW) in the US and Amsterdam Schiphol (AMS) in Europe which all have multiple runway systems.

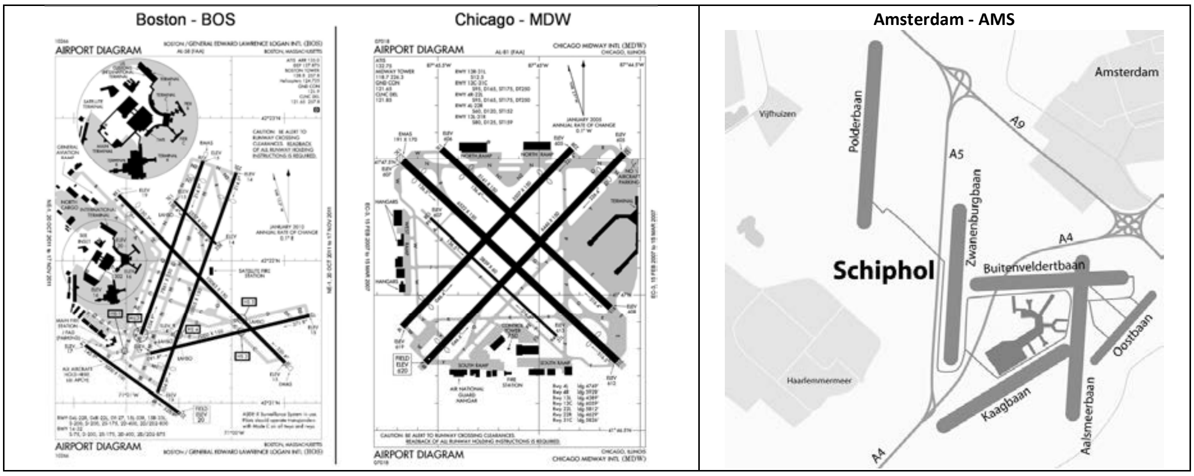


Figure 2.9: Airport layouts (BOS, MDW, AMS)

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

For this reason, the number of runways used for the

Use of runways at the airports

In previous versions of the report the number of existing physical runways was used for the computation of the indicators in Table 2-2.

Acknowledging that not all physical runways are available for use at any one time, a different

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

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

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

comparison of operations at the 34 main airports in the US and in Europe in Table 2-2 was based on statistical analysis (see grey box) rather than the physical runway count.

The passenger numbers are based on Airport Council International (ACI) data and refer to all operations whereas Figure 2.8 is limited to scheduled operations only.

methodology was used to determine the number of runways in use at each of the airports.

In a first step, the number of simultaneously active runways was determined for each 15 minute interval (a runway (e.g. 09R/27L) was considered as being active if used in any of the directions). In a second step, the upper 10th percentile of the distribution was used as the number of simultaneously active runways at the respective airport. The number of physical runways might be higher.

Table 2-2: Comparison of operations at the 34 main airports in the US and Europe

Main 34 airports	Europe 2012	Europe vs. 2008	US 2012	US vs. 2008	US vs. Europe
Avg. number of annual IFR movements per airport ('000)	233	-8.8%	382	-6.6%	+64%
Avg. number of annual passengers per airport (million)	25.1	+2.9%	32.7	+2.0%	+30%
Passengers per IFR movement	108	+12.7%	85	+9.2%	-20.7%
Average number of runways per airport	2.1	-1.4%	3.1	0.8%	+50.2%
Annual IFR movements per runway ('000)	113	-7.4%	124	-7.4%	+9.2%
Annual passengers per runway (million)	12.2	+4.3%	10.6	+1.2%	-13.4%

There were several airport development projects in the US between 2008 and 2012. These included new runways at Chicago O'Hare (ORD), Charlotte (CLT), Seattle (SEA), and Dulles (IAD). A runway extension was also completed for Philadelphia (PHL) that resulted in improved capacity for the airport. In Europe, a fourth runway went into operation at Frankfurt (FRA) airport in October 2011.

Table 2-2 confirms some of the previous findings. The average number of IFR movements (+64%) and the number of annual passengers per airport (+30%) are significantly higher in the US. Consistent with Figure 2.7 and Figure 2.8, the number of passengers per movement is much lower (-21%) in the US.

In order to provide an order of magnitude of the operations of the airports, Figure 2.10 and Figure 2.11 show the average number of daily IFR departures per airport and the number of active runways (bottom) and the changes in departures and passengers compared to 2008 (top) for the 34 main European and US airports included in this study.

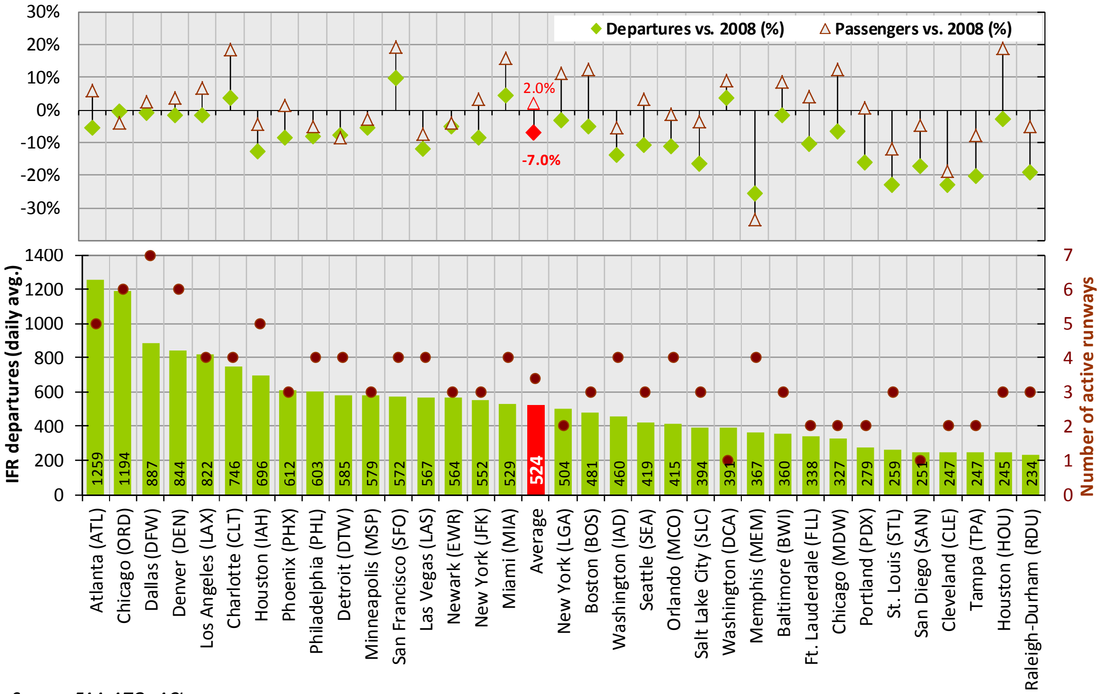
The average number of IFR departures per airport (524) is considerably higher (65%) in the US, compared to 318 average daily departures at the 34 main airports in Europe in 2012 [18].

As a result of the economic crisis which started in 2008, the average number of departures at the main 34 airports decreased in the US and in Europe with -7% and -8.8% versus 2008 respectively. It is interesting to note that during the same time, passenger numbers at the main 34 airports in

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

the US (+2.0%) and in Europe (+2.9%) increased compared to 2008. This suggests lower number of services but with, on average, larger aircraft or higher passenger load factors.

Average daily IFR departures at the main 34 US airports

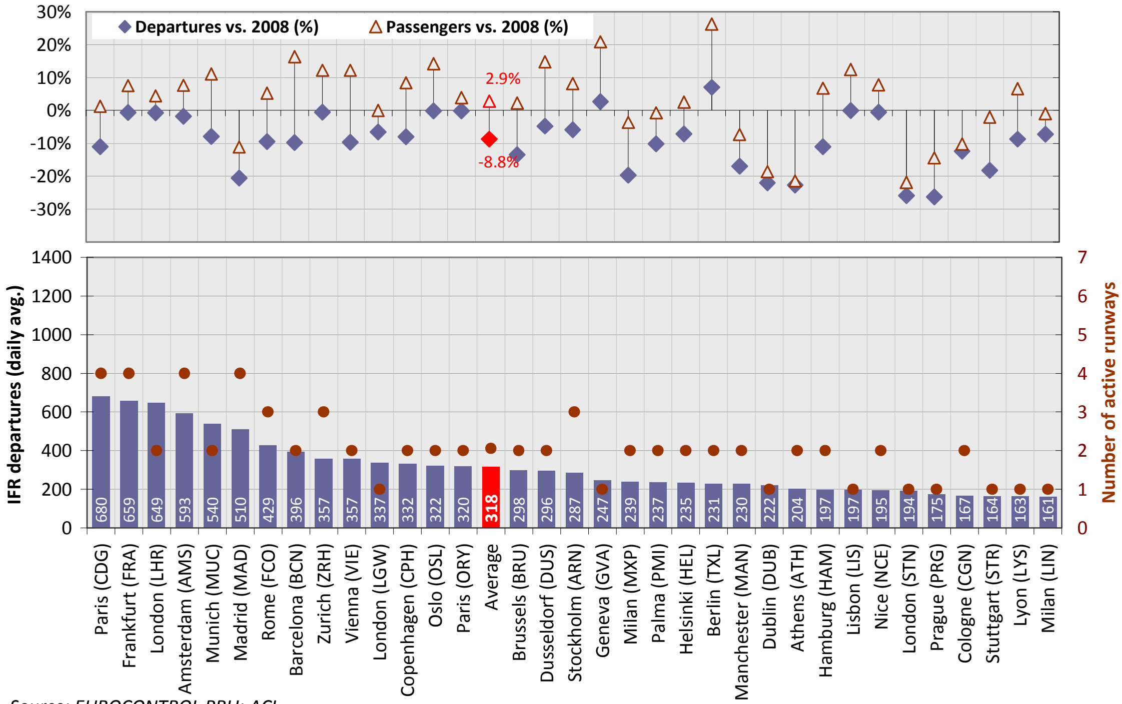


Source: FAA-ATO; ACI

Figure 2.10: Operations at the main 34 US airports (2012)

In the US (see Figure 2.10), the airports with the highest decrease in departures between 2008 and 2012 were Memphis (-25.6%), Cleveland (-23.1%), and St. Louis (-22.9%). Four of the 34 airports showed a growth in departures compared to 2008, most notably San Francisco with an increase of +9.6% versus 2008.

Average daily IFR departures at the main 34 European



Source: EUROCONTROL PRU; ACI

Figure 2.11: Operations at the main 34 European airports (2012)

In Europe (see Figure 2.11), the airports with the highest decrease in terms of departures were Prague (-26.3%), London Stansted (-25.9%), Madrid (-20.6%), Athens (-22.7%), and Dublin (-22.1%). Only two airports showed an increase compared to 2008, most notably Berlin Tegel which was mainly due to the delayed opening of the new Berlin Brandenburg airport in Germany.

The difference in IFR departures and the drop in traffic as measured by IFR departures fit well with the overall operations as reported in Table 2-2. The ATM performance measurements used throughout this report will make use of radar and operator reporting databases available to both FAA and EUROCONTROL. The IFR flights shown in Figure 2.10 and Figure 2.11 are the basis for the majority of the trends and analysis presented in this report.

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.

2.2 Air transport service quality in the US and in Europe

There are many factors contributing to the "service quality" of air transport. In fact, it can be seen as the "end product" of complex interactions between airlines, ground handlers, airport operators, and ANSPs, from the planning and scheduling phases up to the day of operation.

This section starts with a high level evaluation of the number of delayed flights compared to airline schedules, which is often used as a proxy for the service quality provided. It furthermore assesses trends in the evolution of scheduled block times. The last section aims at identifying the main delay drivers by analysing the information reported by airlines in order to get a first estimate of the ATM-related[19] contribution towards overall air transport performance.

2.2.1 ON-TIME PERFORMANCE

Figure 2.12 compares the industry-standard indicators for punctuality, i.e. arrivals or departures delayed by more than 15 minutes versus schedule. The results need to be seen together with the time buffers included in airline schedules in order to achieve a certain level of on-time performance. A more detailed discussion on how increasing block time can lead to an apparent improvement in performance is included in the next section (see Section 2.2.2).

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

Punctuality/ On-time performance

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

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

Between 2003 and 2007, on-time performance degraded in the US and in Europe. It is interesting to note that during the same time, traffic in Europe increased substantially but remained similar at system level in the US (compare Figure 2.1).

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

The observed service degradation in the US during that time was due to an increase of traffic for already congested airports (New York airports and Philadelphia) which resulted in an increase in the number of delayed flights at those airports[20].

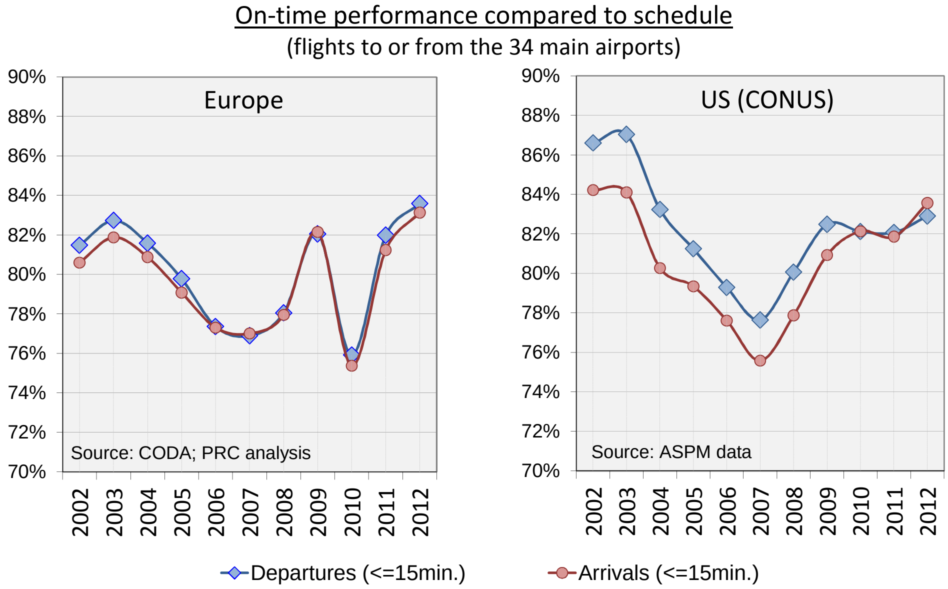


Figure 2.12: On-time performance (2002-2012)

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

In 2010, punctuality in Europe was the worst recorded since 2001, although traffic was still below 2008 levels. The main factors for this deterioration were a large number of industrial actions and higher than usual weather-related delays (snow, freezing conditions) during the winter seasons of 2009 and 2010. The volcanic ash cloud in April/May 2010 had only a limited impact on punctuality, as the majority of the flights were cancelled and are, thus, excluded from the calculation of on-time performance indicators.

Since 2010, punctuality in Europe has improved again and continued to improve in the US. In 2012, arrival punctuality in the US and in Europe is at a similar level of 83%.

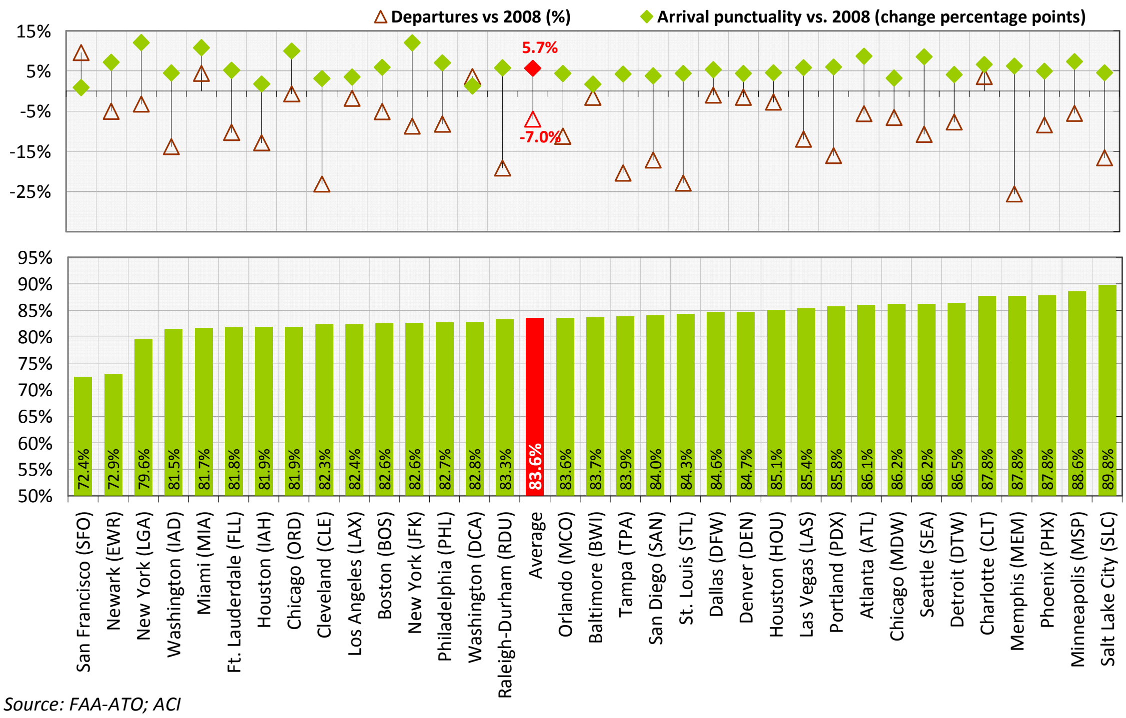
A notable difference was the gap between departure and arrival punctuality that occurred prior to 2010 in the US, and which was not observed for Europe. The reasons for this gap are not fully understood but may involve policy, differences in flow management techniques as well as other incentives to have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

While in the US, flow management strategies focus more on the gate-to-gate phase, in Europe flights are usually held at the gates with only comparatively few constraints once an aircraft has left the gate. However from 2010-2012 this gap has largely disappeared with a trend similar to Europe.

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

The system-wide on-time performance is the result of contrasted situations among airports. Figure 2.13 and Figure 2.14 show arrival punctuality in 2012 (bottom) and the punctuality and traffic changes compared to 2008 (top) for the 34 main European and US airports included in this study.

Arrival punctuality at the main 34 US airports (2012)



Source: FAA-ATO; ACI

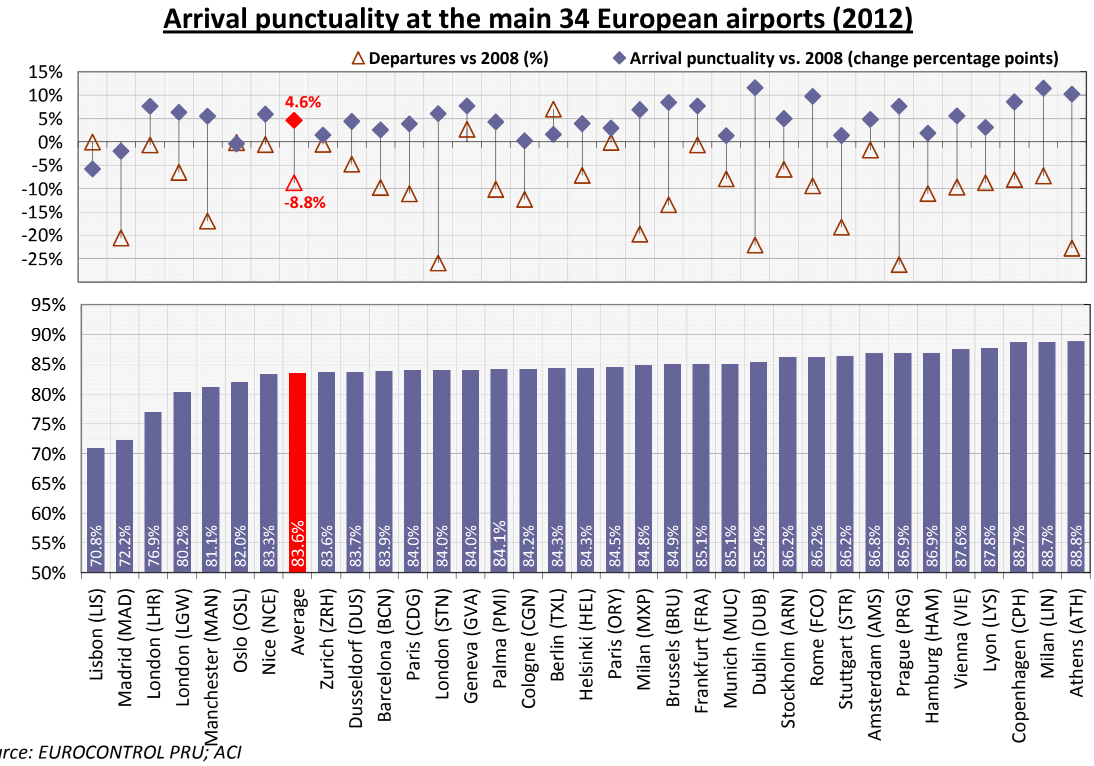
Figure 2.13: Arrival punctuality at the main 34 US airports (2012)

In the US, San Francisco (SFO) had the lowest on-time performance (arrivals) followed by the airports in the New York area. Compared to 2008, New York La-Guardia (LGA) airport shows the highest improvement (+12.1%pt.[21]), followed by New York JFK (+12%pt.), Miami (+10.8%pt.), and Chicago O'Hare (+10%pt.).

The reasons behind the improvement in on-time performance in the US are a mix of improved Air Traffic Service (ATS), infrastructure investment, policy, and airline practice. 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.

In Europe, Lisbon (LIS), Madrid (MAD) and the two London airports (LHR, LGW) had the lowest level of arrival punctuality in 2012 (bottom chart in Figure 2.14). Compared to 2008, Dublin (DUB), Milan Linate (LIN), Rome Fiumicino (FCO), and Athens (ATH) show the highest improvements.

[21] Percentage point refers to the difference between two percentages.



Source: EUROCONTROL PRU; ACI

Figure 2.14: Arrival punctuality at the main 34 European airports (2012)

As already mentioned at the beginning of this chapter, it is important to understand that on-time performance is the 'end product' of complex interactions involving many stakeholders, including ATM. Arrival punctuality is influenced by departure punctuality at the origin airport and often by delays which already occurred on previous flight legs (see also Section 2.2.3). Depending on the type of operation at airports (hub & spoke versus point to point) and airline route itinerary, local performance can have an impact on the entire network through ripple effects but also on the airport's own operation.

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

2.2.2 AIRLINE SCHEDULING AND ON-TIME PERFORMANCE

On-time performance is linked to airline scheduling. The inclusion of "time buffers" in airline schedules to account for a certain level of anticipated travel time variation on the day of operations and to provide a sufficient level of on-time performance may therefore hide changes in actual performance (see Figure 2.15 and grey box on page 22).

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

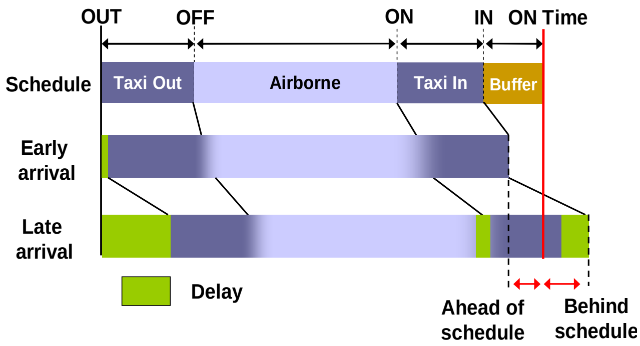


Figure 2.15: Time buffer included in airline schedules (illustration)

Airline scheduling

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

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

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

Nevertheless, it should be pointed out that efficiency improvements in actual flight time distributions do not automatically result in improved on-time performance, as the airline schedules for the new season are likely to be reduced by applying the punctuality target to the set of improved flight times (block times are cut to improve utilisation of aircraft and crews).

Figure 2.16 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[22]). Generally speaking, the scheduled block times follow the pattern of the actual block times of the previous season.

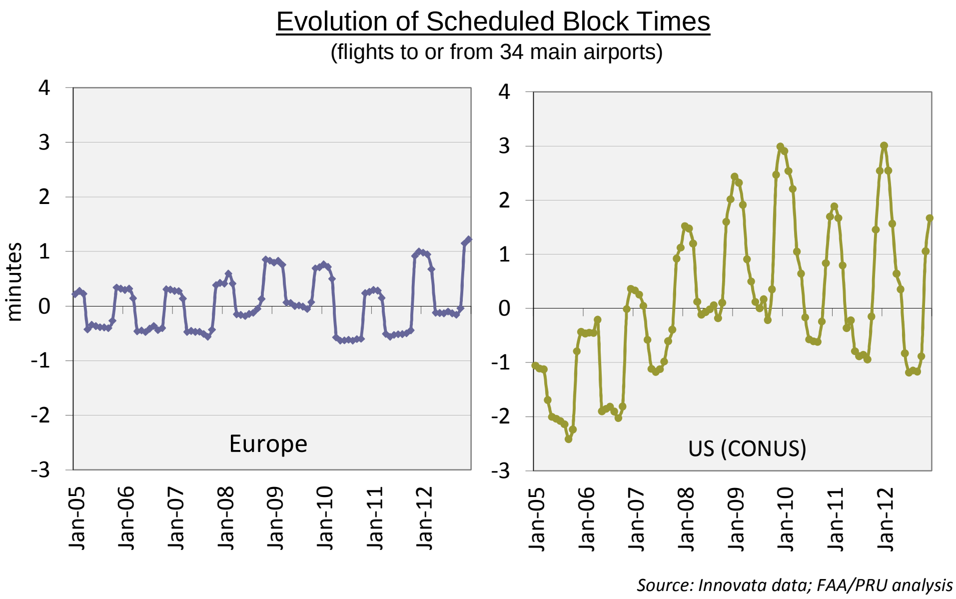


Figure 2.16: Scheduling of air transport operations (2005-2012)

[22] The Difference from Long-Term Average (DLTA) metric is designed to measure changes in time-based (e.g. flight time) performance normalised by selected criteria (origin, destination, aircraft type, etc.) for which sufficient data are available. It provides a relative change in performance without underlying performance driver.

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

In combination with Figure 2.12, it can be seen that not only did on-time performance decrease between 2004 and 2007 but scheduled airline block times also increased in the US, meaning that the real performance deterioration was to some extent masked by costly airline schedule padding. Schedule padding can cost an airline more than $50 per minute and costs airlines even when flights are early (under most airline labour agreements, pilots and crew are paid the maximum of actual or scheduled time) [Ref. 12 and Ref. 13].

These observed increases in schedule padding in the US may result from adding block time to improve on-time performance or could be tied to a tightening of turnaround times. The US had seen a redistribution of demand in already congested airports (e.g. JFK and recently SFO) which is believed to be responsible for the growth of actual and scheduled block times.

Seasonal effects are visible in Figure 2.16 with scheduled block times being on average longer in winter than in summer. US studies have shown that the majority of the increase is explained by stronger winds on average during the winter period [Ref. 14].

2.2.3 DRIVERS OF AIR TRANSPORT PERFORMANCE – AS REPORTED BY AIRLINES

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

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

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

- Airline + Local turnaround: The cause of the delay is due to circumstances within local control. This includes airlines or other parties, such as ground handlers involved in the turnaround process (e.g. maintenance or crew problems, aircraft cleaning, baggage loading, fuelling, etc.). As the focus of the paper is on ATM contribution, a more detailed breakdown of air carrier + local turnaround delays is beyond the scope of the paper.

- Extreme Weather: Significant meteorological conditions (actual or forecast) that in the judgment of the carrier, delays or prevents the operation of a flight such as icing, tornado, blizzard, or hurricane. In the US, this category is used by airlines for very rare events like hurricanes and is not useful for understanding the day to day impacts of weather. Delays due to non-extreme weather conditions are attributed to the ATM system in the US.

- Late-arriving aircraft/reactionary delay: Delays on earlier legs of the aircraft that cannot be recuperated during the turnaround phases at the airport. Due to the interconnected nature of the air transport system, long primary delays can propagate throughout the network until the end of the same operational day.

- Security: Delays caused by evacuation of a terminal or concourse, re-boarding of aircraft because of security breach, inoperative screening equipment, and/or other security related causes.

- ATM System: Delays attributable to ATM refer to a broad set of conditions, such as non-extreme weather conditions, airport operations, heavy traffic volume, ATC.

Figure 2.17 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.

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

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

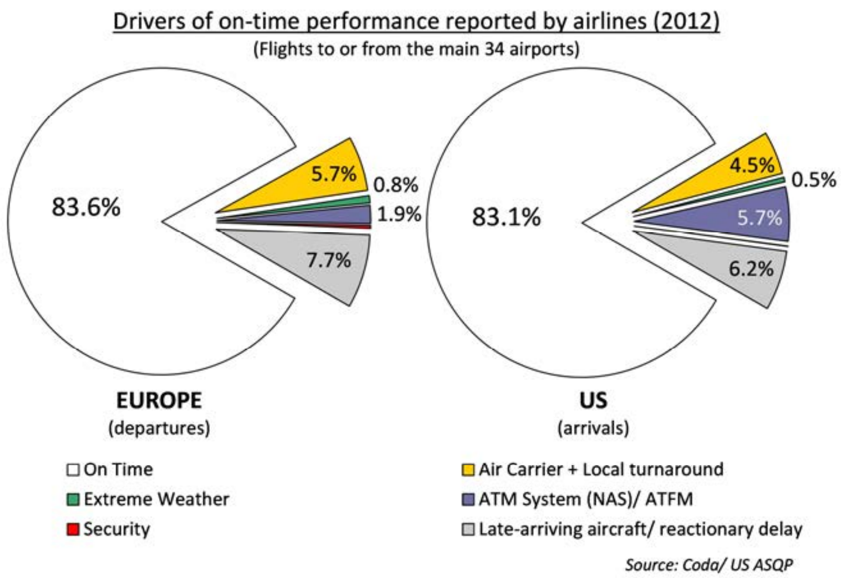


Figure 2.17: Drivers of on-time performance in Europe and the US (2012)

It should be noted that the ATM system related delays in Figure 2.17 result from not only en route and airport capacity shortfalls but also include weather effects which negatively influence ATM and aircraft operations (IMC approaches, convective weather). According to FAA analysis, by far the largest share of ATM system related delay is driven by weather in the US [Ref. 15].

Figure 2.18 and Figure 2.19 show time series analyses of the delays reported by airlines for Europe and the US. In order to ensure comparability, only the share of flights with an arrival delay (all possible delay causes) of more than 15 minutes compared to schedule were included.

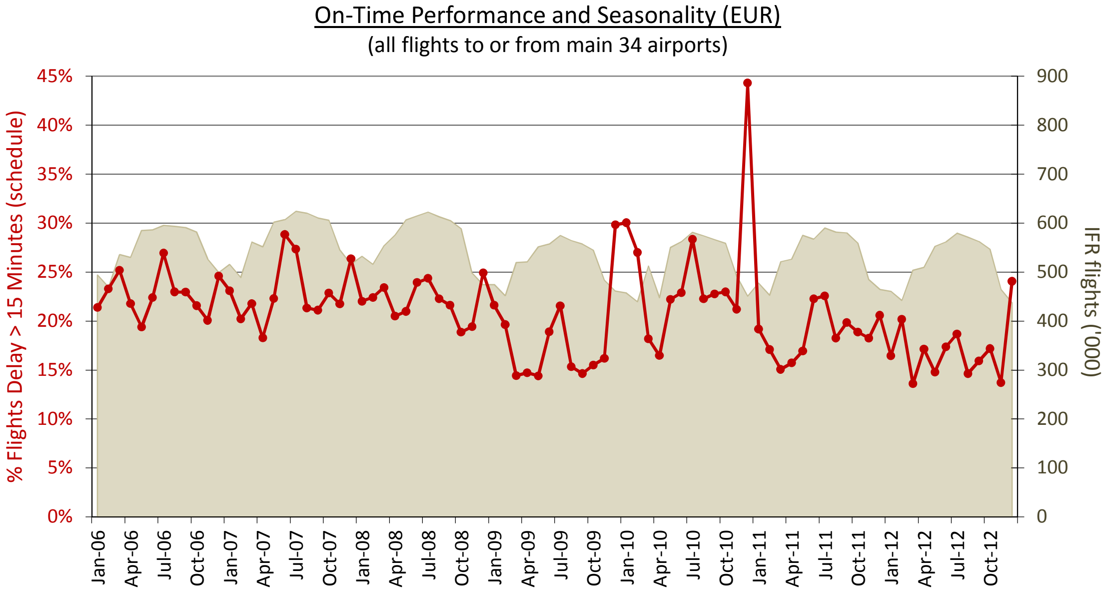


Figure 2.18: Seasonality of delays (Europe)

The red line in Figure 2.18 and Figure 2.19 shows the seasonality of delay for flights to or from the top 34 airports in Europe and the US. In Europe and the US, a clear pattern of summer and winter peaks is visible.

Whereas the winter peaks are more the result of weather-related delays at airports, the summer peaks are driven by the higher level of demand and resulting congestion but also by convective weather in the en route airspace in the US and a lack of en route capacity in Europe. The strong increase in Europe in December 2010 is due to exceptional weather conditions (ice & snow).

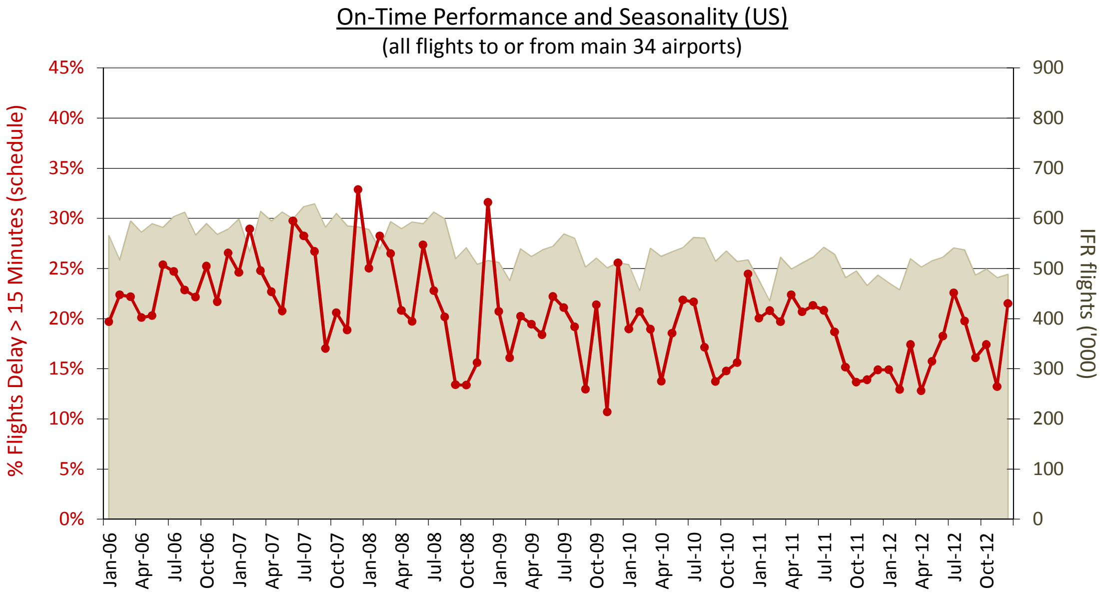


Figure 2.19: Seasonality of delays (US)

Figure 2.20 provides a first analysis of how the duration of the individual flight phases (gate departure delay[23], taxi-out, airborne, taxi-in, total) have evolved over the years in Europe and the US. The analysis is based on the DLTA Metric (see footnote 22 on page 22) and compares actual times for each city pair with the long-term average for that city pair over the full period (2003-2012). For example, in the US at the peak of the curve at the end of 2008, total average actual flight time among city pairs had increased over 8 minutes since 2004 and was 4 minutes above the long-term average.

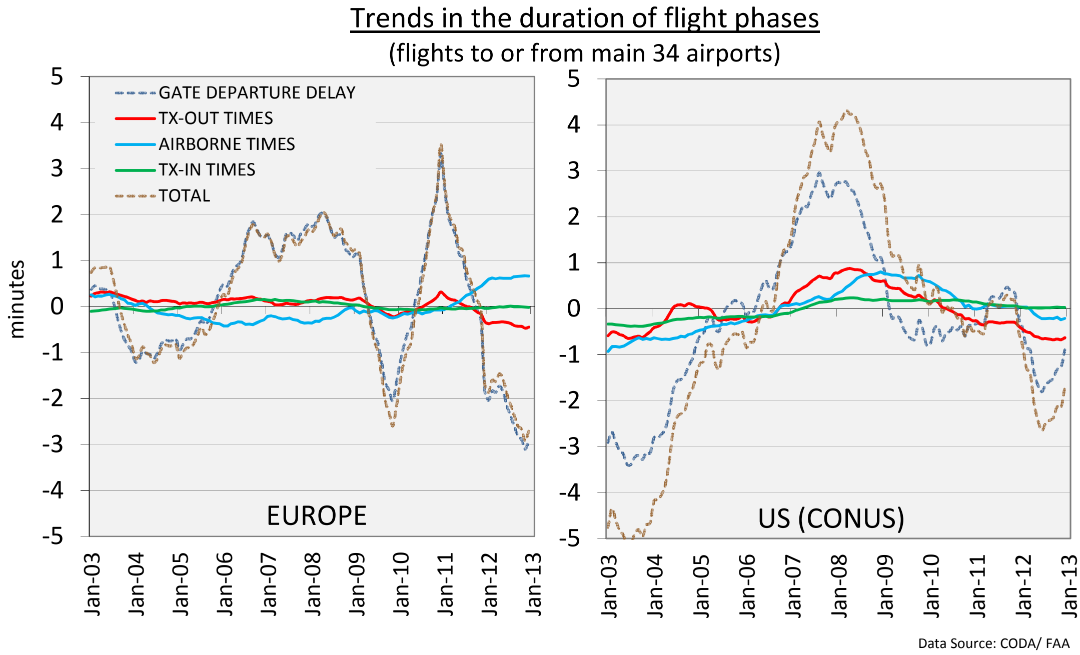


Figure 2.20: Trends in the duration of flight phases [2003-2012]

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

In the US, the trailing 12-month average began to decline at the beginning of 2008. Similar to Europe, departure delay was the largest component associated with the change in average flight time. Between 2008 and 2010, most flight components went back to their long-term average and improved even further between 2010 and 2012. A substantial improvement is also visible for taxi-out times as a result of the initiatives to improve performance in this area.

After a high level analysis of key characteristics of the two air transport systems, the next section provides an overview of the two ATM systems highlighting similarities and the main differences in the application of air traffic flow management techniques.

---

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

2.3 Overview of air traffic management (ATM) in the US and Europe

Broadly speaking, air traffic management (ATM) consists of Air Traffic Control (ATC), Air Traffic Flow Management (ATFM) and Airspace management (ASM). Whereas ATC is more concerned with ensuring the safe separation between aircraft[24], the role of ATFM is to ensure safety by preventing overloads, and regulating demand according to available capacity. ATFM covers a longer time horizon (up to days before the day of operations).

While the US and the European system are operated with similar technology and operational concepts, there is a key difference. The US system is operated by one single service provider using the same tools and equipment, communication processes and a common set of rules and procedures.

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

Figure 2.21 shows the diversity of flight data processing (FDP) suppliers in use in Europe [Ref. 4].

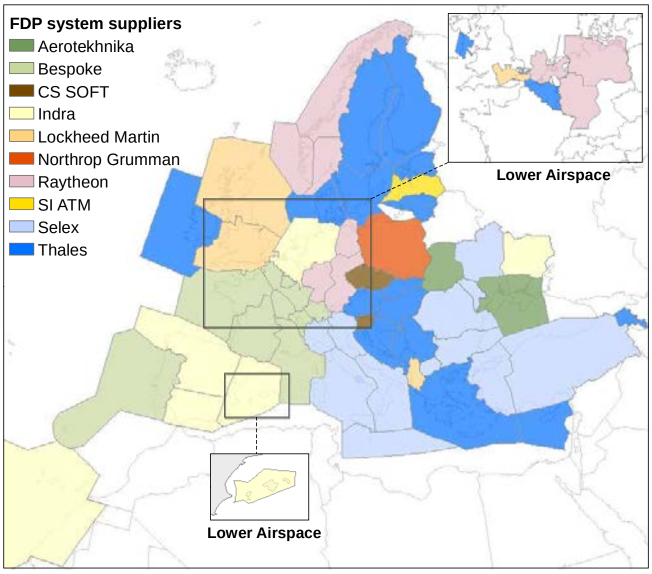


Figure 2.21: Flight data processing (FDP) systems supplier in Europe (2011)

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

2.3.1 Airspace management (ASM)

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

However, the design of airspace and related procedures are not carried out or implemented in isolation in Europe. Inefficiencies in the design and use of the air route network are considered to be a major causal factor of flight inefficiencies in Europe (see also Section 3.3.3) and a number

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

of initiatives, coordinated by EUROCONTROL, aim at improving the design and use of the European route network.

For those States subject to Single European Sky legislation, the European Commission Regulation for ATM Network Functions [Ref. 16] requires the Network Manager to produce a European Route Network Improvement Plan as part of the Network Operations Plan to:

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

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

Also, one of the action points of the European flight efficiency plan [Ref. 17], signed by IATA, CANSO, and EUROCONTROL in August 2008 was to enhance European en route airspace design. Priority was given to the support of the initial implementation of free route airspace (see grey box).

The implementation of "Free route airspace (FRA) initiatives" aims at enhancing en route flight efficiency with subsequent benefits for airspace users in terms of time and fuel and a reduction of CO_2 emissions for the environment. FRA initiatives in Europe have been implemented in Ireland, Portugal, Sweden and Denmark and also partly in the en route centres, Maastricht and Karlsruhe.

Free Route Airspace (FRA) Concept

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

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

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

Figure 2.22 shows the filed flight plans for a typical weekday in May 2013. The higher level of flexibility for airspace users to file flight plans is clearly visible as the flight plan trajectories are much more scattered in those areas where FRA has been implemented (red arrows). The brown areas in Figure 2.22 represent segregated airspace (see also next section).

Whereas the local FRA initiatives (national/ FAB level) will continue to improve flight efficiency, a harmonised implementation coordinated at European system level to ensure interconnectivity between the various initiatives is vital.

In another initiative aimed at reducing the level of fragmentation in Europe, States[25] subject to EU Single European Sky legislation [Ref. 18] were requested to take necessary measures to ensure the implementation of Functional Airspace Blocks (FABs) by December 2012. The underlying rationale was to enhance cooperation among ANSPs in order to optimise and improve performance.

[25] The comparison also includes States that are not members of the European Union and therefore not subject to the Single European Sky regulations.

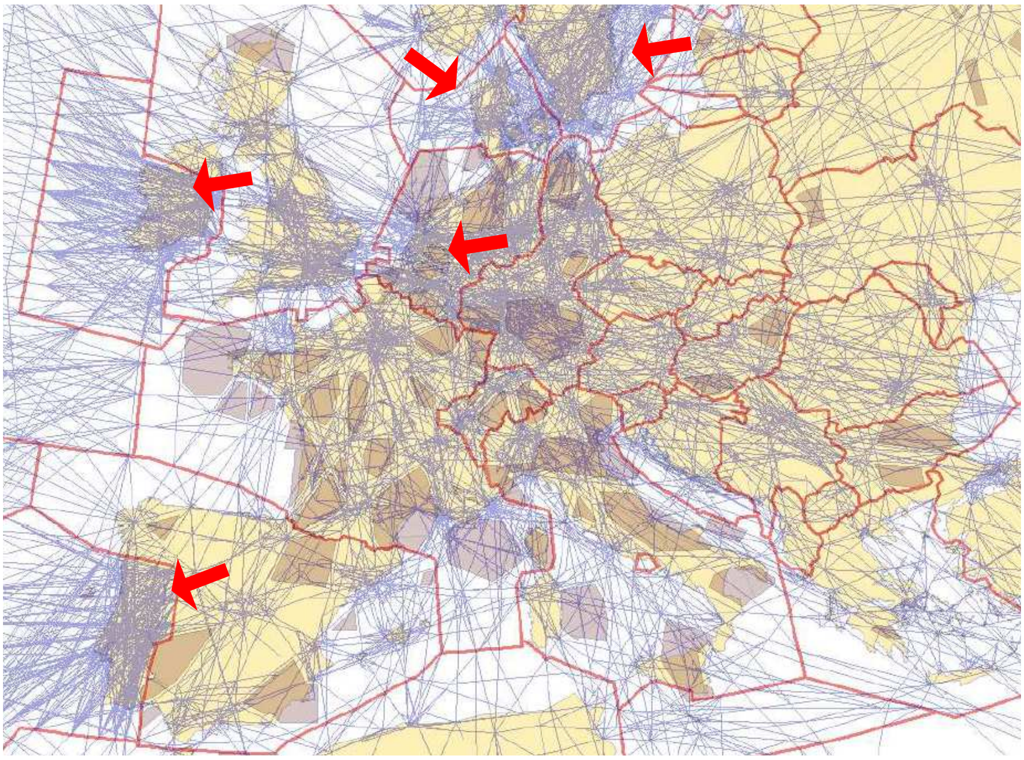


Figure 2.22: Free route airspace implementation in Europe (ANSP level)

FAA recently initiated its Optimization of Airspace Procedures in the Metroplex (OAPM) project which looks to reorganise airspace in the largest metro airports in the US. This project will work to create new standard arrival and departure routes that eliminate today's inefficiencies. The advanced routing capability afforded through OAPM and NEXTGEN will permit procedure design that will reduce or eliminate inefficient routes and the need to carry additional fuel for the longer distances flown. More efficient departure profiles using NEXTGEN and area navigation capabilities will more quickly put aircraft on their desired route.

Improvements in route design are, by definition, a network issue which requires a holistic, centrally coordinated approach. Uncoordinated, local initiatives may not deliver the desired objective, especially if the airspace is comparatively small. In view of the fragmented European ATM system, a harmonised and well-coordinated implementation of initiatives aimed at improving the route network at system level is more difficult to achieve in Europe than in the US where only one entity is responsible for the optimisation of the route network.

A further challenge is the integration of military objectives and requirements which need to be fully coordinated within the respective ATM system. To meet their national security and training requirements whilst ensuring the safety of other airspace users, it is occasionally necessary to restrict or segregate airspace for exclusive use which may conflict with civilian objectives to improve flight efficiency as they have to detour around these areas.

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

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

The comparison of Special Use Airspace (SUA)[26] between the US and Europe (in Europe, SUA is mostly referred to as segregated airspace) in Figure 2.23 illustrates a significant difference in the number and location of the special use airspace within the respective ATM systems[27].

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

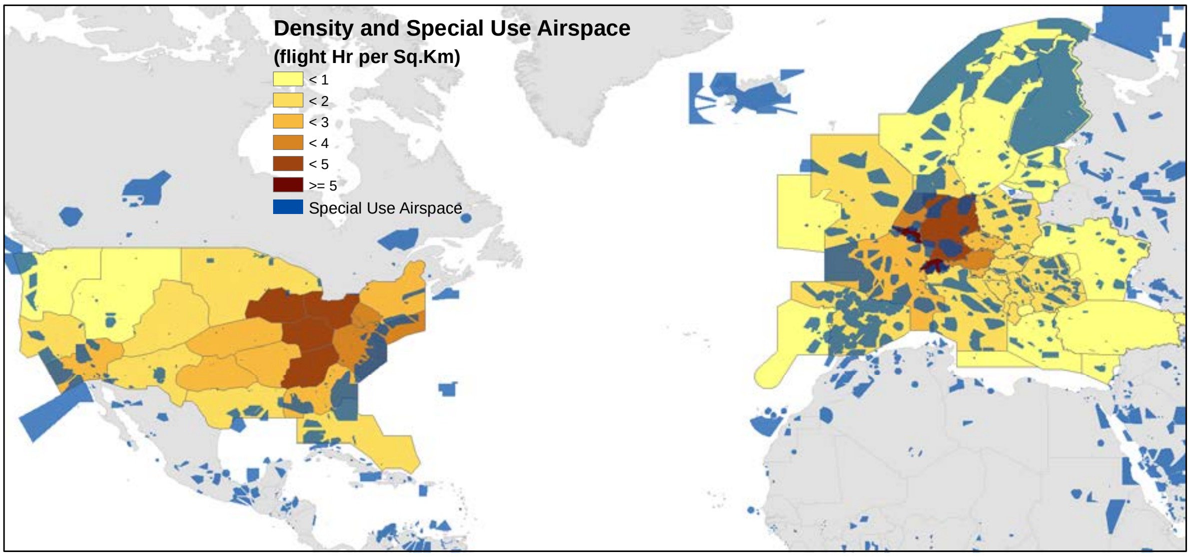


Figure 2.23: Comparison of Special Use Airspace (SUA)

A further difference between the US and Europe with potential implications for ATM performance is the organisation of the civil/military cooperation. In the US, the FAA Headquarters is the final approval authority for all permanent and temporary SUA[28] and operations are organised according to a common set of rules.

In Europe, civil/military cooperation arrangements may differ across States.

Since 1996, EUROCONTROL States have been applying the FUA concept to meet the requirements of both civil and military airspace users, and this was formalised as part of SES legislation, applicable to the EU member States, in EU Regulation 2150/2005 [Ref. 19].

The Flexible use of Airspace (FUA) Concept

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

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

More detailed comparison on the utilisation and coordination of SUA will improve the understanding of the impact of ATM civil/military arrangements on ATM performance in Europe and the US. A potential measure for comparison between the US and Europe would be the share

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

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

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

of flights that would enter shared civil/military airspace if great circle or more direct routes were used.

2.3.2 Air traffic flow management (ATFM)

ATFM is a function of air traffic management (ATM) established with the objective of contributing to a safe, orderly, and expeditious flow of traffic while minimizing delays. The purpose of ATFM is to avoid safety risks associated with overloaded ATC sectors by regulating traffic demand according to available capacity.

Both the US and Europe have established system-wide, centralised traffic management facilities to ensure that traffic flows do not exceed what can be safely handled by ATC units, while trying to optimise the use of available capacity. Figure 2.24 provides an overview of the key players involved and the most common ATFM techniques applied.

The next sections will provide a brief overview of the two ATM systems which is essential background information for the more detailed comparison of ATM performance in Chapter 3 .

	Flight phase	Local ATC units	US	Europe	ATFM measures	Network (ATFM) US	Network (ATFM) Europe
Strategic	Origin Airport				Airport scheduling (departure slot)		
Tactical	Taxi-out	Ground control	*Airports with ATC services: 514*	*Airports with ATC services: 433*	Dep. restrictions (ground holding)	Air traffic Control System Command Center (ATCSCC) located in Warrenton, Virginia.	Eurocontrol Network Operations Centre (NOC), located in Brussels, Belgium (formerly - CFMU)..
	Take-off	Tower control					
	En route	En route Area Control	*Air Route Traffic Control Center (ARTCC): 20 US CONUS*	*Area Control Centre (ACC): 63*	Routing, sequencing, speed control, holding		
	Approach	Terminal control	*Terminal Radar Approach Control (TRACONs): 162*	*Approach control units (APPs): 260*	Airborne holding (circular, linear), vectoring		
	Landing	Tower					
	Taxi-in	Ground					
Strategic	Destination Airport				Airport scheduling (Arrival slot)		

Figure 2.24: Organisation of ATFM (Overview)

For a number of operational, geopolitical and even climatic reasons, Air Traffic Flow Management (ATFM) has evolved differently in the US and in Europe.

Overall, it can be noted that the European ATM system is an amalgamation of a large number of individual ANSPs whereas the US system is operated by a single ANSP. Also, the typical size of a European en route centre (ACC) is smaller than the counterparts in the US. There are 20 Air Route Traffic Control Centres (ARTCC) in the US CONUS compared to 63 ACCs in Europe.

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

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

In Europe, the Network Operations Centre (NOC) in Brussels monitors the traffic situation and proposes flow measures but the final approval remains with the local authority. Usually the local Flow Management Positions (FMP), embedded in ACCs to coordinate the air traffic flow management in the area of its responsibility, requests the NOC to implement flow measures.

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

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

ATFM procedures are typically applied when a mismatch between demand and en route or airport capacity is anticipated. The ATFM measures encompass a wide range of techniques aimed at resolving a mismatch between capacity and demand which may originate from temporary excess demand or reduced capacity, as illustrated in Figure 2.25. Typical reasons for capacity reductions are directional winds, severe weather conditions, staffing issues, or equipment failure.

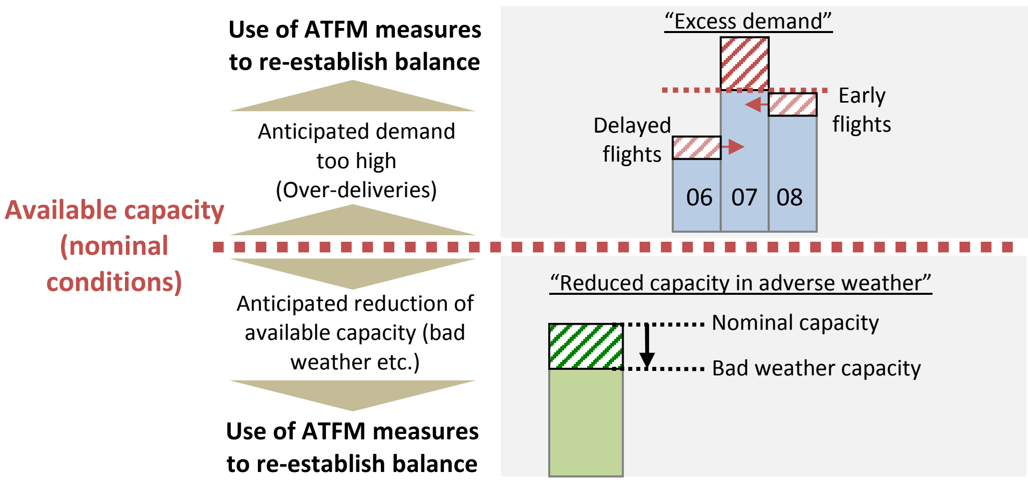


Figure 2.25: Imbalance between demand and capacity

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

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

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

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

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

There are a number of ATFM techniques with different levels of accuracy. The following sections provide a brief overview on the main ATFM measures applied in the US and Europe).

DEPARTURE RESTRICTIONS (GROUND HOLDING)

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

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

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

An analysis of the departure restrictions (ATFM/ EDCT) applied in the US and in Europe can be found in the detailed comparison of operational performance in Section 3.3.1 of this report.

En route flow management (airborne)

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

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

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

Speed control can also be used to adjust transit times. Aircraft are slowed down or sped up in order to adjust the time at which the aircraft arrive in a specific airspace or at an airport.

Arrival flow management (airborne)

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

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

Altitude has different effects on the fuel burn, depending on the airframe/engine combination. Generally speaking, the higher the hold altitude the lower the fuel flow. Figure 2.26 from Airbus [Ref. 20] illustrates this altitude effect for a hold in clean configuration at green dot speed [29].

The holding fuel flow is compared to the minimum fuel flow for the flight levels considered for each type, and the difference expressed as a percentage. For instance, the holding fuel flow for an A319 at FL100 is 11% higher than it is at FL350.

Flight Level	50	100	150	200	250	300	350	400
A300B4-605R	4	2	1	0	3	8	16	
A310-324	11	5	2	0	0	5	9	23
A318-111	13	8	4	2	1	0	0	5
A319-112	19	11	3	1	0	1	0	4
A320-214	13	5	3	1	1	1	0	2
A320-232	7	5	5	5	2	0	4	11
A321-211	14	11	8	3	0	1	5	
A330-203	2	1	0	0	2	4	8	18
A330-223	9	9	5	2	0	1	6	14
A340-343	10	5	1	0	0	2	7	16

Figure 2.26: Effects of altitude on fuel burn in clean configuration

Although varying by aircraft type, there appear to be significant potential savings if the increase in cruise time can be used to reducing the time in holding patterns at lower altitude.

ATM-related inefficiencies per flight phase are analysed in more detail in the comparison of operational performance in Section 3.3.4 of this report.

2.3.2.1 BALANCING DEMAND WITH CAPACITY (EN ROUTE)

The capacity in the en route environment is primarily determined by safety concerns to ensure safe separations between aircraft, and the limits on the number of aircraft that can be managed by a controller. Because of the many factors involved (staff availability and experience, controller workload, airspace configuration, sectorisation, traffic patterns and mix, etc.), it is difficult to exactly determine en route capacity. Additionally, the en route capacity may also be affected by external factors such as convective weather and the availability of special use airspace.

Convective weather in the summer is quite severe and widespread in the US and may require ground holds and continent wide re-routing of entire traffic flows. The NAS playbook offers a set of pre-validated routes for a variety of weather scenarios to re-route aircraft around affected areas. The validated scenarios have been developed over years and applied successfully for the overall benefit of the entire system.

During periods of convective activity or significant system constraints, local ATC units are called upon to accept traffic that is not normally routed through their area. Hence, capacity constrained en route sectors can often be bypassed by selecting an alternative route.

---

[29] For all aircraft, the minimum fuel consumption speed is very close to the maximum lift-to-drag ratio (Green Dot) speed.

The US appears to have less en route capacity restrictions and constraints which enable the US ATM system to absorb a considerable amount of time through speed control and vectoring in en route airspace to achieve the metering required by terminal control units. In general, the regions in the US with the most en route constraints correspond to the most “dense” airspace shown in Figure 2.3.

The difference appears to be linked to the fragmentation of service provision and the number and location of special use airspace in Europe (see Figure 2.23) which limits the level of flexibility to manage traffic flows in the en route airspace.

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

Instead, departure restrictions at the various origin airports are used as the primary means of ATFM for handling en route capacity constraints. In the US, the ATM system appears to be more flexible to tactically adjust to capacity and demand variations on the day of operations. Departure restrictions are only used as a last resort when all other ATFM measures are considered to be insufficient (see also Table 3-1 on 55).

2.3.2.2 BALANCING DEMAND WITH CAPACITY (AIRPORTS)

Airports are key nodes of the ATM system and in Europe and the US alike, airport capacity is considered to be a major contributor to the overall ATM capacity enhancement goal. A fundamental difference between the US and Europe is the involvement of the service provider in facilitating airport development and surface safety. In the US, the FAA has a significant role in airport infrastructure enhancement, whereas in Europe the ANSPs, in most cases, do not have a direct role in airport improvement projects. The FAA’s Office of Airports provides leadership in planning and developing a safe and efficient national airport system, taking into account economics, environmental compatibility, local proprietary rights, and safeguarding the public investment. This means developing the National Plan of Integrated Airport Systems (NPIAS) and maintaining a level of investment for airport infrastructure projects that benefits the National Airspace System. However in Europe, the ANSPs and airport operations are in most cases different entities.

Although airport capacity encompasses more than the runway, the focus of ATM is on runway throughput. Because of the economic value put on each extra movement, it is crucial to ensure the maximisation of valuable runway capacity.

Runway throughput depends upon a number of factors as well as on interactions between them which all affect runway capacity to some degree. In addition to physical constraints, such as airport layout (see also Section 2.1.6), there are “strategic” factors such as airport scheduling and “tactical” factors which include, inter alia, the sequencing of aircraft and the sustainability of throughput during specific weather conditions.

In the US and Europe, it is generally accepted that some delay is unavoidable to achieve a high runway utilisation desirable at capacity constrained airports. Small imbalances between demand and capacity during peak times are usually managed tactically by local holdings which also serve as a short term buffer to ensure a constant reservoir of aircraft to maximise runway throughput.

AIRPORT SCHEDULING IN THE STRATEGIC PHASE

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

Airports are usually designated as 'coordinated' when the airport capacity is insufficient to fulfil airlines' demand during peak hours. The subsequent airport scheduling process aims at matching airline demand with airport capacity several months before the actual day of operations to avoid frequent and significant excess of demand on the day of operations. This is the case for 31 of the 34 European airports analysed in this report which are coordinated (IATA Level 3) [30].

The declared airport capacity[31] takes account of airport infrastructure limitations and environmental constraints and is decided by the coordination committee[32] and/or by the respective States themselves. It represents an agreed compromise between the maximisation of airport infrastructure utilisation and the quality of service considered as locally acceptable. This trade-off is usually agreed between the airport managing body, the airlines, and the local ATC provider during the airport capacity declaration process. The so called "coordination parameters" can vary by time of day and for arrivals and departures.

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

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

The few schedule constrained airports in the US are typically served by a wide range of (international) carriers and are located in high density areas in the US core airspace. In 2007, schedule constraints existed only at New York LaGuardia (LGA), Chicago O'Hare (ORD), and Washington National (DCA). During the 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 a new runway.

The European airport capacity declaration process requires a strategic trade-off between the locally acceptable service level and the utilisation of scarce airport capacity six months before the day of operations. However, airport capacity on the day of operations can vary quite significantly as it is influenced by a number of factors which are difficult to predict months in

---

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

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

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

advance. Hence, a declared airport capacity close to IMC conditions can support overall stability of operations but there is a risk that resources might be underutilised for considerable periods.

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

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

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

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

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

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

95th percentile airport peak arrival throughput

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

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

Figure 2.27 provides a first comparison of the two types of capacities and throughput described above. Although they are developed and used for different purposes, the values may provide some insights into the role of capacity on operational performance.

The figure depicts the peak arrival capacity (peak called arrival rates for US airports and peak declared arrival capacities for European airports) together with the airports’ 95th percentile peak arrival throughput (see grey box). The airports are furthermore categorised by the number of active runways (see Section 2.1.6 for the computation of the number of active runways).

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

In the US and Europe, airports with one and even two active runways are more comparable in terms of peak arrival capacity for the two regions. For the US, the two active runway case average value (47) is influenced by the ability to operate in mixed mode with independent runways for Tampa (TPA) and Portland (PDX). Otherwise the grouping is more comparable (39 vs. 38).

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

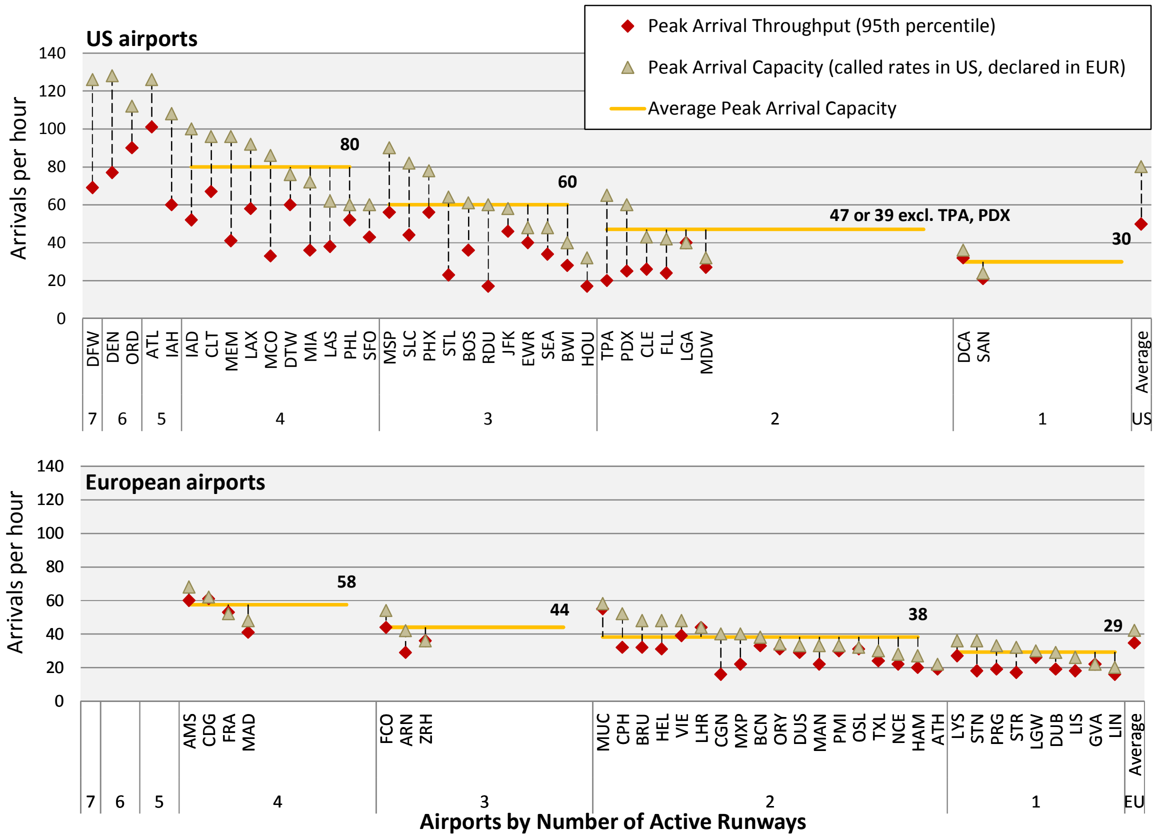


Figure 2.27: Actual airport throughput vs. declared capacity (2012)

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

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

There are a number of key challenges in providing a true like-with-like comparison of airport capacities and throughput for the two regions. One difficulty in this exercise is that airports within each active runway group may not be directly comparable due to differences in runway layout. Munich (MUC), having two parallel independent runways and the highest throughput in its two-runway class, is not directly comparable to LaGuardia (LGA), which also has two active runways, but in a dependent crossed configuration. The throughput values for the two airports are, therefore, very different. More analysis is needed to better group and compare European and US airports based on runway layout, runway dependency, and mixed and single mode operations. Another difficulty is that throughput is highly sensitive to demand. High demand drives high throughput and vice-versa. It is difficult to properly assess throughput as demand levels are lower on both sides of the Atlantic with some airports having larger demand drops than others. Lastly, measuring throughput is dependent on the time interval used for the assessment. In this analysis, peak throughput was measured every five minute rolling hour. Results using a different approach may reveal a difference not seen at the five minute rolling hour level.

Further study is needed to determine a more refined method for measuring and comparing throughput and capacity in the two regions. Additional factors affecting the throughput of an airport and runway are discussed in more detail in the following sections.

ENSURING HIGH RUNWAY THROUGHPUT ON THE DAY OF OPERATIONS

Safe operation of aircraft on the runway and in surrounding airspace is the dominant constraint of runway throughput. Airport layout and runway configuration (see also Section 2.1.6), traffic mix (see also Section 2.1.5), runway occupancy time of aircraft during take-off and landing, separation minima, wake vortex, ATC procedures, weather conditions and environmental restrictions - all affect the throughput at an airport.

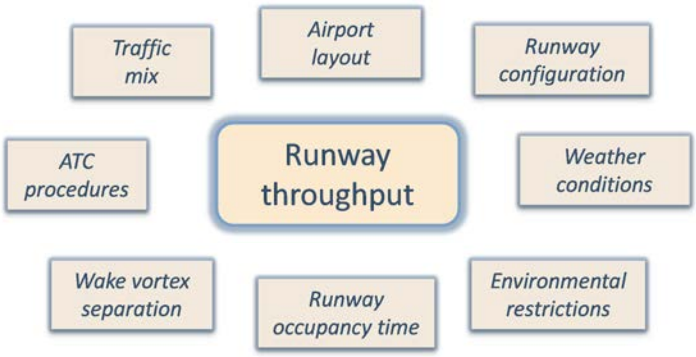


Figure 2.28: Factors affecting runway throughput

The runway throughput is directly related to the time needed to accommodate each flight safely. The separation requirements in segregated mode[33] depend on the most constraining of any one of the three parameters: (1) wake vortex separation, (2) radar separation, or (3) runway occupancy time. The challenge is to optimise final approach spacing in line with wake vortex and radar separation requirements so that the spacing is close to runway occupancy time.

For mixed mode runway operations[34], throughput is driven by inter arrival spacings into which departures are interleaved. Here the required spacing between departures and arrivals virtually eliminates wake vortex and radar separation requirements on final approach.

Runway occupancy time (departure & arrival): depends on pilot performance, type of aircraft, and the location and type of exits from the runway. On the inbound flow, well placed high speed exits can increase the arrival throughput of an airport enabling ATC to clear the next aircraft for take-off, or to apply minimum spacing for the next aircraft on final approach. Extended

---

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

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

occupancy times tend to reduce capacity and in the US and in Europe there are initiatives to reduce occupancy times to the necessary minimum.

Wake vortex separations: Spacing between successive arrivals or successive departures are governed by a set of separation requirements designed to minimise the risk of a wake vortex incident [35] and to ensure safe operations (i.e. protect lighter aircraft from the hazards posed by wake vortices generated by heavier aircraft).

Generally speaking, the larger an aircraft (aircraft class is usually based on maximum take-off weight), the more spacing between aircraft is required and consequently, the lower the airport throughput. On approach, wake vortex separation is defined in terms of distance. For departures, separation is defined in terms of time.

With the exception of the UK which is closer to the standards used in the US[36], most ANSPs in Europe apply the categories specified by ICAO. Although the US apply ICAO rules in certain situations, the US have their own procedures prescribed in the FAA Order 7110.65 for use by personnel providing ATC services in the USA.

Radar separation minima: In addition to wake vortex separation, controllers must apply radar separation minima which may differ according to available radar equipment but which must not be below the required wake vortex separations. Certain airports in the US and in Europe apply a minimum of 2.5NM (subject to wake vortex separation) during favourable weather conditions. Adherence to speed control by pilots is essential to maintain the required spacing between aircraft while maximising the use of scarce runway capacity.

In addition to the airborne wake vortex and radar separation requirement, there is also the requirement that the trailing aircraft must not touch down on the runway before the leading aircraft has vacated the runway. The prevailing weather conditions can have a significant impact here. In IMC conditions, the airborne separation is often the most constraining requirement. In VMC conditions, when visual separations are allowed, the need to clear the runway can become the restrictive requirement.

Provided conditions and national regulations allow, conditional line up and landing clearances[37] are used by controllers in the US and to a lesser extent in Europe to maximise throughput.

IMPACT OF WEATHER CONDITIONS ON RUNWAY THROUGHPUT

Runway throughput at airports is usually impacted by meteorological conditions. As weather conditions deteriorate, separation requirements generally increase and runway throughput is reduced. The impact of weather (visibility, wind, convective weather, etc.) on operations at an airport and hence on ATM performance can vary significantly by airport and depends on a

---

35 Where an aircraft experiences disturbance caused by flying through the wake turbulence of another aircraft.

36 The UK uses four categories instead of the three ICAO categories in which aircraft following some larger types (e.g. B757) are provided with greater separation. Details on the UK Wake Vortex Categories are available from the UK CCA in CAP493 Manual of Air Traffic Services Part 1.

37 A conditional clearance is a clearance issued by an air traffic controller which does not become effective until a specified condition has been satisfied. Conditional phrases, such as “behind landing aircraft” or “after departing aircraft”, shall not be used for movements affecting the active runway(s), except when the aircraft concerned is seen by the appropriate controller and pilot. The aircraft causing the condition in the clearance issued shall be the first aircraft to pass in front of the other aircraft concerned. The precise format of a conditional clearance is specified by ICAO.

number of factors such as, inter alia, ATM and airport equipment (instrument approach system, radar, etc.), runway configurations (wind conditions), and approved rules and procedures.

As illustrated in Figure 2.29, movement rates depend on visibility conditions. Runway throughput can drop significantly when Low Visibility Procedures (LVP)[38] need to be applied.

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

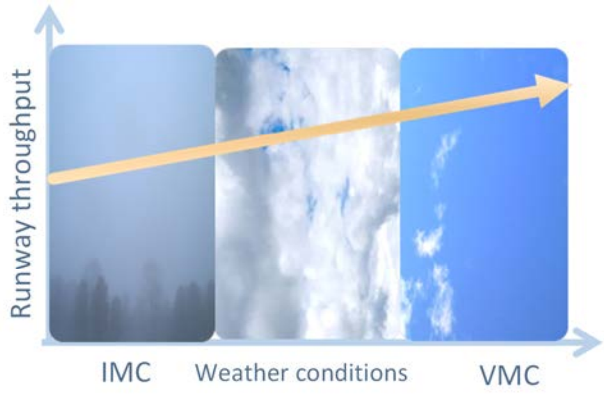


Figure 2.29: Impact of visibility conditions on runway throughput

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

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

The capacity declaration process at European airports arguably results in schedule limitations closer to IMC capacity while in the US, where demand levels are controlled by airlines and capacity is managed more tactically, the ATM system appears to be more flexible to gear throughput according to prevailing conditions and thus potentially operate closer to VMC capacity when possible [Ref. 21].

The analysis of performance by meteorological condition provides an indication of how weather affects system performance and which airports are most impacted by changes in weather condition. Tracking these values over time may provide an indication of how weather may influence system performance over time.

Both US and European performance groups use detailed weather observation reports known as METAR[39] and both groups have developed procedures for assessing weather's impact on aviation performance [Ref. 22 and 23]. A typical METAR contains data on temperature, dew point, wind speed and direction, precipitation, cloud cover and heights, visibility, and barometric pressure.

Despite a number of local initiatives, the ability to consistently quantify the impact of weather

---

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

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

on air traffic in Europe is not as developed as is in the US (convective weather forecast, WITI[40] Metric, etc.). Due to differences in data availability, direct comparisons are difficult. Hence, the next two sections illustrate the observed impact of weather on the airports separately for Europe and the US.

Figure 2.30 shows the average airport arrival ATFM delay by category at the main 34 European airports between 2008 and 2012.

Overall, ATFM airport regulations due to visibility are the main driver of delay, followed by wind, thunderstorms and precipitation.

A notable exception is observed for 2010 where precipitation (mainly snow) was the main cause for weather related airport ATFM regulations. The severe weather conditions in 2010 had a notable impact on punctuality as shown in Figure 2.19 on page 25.

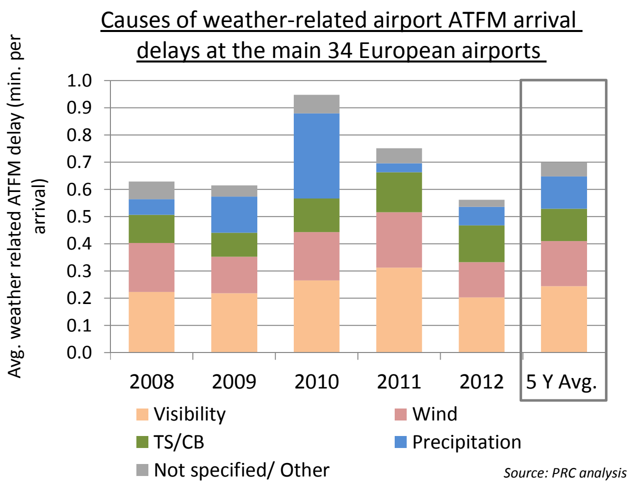


Figure 2.30: Causes of weather-related airport ATFM delays at the 34 main European airports

Compared to 2008 and particularly 2010, average weather related airport ATFM delays at the 34 main airports are at the lowest level in 2012.

The analysis of the main 34 European airports in Figure 2.31 shows the peak declared arrival capacity, the peak arrival throughput (95th percentile), and the average weather-related airport arrival ATFM delay by delay category (as provided by the FMP when requesting the ATFM regulation) in 2012.

London Heathrow (LHR) shows by far the highest impact of weather on operations, followed by Munich (MUC), Amsterdam (AMS), Frankfurt (FRA), and Zurich (ZRH).

The average weather-related airport arrival ATFM delays at London (LHR) were mainly related to wind and visibility. A high average weather-related airport arrival delay is usually the result of a notable capacity reduction in bad weather combined with a high level of demand (i.e. peak throughput close to or higher than the declared capacity).

40 The Weather Impact Traffic Index (WITI) is a product used to measure weather impact on air traffic across the major US airports. In the US, weather has been identified as the most significant cause of delays and air traffic problems across the National Airspace System. The WITI is a composite measure of the "front-end" impact of weather and traffic demand on the NAS.

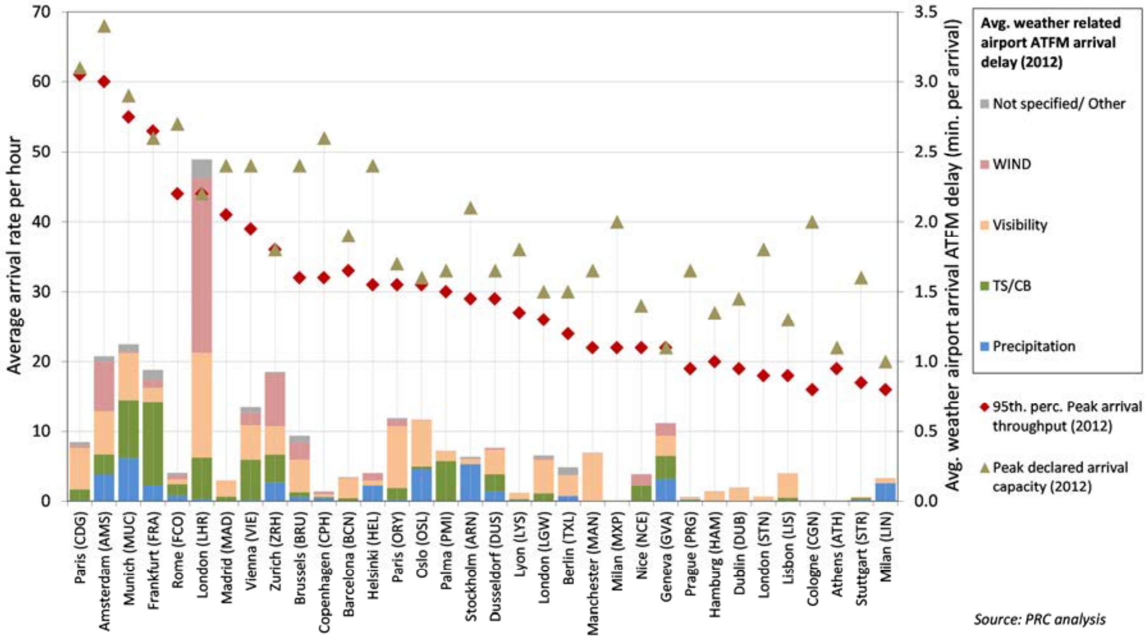


Figure 2.31: Avg. arr. rates and ATFM delays due to weather at the 34 main European airports

As already mentioned, due to different data availability, the analysis of the main US airports in the next section is not directly comparable to the analysis of European airports in the previous section. It nevertheless provides an indication of the impact of weather on operations at the main US airports.

Different from Europe, the FAA collects facility reported Airport Arrival Acceptance Rates (AAR) and assesses and reports airport capacity variations due to weather in the Airport Capacity Benchmark Reports [Ref.24].

Historically, many of the performance analysis measures and modelling processes at FAA segregate time periods into visual or instrument meteorological conditions (VMC/IMC). This provides a simple, first-order examination of the effects of weather on performance using ceiling and visibility as the primary criteria for defining weather. Performance by VMC/IMC was also examined in the previous 2010 benchmark report as a practical way of comparing weather changes over time and weather differences between facilities.

Precise definitions differ between US and Europe but for the analysis in the next section, a cloud ceiling of less than 1000 feet and visibility of 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 2-3: 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

Assessing weather is complicated by the fact that weather may change during the flight time from origin 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 departure were used to determine representative weather for a flight.

Figure 2.32 shows the share of arrival and departure operations by ceiling and visibility criteria at the main 34 US airports between 2009 and 2012.

In 2012, approximately 86.3% of the operations at the main 34 airports in the US occurred during VMC with 9.2% occurring in marginal and 4.6% in instrument conditions. US airports overall experienced better weather in 2012 than previous years (2009-2012).

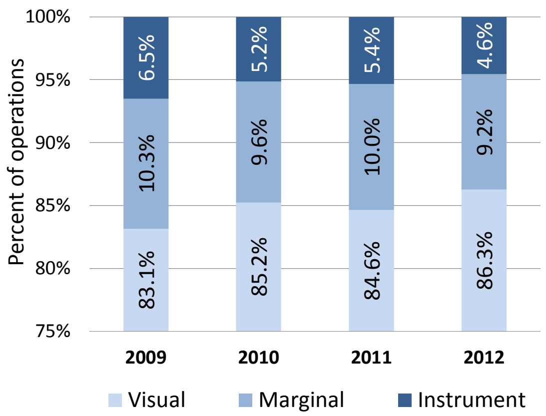


Figure 2.32: Share of operations by category at the main 34 US airports (2009-2012)

However, the number of flights arriving or departing in IMC conditions varies considerably by US airport. During the time period from 2010 to 2012, scheduled operations at the main 34 US airports declined by 3%. At the same time, operations in IMC conditions dropped by over 14% suggesting that weather conditions in the US were more favourable in 2012 than in 2010.

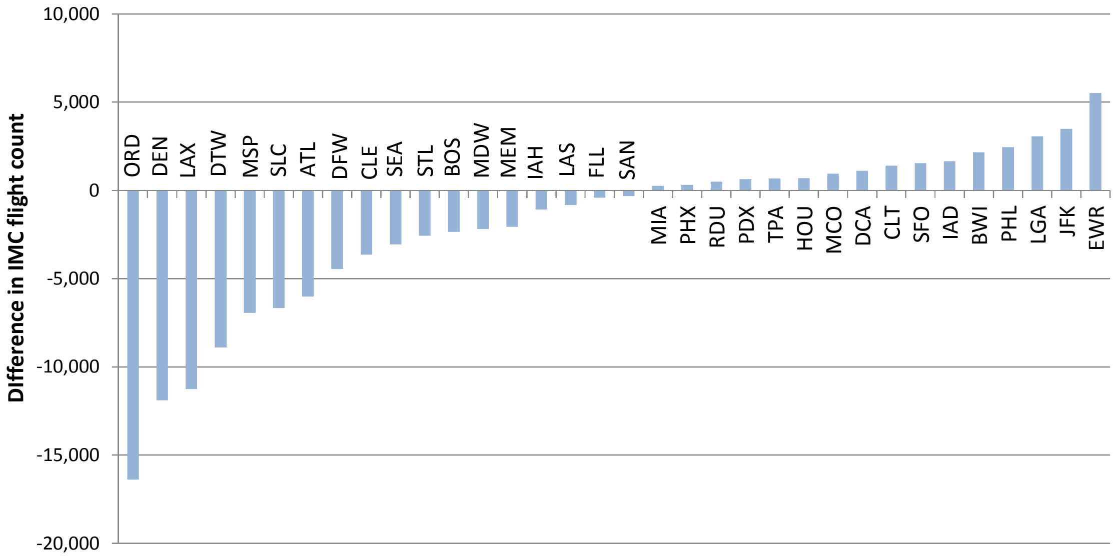


Figure 2.33: Difference in flights occurring in IMC at the main 34 US airports (2010-2012)

Figure 2.34 shows how the 14% decrease in operations in IMC is broken down by US airport. Note these changes reflect both changing demand levels and changing weather conditions. Airports in the Northeast and Mid-Atlantic region of the US experienced worse weather in 2012 compared to 2010 as indicated by the increase in IMC flight count.

In terms of performance, the observed capacity gap, traffic volume, and frequency of IMC conditions drive overall system performance. As the US system is more geared towards maximising airport throughput thus tending to schedule closer to the higher VMC capacity, when adverse weather occurs, US airports are more susceptible to capacity shortfalls, widespread delays, and in extreme cases, flight cancellations.

As IMC occurs relatively infrequently compared to better weather conditions, comparing average delay difference in VMC and IMC should be viewed in conjunction with the frequency of IMC operations. Figure 2.34 shows how average departure delay at the 34 main US airports changes by weather condition and the share of IMC operations by airport.

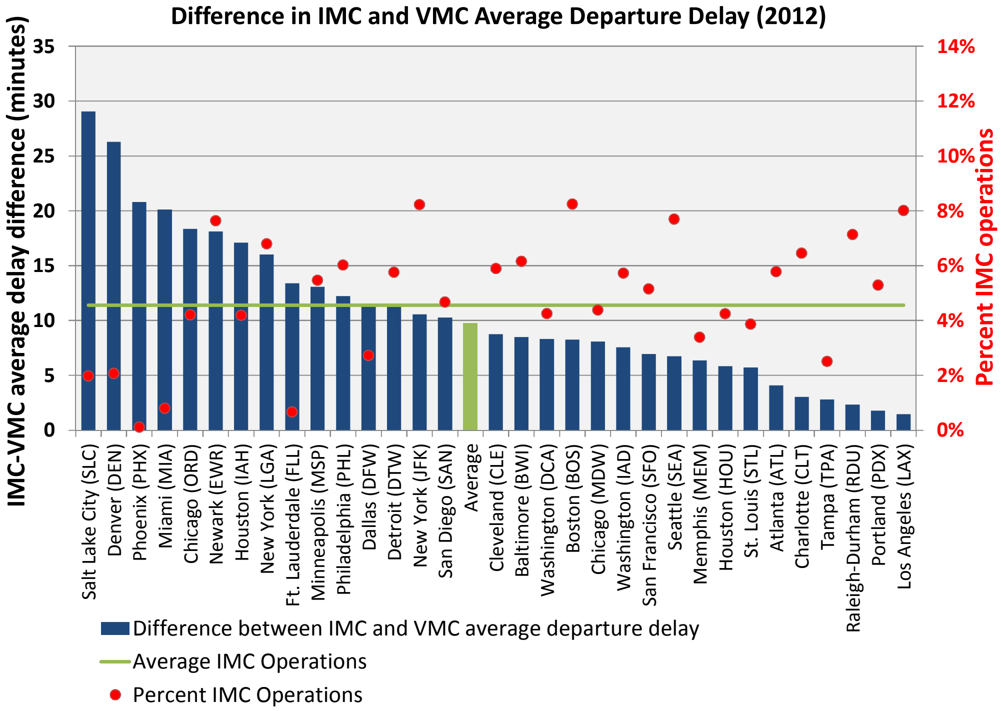


Figure 2.34: Difference in average departure delay between IMC and VMC at main US airports

Several airports, such as Phoenix (PHX), Miami (MIA), and Fort Lauderdale (FLL) show a large delay difference but the result in not representative because the percentage of IMC operations is less than 1%. Generally speaking, the higher the difference between IMC and VMC and the higher the share of IMC operations, the larger the impact on the ATM system. The high impact airports as indicated by the figure, such as LaGuardia (LGA) and Newark (EWR), also rank among the top in terms of Estimated Departure Clearance Time (EDCT) delays issued due to a Ground Delay Program (Figure 3.5 page 57).

In Figure 2.32 - Figure 2.34, the assessment is limited to using ceiling and visibility as the primary driver in assessing changes to system performance. The results are intuitive; however, further analysis to link these changes with other ATM drivers, such as a capacity reduction, reveal shortcomings.

To complete the linkage between weather, capacity variation and performance, it is necessary to include additional METAR weather data, such as cloud cover, winds, and precipitation events. It is also the case that not all capacity variation and performance changes can be explained by meteorological conditions as facilities may operate at low capacity rates during good weather due to other events such as temporary runway maintenance or dependencies with traffic flow of nearby airports.

For this reason, it is more straightforward to assess capacity variation using a percentile method that does not depend on a link to all the causal reasons described above. Different from the 2010 EU/US Report, Figure 2.35 combines the various elements (volume, capacity reduction, and frequency) which drive performance at US airports using percentiles rather than VMC/IMC categories. In the previous sections, peak capacity and throughput values were presented. In the following section, the focus is on how much capacity varies from low to high values and how often this variation becomes a strain on airports due to demand levels close to or exceeding capacity. Note that capacity and demand do not have to be at a peak level for an airport to be impacted or strained. In general, it only takes a mismatch of the two entities and not necessarily high levels of each.

The left side of the chart shows the percent capacity variation (arrival & departure) between the 85th and 15th percentile capacities for the most critical US airports in 2012.

Using New York (LGA) as an example, Figure 2.35 would indicate that *at least 15%* of the time there is *at least a 20%* reduction in capacity from the target ideal value represented by the 85th percentile. Frequency of time (15%) and magnitude of capacity reduction (20%) may actually be higher depending on the individual airport's distribution of capacity values. Alternatively, this can be interpreted as 70% of the time (85%-15%), LGA experienced a capacity reduction of *up to 20%.*

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

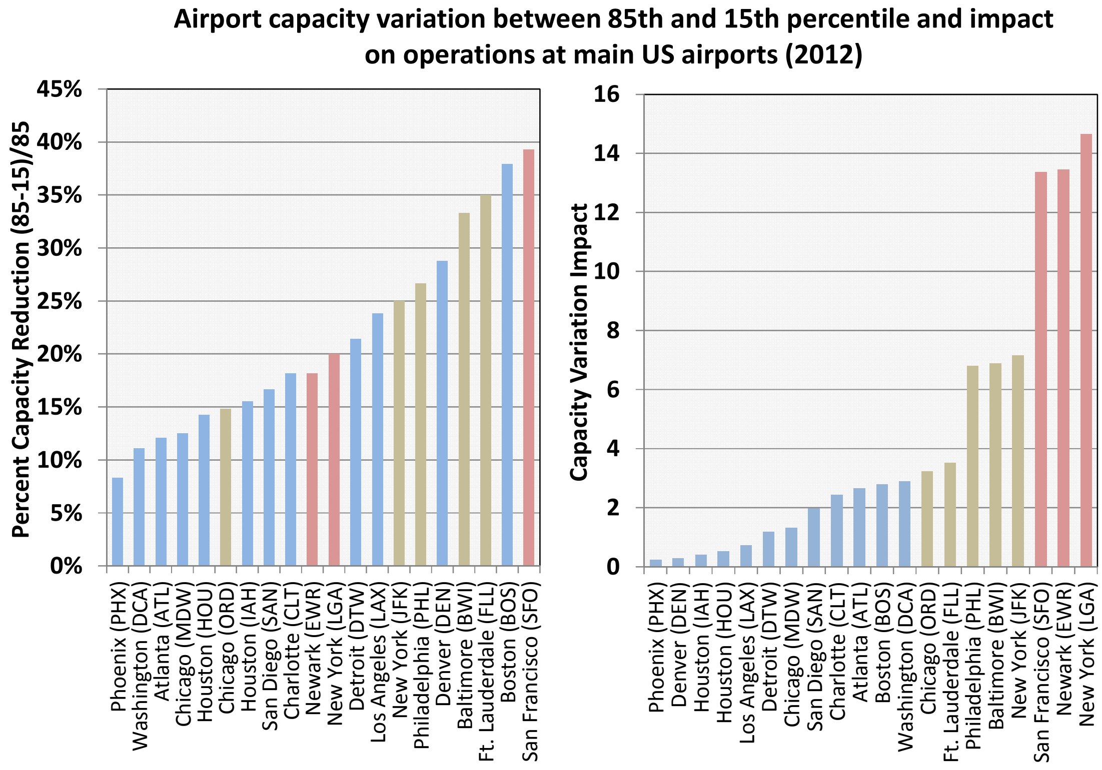


Figure 2.35: Capacity variation (85th-15th percentile) and impact on operations at US airports

The right side of Figure 2.35 shows a composite 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 when demand at the airport is at 80% or higher of its called capacity. Airports with high demand relative to capacity are more likely to have performance affected by capacity changes that may occur due to adverse weather or other capacity constraining events. By this measure, the New York airports, San Francisco (SFO), Baltimore (BWI), and Philadelphia (PHL) are the airports which are impacted the most by changes in capacity when also considering demand.

Although a percentile method was used to characterise airport capacity variation, it is still important for performance analysis groups to link these changes to causal factors. At this time, it is difficult to apply a practical automated process that can explain capacity variation across all facilities. For example, it is known that for San Francisco (SFO), variation can be tied to precipitation, haze, fog and other METAR cloud cover conditions which are not captured by ceiling/visibility alone. For Philadelphia (PHL), the capacity variation can be linked to wind effects [Ref. 25]. Additional performance data development and automated procedures are needed to assess these effects across airports.

A key challenge for ATM is to ensure safe operations while sustaining a high runway throughput in the various weather conditions. Even small improvements at high density airports will yield a considerable benefit for airspace users and the entire network. This will encompass the use of new and enhanced technology as foreseen in NextGen and SESAR.

More research is needed to better understand weather impacts on the ATM system and on airport throughput in particular. In view of the current difficulties in comparing the impact of weather conditions on ATM performance, it would be desirable to identify and develop metrics which allow for better comparisons between the US and Europe in this field.

CAPACITY AND AIRPORT INFRASTRUCTURE

Capacity variation tends to be a key indicator of facilities that show the most room for performance improvements. For the study period from 2008 to 2012, despite overall falling traffic levels in the US, many facilities managed to call a higher arrival capacity, which may in part be tied to improved weather and changing airport infrastructure.

In Figure 2.36, the average hourly arrival acceptance rates for the 34 main US airports are shown with the percent change in IFR arrivals with respect to 2008. Most US airports report an increase in airport arrival rate despite an overall decrease in IFR arrivals.

Memphis (MEM), Cleveland (CLE), and St. Louis (STL) experienced the greatest decline in traffic from 2008 to 2012, but all three airports experienced increases in average arrival rates called at the facility. San Francisco (SFO) and Charlotte (CLT) showed both growth in IFR arrivals and airport capacity from 2008 to 2012.

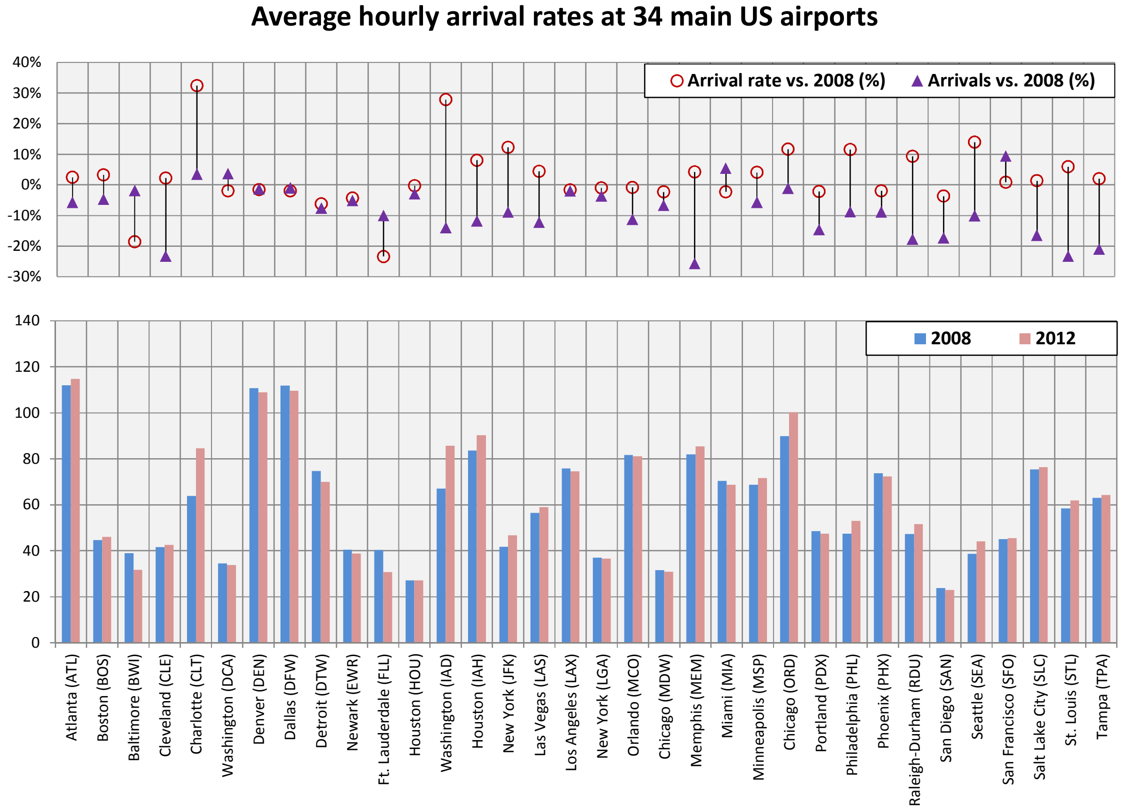


Figure 2.36: Average hourly arrival rates at 34 main US airports (2008-2012)

The period from 2008 to 2012 saw several airport development projects resulting in improved capacity at US airports. These included new runways at Chicago O'Hare (ORD), Charlotte (CLT), Seattle (SEA), and Dulles (IAD) and a runway extension at Philadelphia (PHL). Airports such as Baltimore (BWI) and Fort Lauderdale (FLL) saw drastic drops in capacity due to runway closures and reconstruction projects in 2012. Runway improvements were also made at Memphis (MEM), Minneapolis (MSP), and Raleigh Durham (RDU).

ENVIRONMENTAL CONSTRAINTS

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

The main affecting factors are (1) Noise Preferential Routes and Standard Instrument Departure, (2) Restrictions on runway mode of operations and configurations, and (3) night noise regulations. In the early morning, night noise curfews might even result in considerable arrival holding with a negative impact on fuel burn and thence CO_2 emissions.

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

3 COMPARISON OF ATM-RELATED OPERATIONAL SERVICE QUALITY

This chapter evaluates ATM-related operational service quality with a focus on the predictability and efficiency of actual operations by phase of flight in order to better understand the ATM contribution and differences in traffic management techniques between the US and Europe.

3.1 Introduction

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

3.1.1 Approach to comparing ATM-related service quality

Although the analysis of performance compared to airline schedules (on-time performance) in Chapter 2.2.1 is valid from a passenger point of view and provides valuable first insights, the involvement of many different stakeholders and the inclusion of time buffers in airline schedules require a more detailed analysis for the assessment of ATM performance.

Figure 3.1 shows the conceptual framework for the analysis of ATM-related service quality by phase of flight applied in the next sections of this report.

The high level passenger perspective (on time performance) is shown at the top together with the airline scheduling. The various elements of ANS performance analysed in more detail in the following sections are highlighted in blue in Figure 3.1.

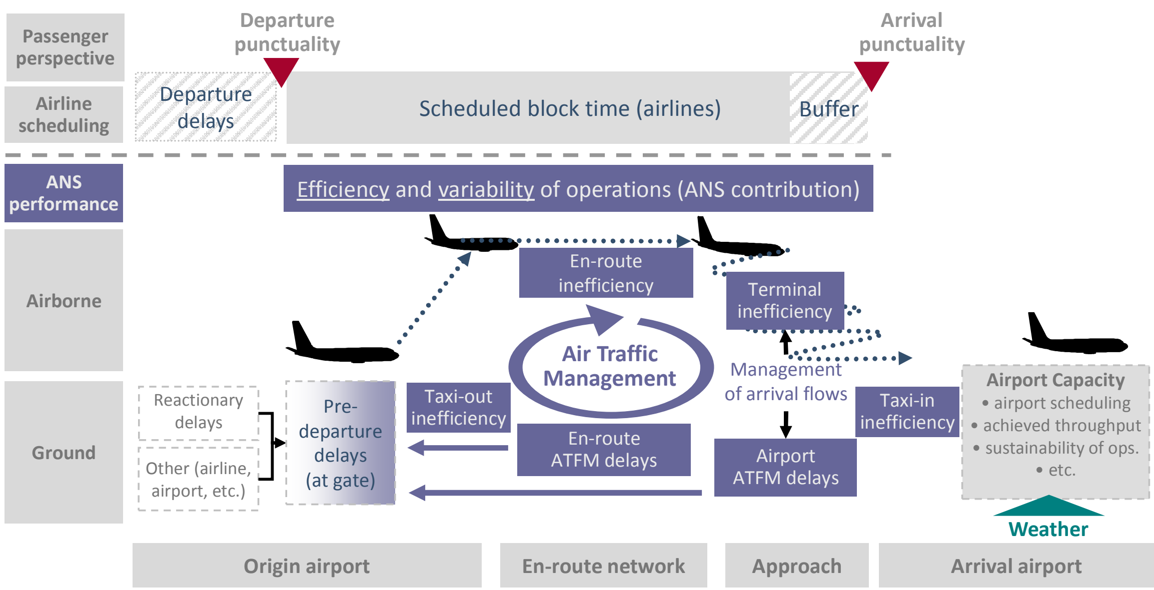


Figure 3.1: Conceptual framework to measuring ATM-related service quality

The evaluation of ATM-related service quality in the remainder of this report focuses on the Efficiency (time, fuel) and the Variability (predictability) of actual operations by phase of flight (see information box) in order to better understand the ATM contribution and differences in traffic management techniques between the US and Europe.

ATM may not always be the root cause for an imbalance between capacity and demand (which may also be caused by other stakeholders, weather, military training and operations, noise and environmental constraints, etc.). However, depending on the way traffic is managed and distributed along the various phases of flight (airborne vs. ground), ATM has a different impact on airspace users (time, fuel burn, costs), the utilisation of capacity (en route and airport), and the environment (emissions).

Efficiency and Variability

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

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

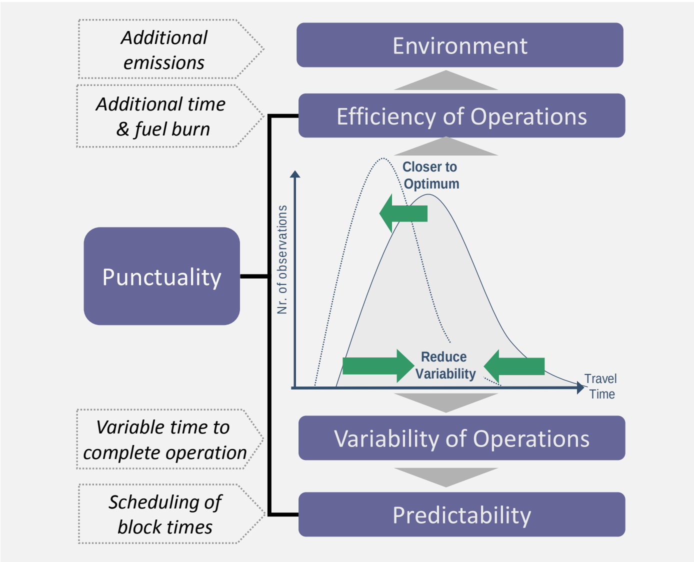
'Efficiency' in this report measures the difference between actual time/distance and an unimpeded reference time/distance. "Inefficiencies" can be expressed in terms of time and fuel and also have an environmental impact.

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

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

While maximising the use of scarce capacity, there are trade-offs[41] to be considered when managing the departure flow at airports (holding at gate vs. queuing at the runway with engines running).

Similarly, the management of arrival flows needs to find a balance between the application of ground holding, terminal airborne holdings and en route sequencing and speed control [Ref. 26] .



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

3.2 Variability by phase of flight

This chapter looks at variability by phase of flight using airline provided data for gate "out," wheels "off," wheels "on," and gate "in" data. This out, off, on, in data is often referred to as OOOI data and is almost entirely collected automatically using a basic airline data-link system (see Section 1.3 for more information on data sources).

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

Predictability evaluates the level of variability in each phase of flight as experienced by the airspace users[42]. In order to limit the impact from outliers, variability is measured as the difference between the 85th and the 15th percentile for each flight phase.

This captures 70% of flights and would be representative of one standard deviation if in fact travel times were normally distributed and not skewed due to delay. In targeting high levels of punctuality, airlines may in fact require "certainty" around a broader population of flights than 70% and therefore view the system as more "variable" and less predictable than what is shown below. However, the focus on this report is to compare the US and Europe using a common methodology.

Figure 3.2 shows that in both Europe and the US, arrival predictability is mainly driven by gate departure predictability. Despite the lower level of variability, improvement in the gate-to-gate phase – especially in the taxi-out and terminal airborne phase – can warrant substantial savings in direct operational and indirect strategic costs for the airlines.

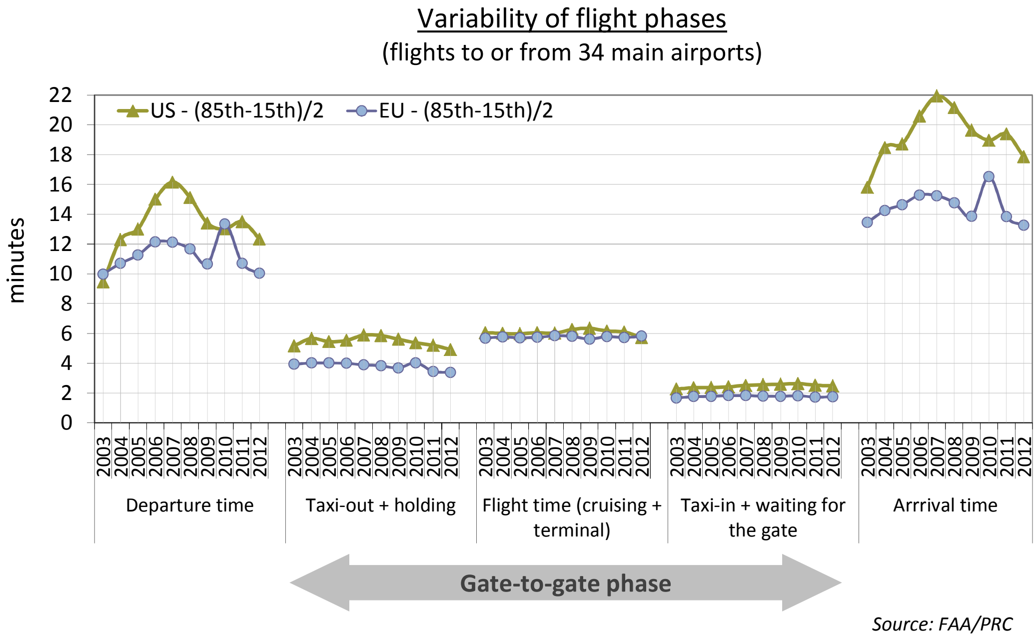


Figure 3.2: Variability of flight phases (2003-2012)

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

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

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

Figure 3.3 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 2.16).

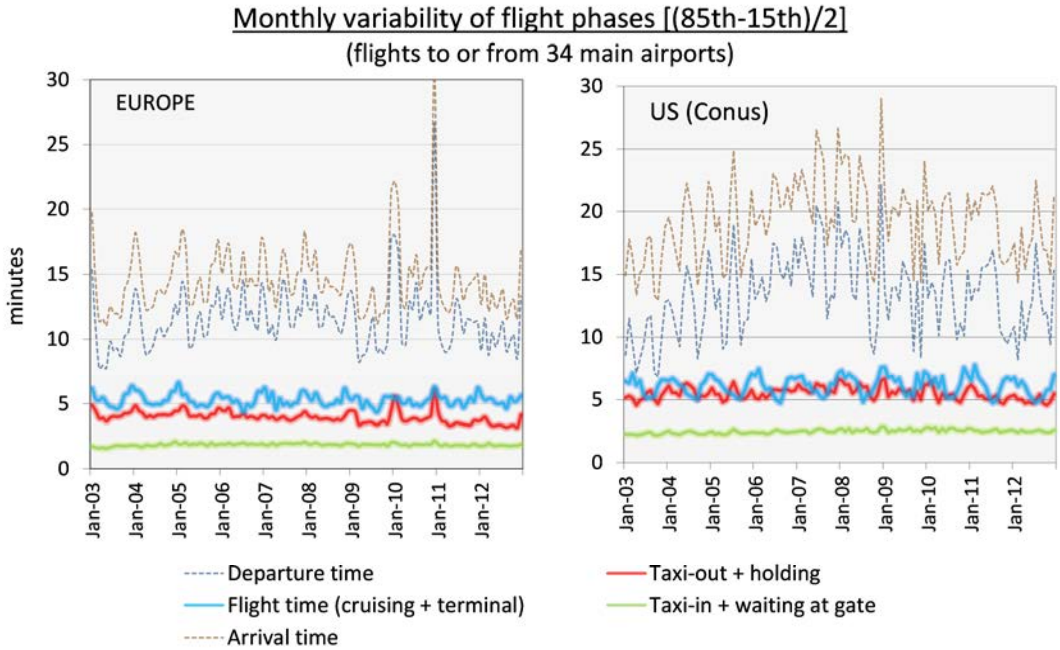


Figure 3.3: Monthly variability of flight phases (2003-2012)

In the departure phase, ATM can contribute to the variability through ATM-related departure holdings and subsequent reactionary delays on the next flight legs. The ATM-related departure delays are analysed in more detail in Section 3.3.1. Due to the interconnected nature of the aviation system, variability originating at constrained airports can propagate throughout the entire network [Ref. 27].

The gate-to-gate phase is affected by a multitude of variables including congestion (queuing at take-off and in TMA), wind, and flow management measures applied by ATM (see Chapter 2.3).

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

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

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

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

3.3 ATM-related efficiency by phase of flight

Efficiency generally relates to fuel efficiency or reductions in flight times of a given flight. The analyses in this chapter consequently focus on the difference between the actual travel times and an optimum time of the various phases of flight illustrated in Figure 3.1 on page 50. For the airborne phase of flight, this "optimum" may be a user preferred trajectory which would include both the vertical and horizontal profile.

3.3.1 DEPARTURE RESTRICTIONS (GROUND HOLDING)

As described in Section 2.3.2, the use of departure ATFM restrictions to balance capacity with demand differs between the US and Europe.

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

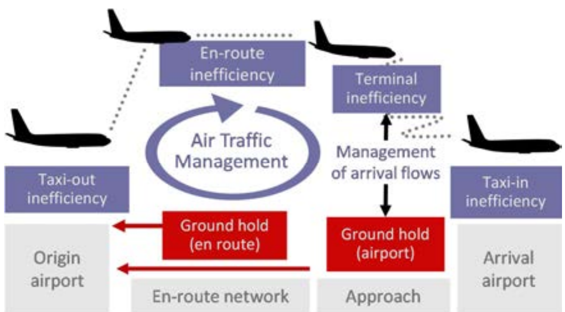


Table 3-1 compares ATM-related departure restrictions imposed in the two ATM systems due to en route and airport constraints. For comparability reasons, only EDCT and ATFM delays larger than 15 minutes were included in the calculation[43].

In 2012, flights to and from the main 34 airports account for 67% (Europe) and 66% (US) of the controlled flights but experience 78% and 91.6% of total ATFM/EDCT delay, respectively. The delays are calculated with reference to the estimated take-off time in the last submitted flight plan (not the published departure times in airline schedules).

As was expected, the share of flights affected by departure ground restrictions at origin airports differs considerably between the US and Europe. Despite a reduction from 5% in 2008 to 1.9% in 2012, flights in Europe are still almost 20 times more likely to be held at the gate for en route

[43] The FAA values are for EDCT delays greater than or equal to 15 minutes.

constraints than in the US where the percentage remained constant at 0.1% of flights. The significant improvement in Europe in 2012 is partly due to lower traffic levels than in 2008 but also due to an increased focus on this average ATFM en route delay per flight indicator in the first reference period of the Single European Sky performance scheme (2012-2014).

Table 3-1: ATM-related departure delays (flights to or from main 34 airports within region)

Only delays > 15 min. are included.		**EUROPE**			**US (CONUS)**		
		2008	**2010**	**2012**	**2008**	**2010**	**2012**
	IFR flights (M)	**5.5**	**5.0**	**4.9**	**9.2**	**8.6**	**8.4**
En route related delays >15min. (EDCT/ATFM)	% of flights delayed >15 min.	5.0%	5.8%	1.9%	0.1%	0.1%	0.1%
	delay per flight (min.)	1.4	1.9	0.5	0.1	0.1	0.1
	delay per delayed flight (min.)	28	32	28	63	48	62
Airport related delays >15min. (EDCT/ATFM)	% of flights delayed >15 min.	2.8%	3.1%	2.0%	2.4%	1.5%	1.4%
	delay per flight (min.)	0.9	1.1	0.6	1.9	1.1	1.0
	delay per delayed flight (min.)	32	36	32	76	71	69

For airport related delays, the percentage of delayed flights at the gate is more comparable in the US and in Europe. However the delay per delayed flight in the US is more than twice as high as in Europe.

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

In Europe, ground delays (ATFM) are used much more frequently for balancing demand with en route and airport capacity, which consequently leads to a higher share of traffic affected but with a lower average delay per delayed flight. The results in Table 3-1 are consistent with the differences in the application of flow management techniques described in Chapter 2.3.

Figure 3.4 shows the share of flights with ATM-related departure holdings for airport and en route constraints (ATFM/EDCT) larger than 15 minutes by month for the US and Europe.

As already observed in Table 3-1, the number of flights affected by en route related ATFM departure restrictions is much lower in the US than in Europe. En route related delays show similar summer peaks on both sides of the Atlantic but 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 (see large differences between summer and winter in Europe in Figure 2.5 and Figure 2.6 on page 13).

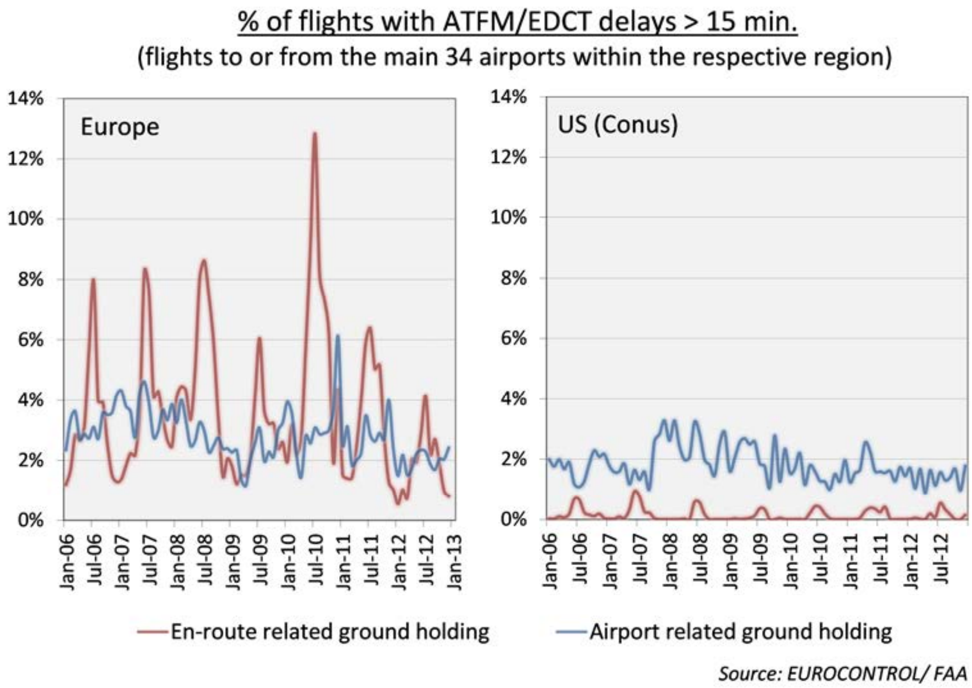


Figure 3.4: Evolution of EDCT/ATFM delays (2006-12)

Figure 3.5 compares airport related ATFM departure delays as attributed to the constraining destination airport by cause of delay. ATFM/EDCT departure delays can have various ATM-related (ATC capacity, staffing, etc.) and non-ATM related (weather, accident, etc.) reasons.

The figure clearly shows that the delays in the US are more concentrated and almost entirely weather related.

In 2012, approximately 82% of the delay is concentrated at five airports in the US with a comparatively high average delay per arrival: Newark (EWR), San Francisco (SFO), Philadelphia (PHL), New York (LGA), and Chicago (ORD). However, flights to four of the top five US airports also experienced the most substantial decreases in EDCT delay from 2008 to 2012.

Mapping of EDCT and ATFM delay causes

The table below shows how the differing delay codes for EU and US were mapped to produce Figure 3.5.

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

In Europe, most airport ATFM delay is also weather related but delays are more evenly spread across airports with London (LHR), Frankfurt (FRA), Amsterdam (AMS) and Zurich (ZRH) being the most constraining ones.

Overall, average EDCT delays to the 34 main US airports decreased by 50% in 2012 compared to 2008. The US airports with the greatest system impact in reducing average EDCT delays from 2008 to 2012 were ATL, ORD, JFK, LGA, PHL, and EWR. The airport responsible for adding the most to EDCT delay was SFO.

In the US, the airports which make up a large percentage of EDCT delays are also the airports having the highest capacity variation impact (see also Figure 2.35 on page 47). Since flights in the US are typically scheduled to VMC capacity, when weather conditions deteriorate, capacity at the airport is considerably reduced while demand levels remain the same. In case of a significant mismatch between demand and capacity, departure restrictions at the various origin airports are applied as a last resort.

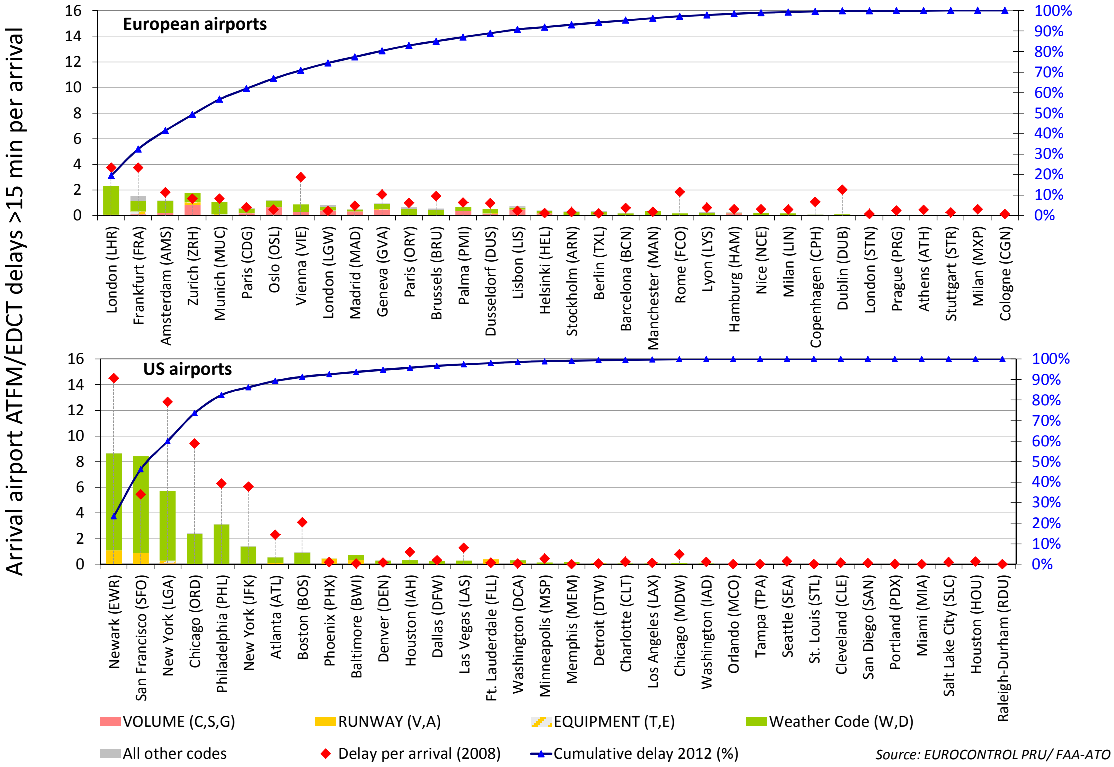


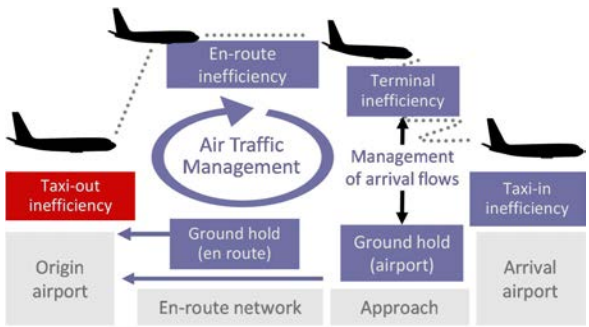
Figure 3.5: Breakdown of ATFM/ EDCT delay by destination airport and cause (2012)

The difference in ATFM strategy between the US and Europe is clearly visible. In the absence of en route sequencing in Europe, reducing ATFM delays (by releasing too many aircraft) at the origin airport when the destination airport's capacity is constrained potentially increases airborne delay (i.e. holding or extended final approaches). On the other hand, applying excessive ATFM delays risks underutilisation of capacity and thus, increases overall delay.

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

3.3.2 ATM-RELATED TAXI-OUT EFFICIENCY

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



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 departure flow restrictions, aircraft type, and remote de-icing, to name a few. Of these aforementioned causal factors, the take-off queue size[44] is considered to be the most important one for taxi-out efficiency [Ref. 28].

In the US, the additional time observed in the taxi-out phase also includes some delays due to local en route departure and MIT restrictions. In Europe, the additional time might also include a small share of ATFM delay which is not taken at the departure gate, or some delays imposed by local restriction, such as Minimum Departure Interval (MDI).

In order to get a better understanding, two different methodologies were applied in Figure 3.6 and Figure 3.7. While the first method is simpler, it allows for the application of a consistent methodology. The method uses the 20th percentile of each service (same operator, airport, etc.) as a reference for the "unimpeded" time and compares it to the actual times. This can be easily computed with US and European data. The breakdown by airport in Figure 3.7 is based on the more sophisticated methodologies by each of the performance groups in the US and Europe[45].

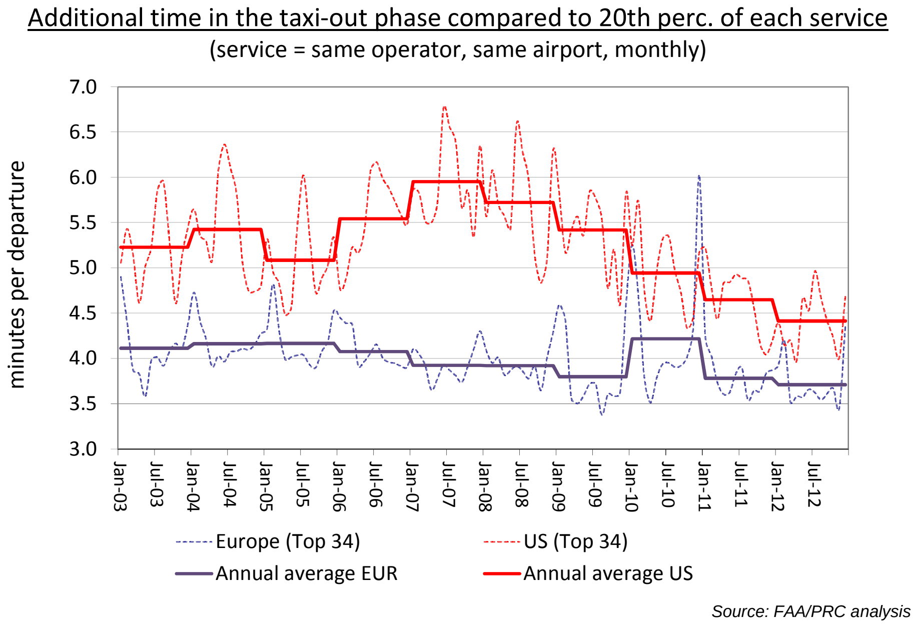


Figure 3.6: Additional times in the taxi-out phase (system level) [2003-2012]

Three interesting points can be drawn from Figure 3.6:

- On average, additional times in the taxi-out phase appear to be higher in the US with a maximum difference of approximately 2 minutes more per departure in 2007. Between 2008 and 2012, US performance improved continuously which narrowed the gap between the US and Europe.
- In Europe, performance remained relatively stable but showed a notable deterioration in 2010, which was mainly due to severe weather conditions in winter.
- Seasonal patterns emerge, but with different cycles in the US and in Europe. Whereas in Europe the additional times peak during the winter months (most likely due to weather conditions), in the US the peak is in the summer which is most likely linked to congestion.

44 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.

45 A description of the respective methodologies can be found in the Annex of the 2010 report [Ref. 7].

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

The high-level result in Figure 3.6 is driven by contrasted situations among airports. Figure 3.7 shows a more detailed comparison of additional time in the taxi-out phase at the major airports in Europe and the US. Although some care should be taken when comparing the two indicators due to slightly differing methodologies, Figure 3.7 tends to confirm the trends seen in Figure 3.6.

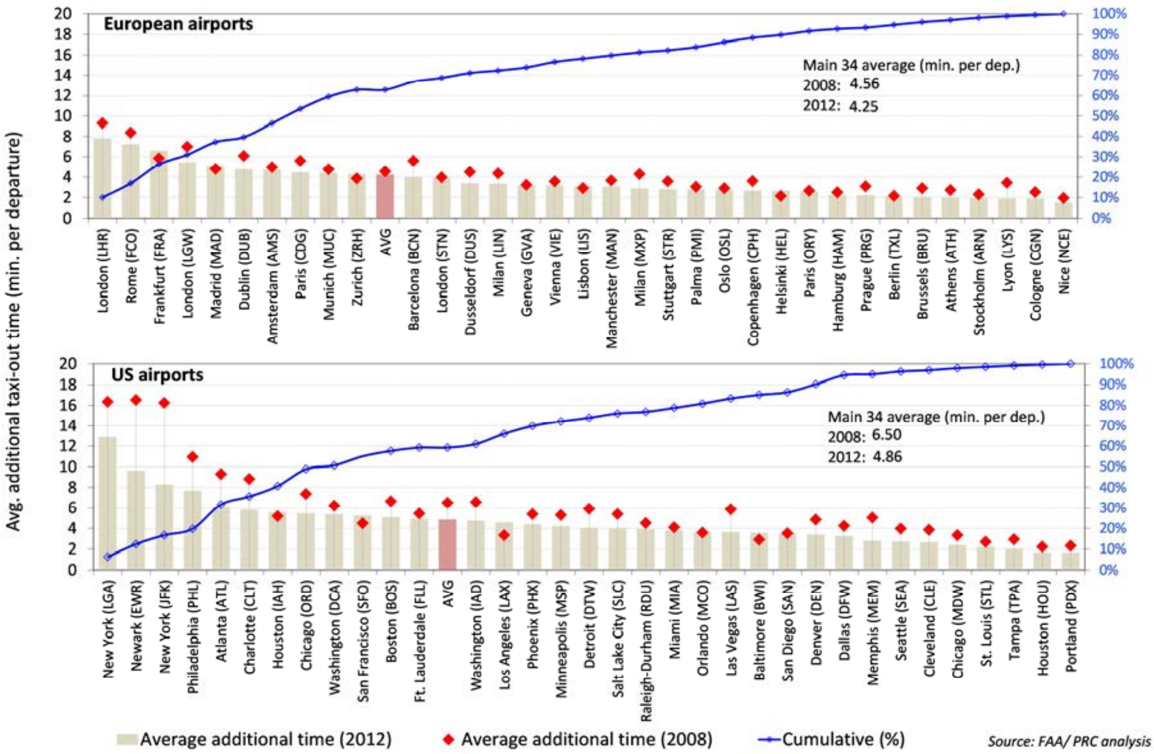


Figure 3.7: Additional time in the taxi-out phase by airport (2012)

Between 2008 and 2012, taxi-out performance improved at almost all US airports whereas the variations at European airports are less prominent. The significant improvement in the US between 2008 and 2012 is due to a number of factors (use of ASDE-X[46] surveillance system, additional departure headings, airline initiatives, and the 3-hour tarmac rule[47]) aimed at improving taxi-out performance at the most penalising airports in the New York area.

Although the impact of ANSPs on total additional time is limited when runway capacities are constraining departures, in Europe Airport Collaborative Decision Making (A-CDM) initiatives try to optimise the departure queue by managing the pushback times.

46 Airport Surface Detection Equipment — Model X (ASDE-X) tracks the movement of aircraft and vehicles on runways and taxiways, and aircraft as they are on approach to the airport for landing. The use of data for controllers help them more efficiently direct aircraft to the active runways, freeing taxiways and enabling smoother movement of aircraft around the airport.

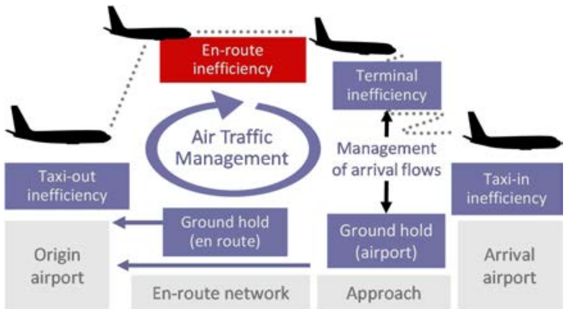
47 The rule prohibits U.S. airlines operating domestic flights from permitting an aircraft to remain on the tarmac for more than three hours without deplaning passengers, with exceptions allowed only for safety or security or if air traffic control advises the pilot in command that returning to the terminal would disrupt airport operations.

The aim is to keep aircraft at the stand to reduce additional time and fuel burn in the taxi-out phase to a minimum by providing only minimal queues and improved sequencing at the threshold to maximise runway throughput. These departure delays at the gate are reflected in the departure punctuality measures. However, the ATM part due to congestion in the taxiway system is presently difficult to isolate with the available data set.

3.3.3 En route flight efficiency

This section evaluates en route flight efficiency in the US and Europe. En route flight efficiency measures assess actual flights against an ideal or benchmark condition.

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



The focus of this section is on the horizontal component of the en route phase.

Ideal altitudes are highly affected by external factors such as aircraft specific weight and performance as well as turbulence and other weather factors. Furthermore, the horizontal component is, in general of higher economic and environmental importance than the vertical component across Europe as a whole [Ref. 29].

Nevertheless there is scope for further improvement, and work on vertical en route flight efficiencies would provide a more complete picture.

In order to ensure the safe, orderly and expeditious flow between airports, the controlled airspace is made up of a complex and dynamic network of routes, waypoints, sectors and centres. Airspace users file a flight plan based on a number of criteria including route availability, minimum time, fuel burn, wind and weather conditions, airspace congestion, and user charges[48].

The measure of en route flight efficiency in this report is limited to the horizontal flight path and is based on the comparison of the actual flight trajectory length to a benchmark achieved distance for each flight (see grey box for more details). It is acknowledged that this distance based approach does not necessarily correspond to the "optimum" trajectory when meteorological conditions or economic preferences of airspace users are considered.

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

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

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

In order to ensure consistency between the flight efficiency indicators used in the Single European Sky performance scheme (see also grey box on page 2) and this report and to further improve the quality of the analysis, the methodology used for the computation of horizontal en route fight efficiency has been refined in this edition of the US/ Europe comparison.

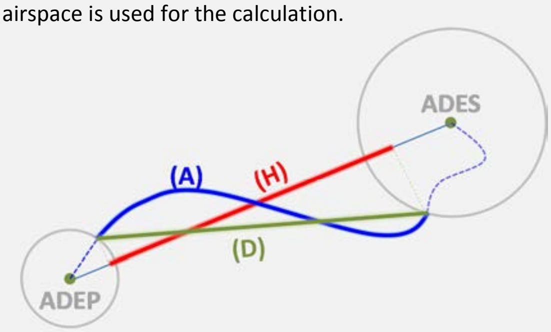
For a flight, the "inefficiency" is the difference between the length of the analysed trajectory (filed flight plan or actual flown) and an "achieved" reference distance (see also grey box). Where a flight departs or arrives outside the respective airspace, only that part inside the airspace is considered.

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

Horizontal en route flight efficiency

Horizontal en route flight efficiency compares the length of flight trajectories (A) to the "achieved" reference distance (H).

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



The refined methodology enables to better quantify between local inefficiency (deviations between entry and exit point within a respective airspace or State) and the contribution to the network (deviation from GCD between origin and destination airport).

The full methodology is described in more detail in the meta data which is available online [Ref. 30].

The flight efficiency in the last 100NM before landing which also includes airborne holdings is addressed in the next section of this report (3.3.4).

The level of total horizontal en route flight inefficiency [(A-H)/H] for flights to or from the main 34 airports in Europe in 2012 was 2.98% compared to 2.73% in the US. An "inefficiency" of 5% for a flight of 1000NM means for instance that the extra distance was 50NM (alternatively, this could be expressed as a flight "efficiency" of 95%).

Figure 3.8 depicts the en route extension for flights to/from the main 34 airports with total flight efficiency broken into terminal effects [(D-H)/H] and en route effects [(A-D)/H].

The flight population is for within the respective region (Intra Europe, US CONUS) with the respective share of flights shown at the bottom of Figure 3.8. For both the US and Europe, flight inefficiency decreases relative to the flight distance.

Overall, horizontal en route flight in-efficiency on flights to or from the main 34 airports in Europe is 0.25% higher than in the US in 2012. Due to the changes in methodology and data in Europe, the figure is not directly comparable to the figures published in previous editions of the report.

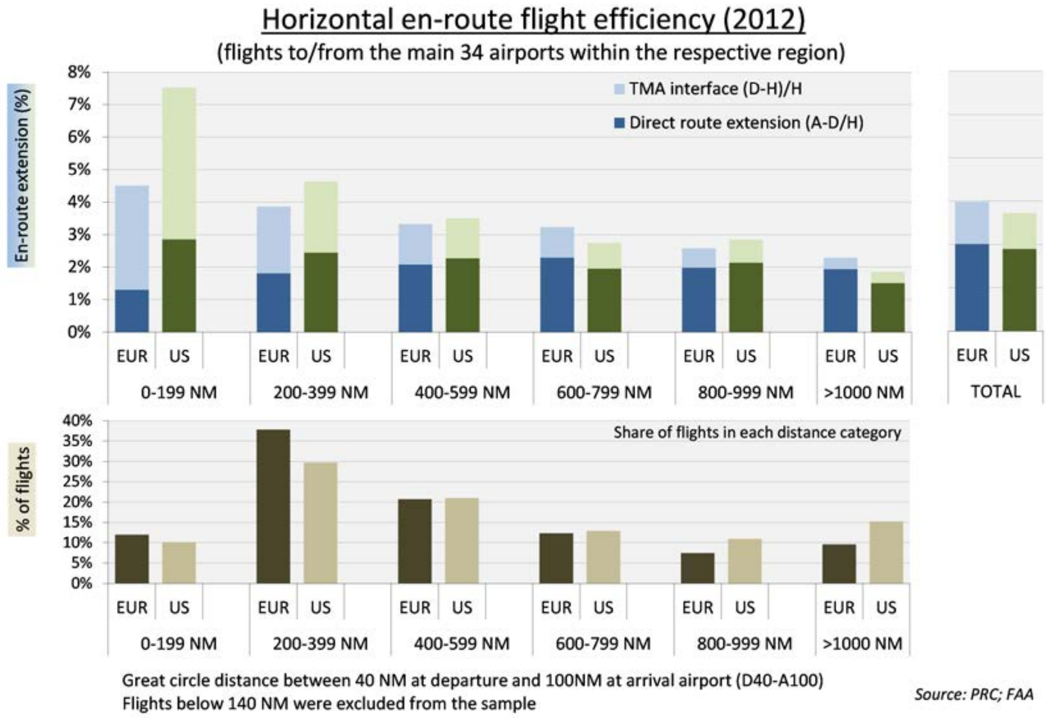


Figure 3.8: Comparison of total en route extension by component (2012)

The high-level result in Figure 3.8 is driven by contrasted situations among airports. Figure 3.9 shows the direct en route extension on flights arriving at the main US and European airports. The results show both magnitude (A-D) and percent [(A-D)/H]. Note that US flights for this population are longer on average than Europe. Identical A-D values would result in a lower percent inefficiency for the US. Direct route extension (A-D) is predominantly driven by ATC routing (flow measures such as MIT but also more direct routing), route utilisation (route selection by airspace users), and en route design (route network).

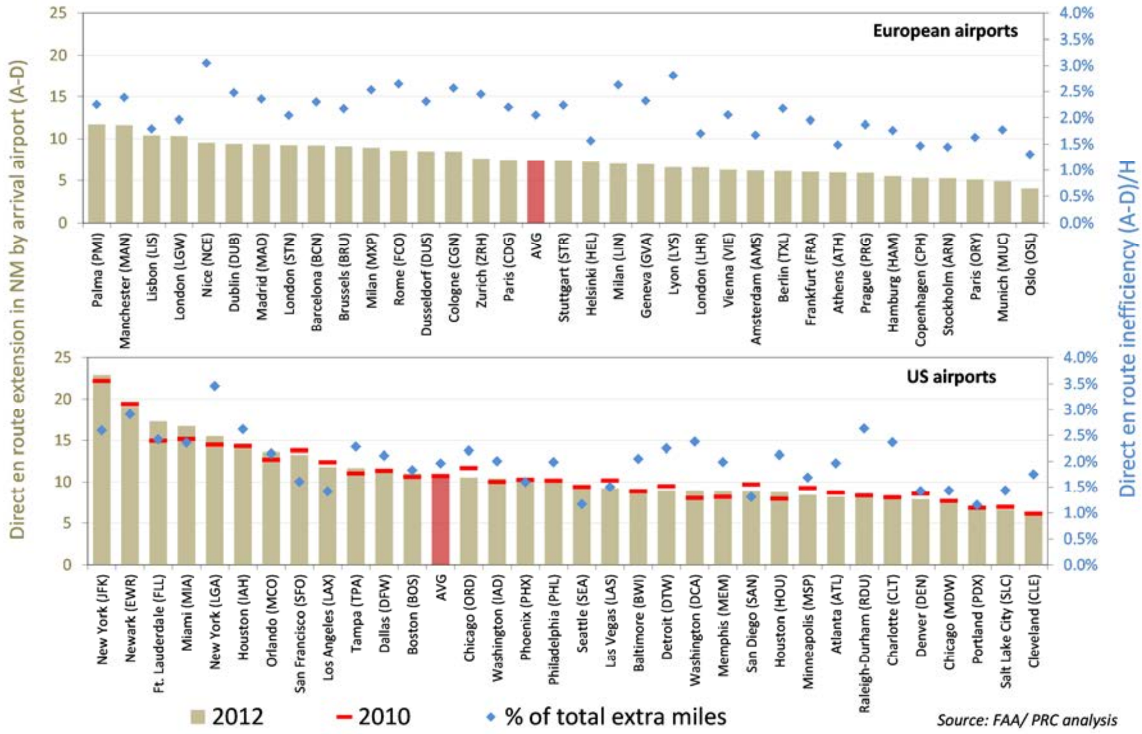


Figure 3.9: Direct en route extension by destination airport

US airports show some clustering and patterns when values are summed by destination airport, particularly for New York Area and Florida airports. In assessing specific city pairs for these facilities, three causal reasons emerge. Almost all direct flights between the New York area and Florida airports would require flight through special use airspace. This is illustrated in Figure 3.12 below. Many of the flights to East Coast and West Coast airport destinations involve long transcontinental flight where large values do not translate into high percentages. Furthermore, these transcontinental flights require much more scrutiny as the ideal flight would consider winds and not be limited to direct flight. Lastly, existing route design into the New York area does not allow for direct flights for some key city pairs (DFW and IAH to New York Area). This may be due to congestion caused by high traffic and the presence of major airports located close together. Alternatively, it may be possible to fly more direct to the New York area as the FAA makes continued improvements to airspace design and more advanced traffic flow management is implemented.

Compared to 2010[49], the changes are small in the US and changes need to be seen in the context of increasing flight lengths (see Figure 2.4 on page 12).

In absolute terms, the average additional mileage in the US is higher due to the longer flights but in relative terms the level of flight inefficiency is lower (i.e. inefficiency per flown distance). This is consistent with the observation in Figure 3.8.

<u>Opportunities and Limitations to improving horizontal flight-efficiency</u>

While there are economic and environmental benefits in improving flight efficiency, there are also inherent limitations. Trade-offs and interdependencies with other performance areas such as safety, capacity, and environmental sustainability as well as airspace user preferences in route selection due to weather (wind optimum routes), route availability, or other reasons (differences in route charges[50], avoid congested areas) affect en route flight efficiency.

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

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

- <u>Basic rules of sectorisation and route design</u>. For safety reasons, a minimum separation has to be applied between aircraft;
- Systematisation of traffic flows to reduce complexity and to generate more capacity;

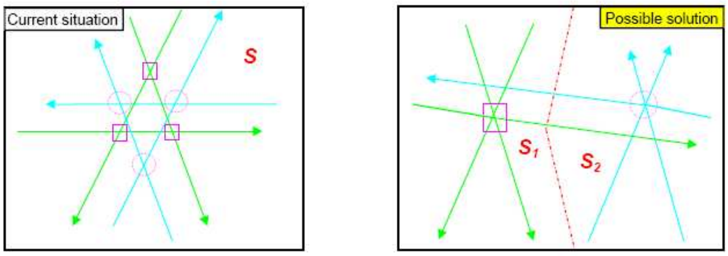


Figure 3.10: Systematisation of traffic flows to reduce structural complexity

[49] The new surveillance data based used for the analysis in Europe is only consistently available as of 2011.

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

- Strategic constraints on route/ airspace utilisation. Figure 3.11 shows a potential route extension on flights between Dallas Fort-Worth (DFW) and Newark (EWR). This example is consistent with other Texas to New York Area traffic. In these cases, the more northern traffic is joining a stream from ORD/MDW which is nearly direct.

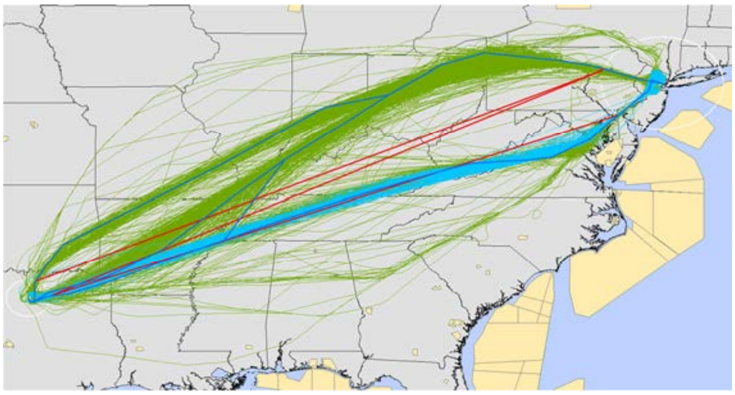


Figure 3.11: Flows into congested airspace

- Figure 3.12 illustrates the impact of Special Use Airspace (SUA) on flight efficiency. The figure on the left shows the 10 most penalising city pairs in Europe in terms of total additional distance for May 2013. The filed routes (flight plan) are shown in red and the actual trajectories are indicated in blue. The SUA areas (upper airspace) are shown in brown. Although direct routing given by ATC provides a number of shortcuts, the impact of the SUA on traffic flows is clearly visible.

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

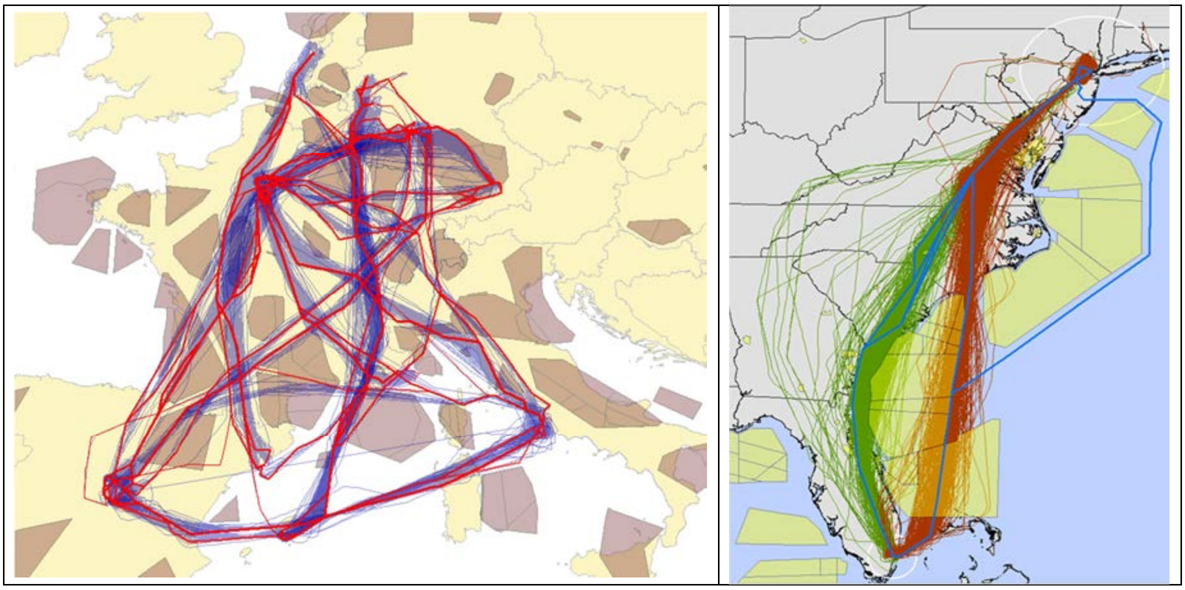


Figure 3.12: Impact of Special Use Airspace (SUA) on horizontal flight efficiency

- Interactions with major airports. Major terminal areas tend to be more and more structured. As traffic grows, departure traffic and arrival traffic are segregated and managed by different sectors. This TMA organisation affects en route structures as over-flying traffic has to be kept far away, or needs to be aligned with the TMA arrival and departure structures (see Figure 3.13).

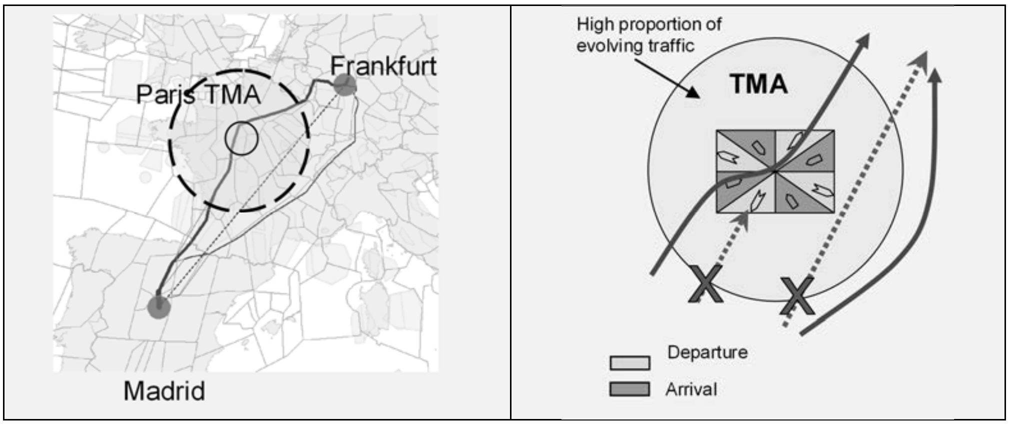


Figure 3.13: Impact of major terminal areas on traffic flows

- Route availability and route planning. Once routes are made available for flight planning, their utilisation is in the hand of flight dispatchers and flow managers. Many airlines prepare flight plans based on fixed route catalogues and do not have the tools/resources to benefit from shorter routes when available. Aircraft operators often rely on tactical ATC routings.

- In Europe, en route flight efficiency is also affected by the fragmentation of airspace (airspace design remains under the auspices of the States) [Ref. 31].

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

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

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

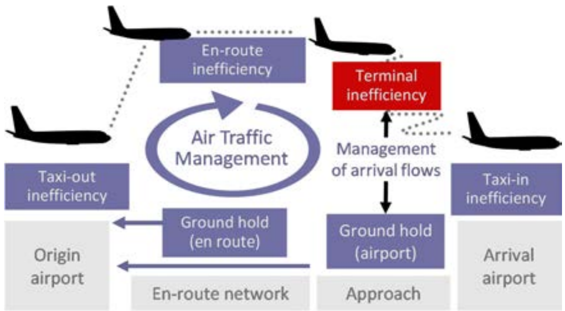
3.3.4 FLIGHT EFFICIENCY WITHIN THE LAST 100 NM

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

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

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

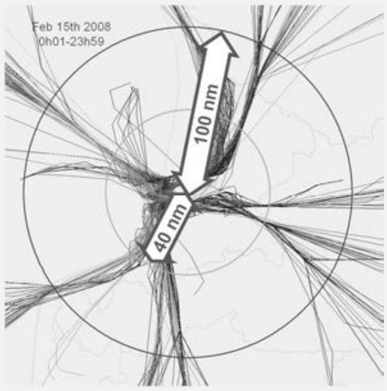
The actual transit times within the 100 NM ASMA ring are affected by a number of ATM and non-ATM-related parameters including, inter alia, flow management measures (holdings, etc.), airspace design, airports configuration, aircraft type environmental restrictions, and in Europe, to some extent the objectives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



<u>Arrival Sequencing and Metering Area (ASMA)</u>

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.



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

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

Figure 3.14 shows the average additional time by airport within the last 100 NM for the US and Europe in 2008 and 2012. At system level, the additional time within the last 100 NM was similar in 2008 but is lower in the US in 2012. However, the picture is contrasted across airports.

In Europe, London Heathrow (LHR) is a clear outlier[51], having by far the highest level of

51 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.

additional time within the last 100 NM, followed by Madrid (MAD) and Frankfurt (FRA) which shows less than half the level observed at London Heathrow. London (LHR) alone accounted for almost 20% of all the additional time observed at the main 34 European airports in 2012.

The US shows a less contrasted picture with many airports improving between 2008 and 2012. Similar to taxi-out performance, there is still a notable difference for the airports in the greater New York area, which show the highest level of additional time within the last 100 NM.

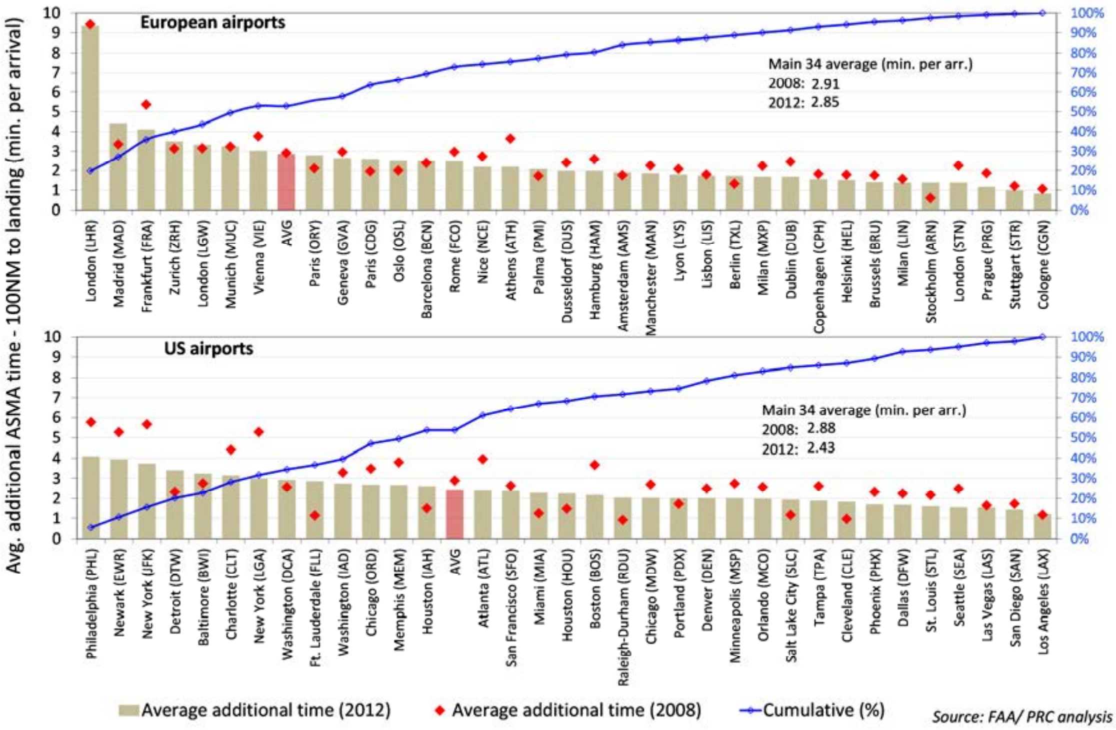


Figure 3.14: Estimated average additional time within the last 100 NM (2012)

Due to the large number of variables involved, the direct ATM contribution towards the additional time within the last 100 NM is difficult to determine. One of the main differences of the US air traffic management system is the ability to maximise airport capacity by taking action in the en route phase of flight, such as in trail spacing.

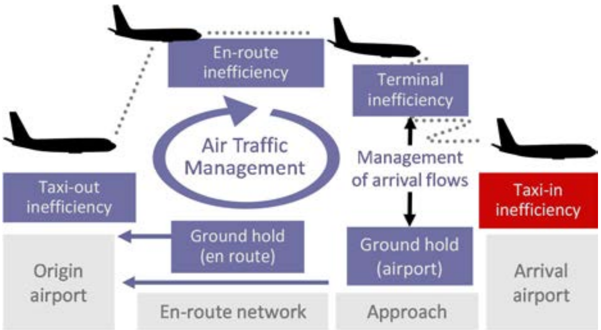
In Europe, the support of the en route function is limited and rarely extends beyond the national boundaries. Hence, most of the sequencing and holding is done at lower altitudes around the airport. Additional delays beyond what can be absorbed around the airport are taken on the ground at the departure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

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

The impact of the respective air traffic management systems on airport capacity utilisation in the US and in Europe is not quantified in this report, but would be a worthwhile subject for further study. However, benchmarking the two systems would require a common understanding of how capacity and throughput is measured for comparable airports.

3.3.5 TAXI-IN EFFICIENCY

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



The analysis in Figure 3.15 mirrors the methodology applied for taxi-out efficiency in Figure 3.6. 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.

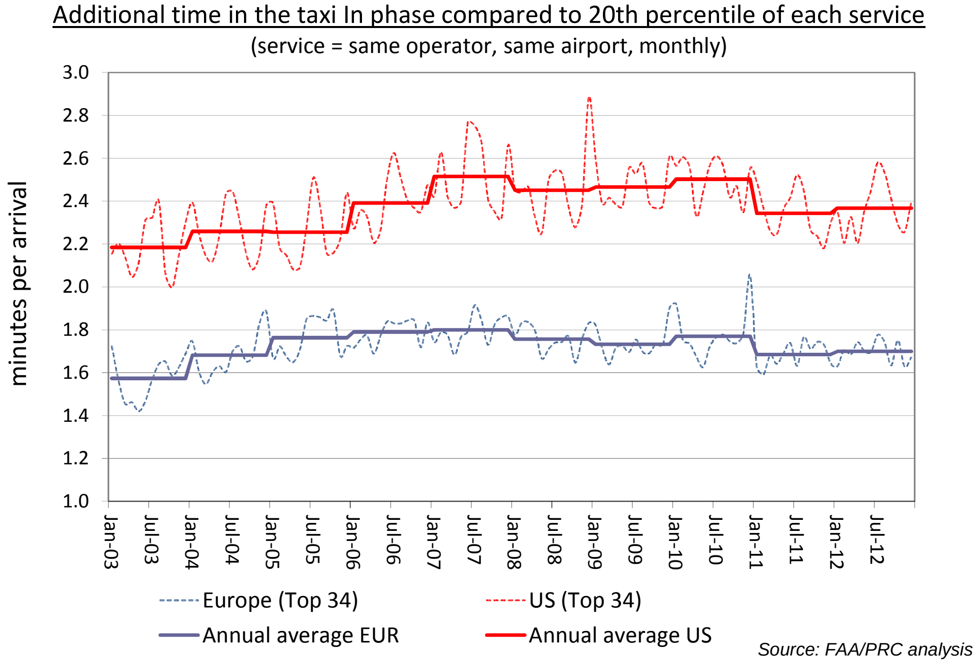


Figure 3.15: Additional times in the taxi-in phase (system level) [2003-2012]

As can be observed in Figure 3.15, at system level, additional time in the taxi-in phase is slightly higher in the US than in Europe but remains relatively stable over time in both systems. Some seasonal patterns are visible (particularly in the US) where an increase can be noted during summer.

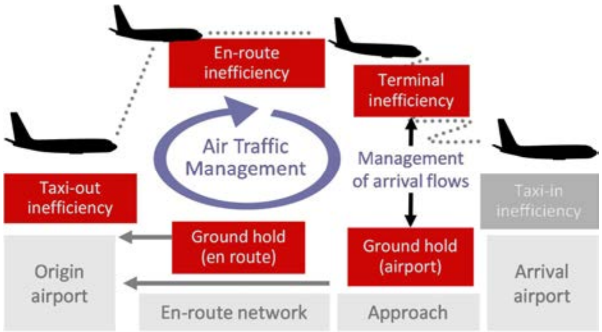
The taxi-in phase and hence the performance measure is influenced by a number of factors, most of which cannot be directly influenced by ATM (i.e. gate availability, apron limitations etc.).

It was included in the comparison for completeness reasons but, due to the number of factors outside the direct control of ATM, it was not included in the estimated benefit pool actionable by ATM in Chapter 3.4.

3.4 Summary of main results & Estimated benefit pool actionable by ATM

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

This section provides a summary of the estimated benefit pool for a typical flight, based on the analysis of traffic from and to the 34 main airports in Europe and the US.



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

- Not all delay is to be seen as negative. A certain level of delay is necessary and sometimes even desirable if a system is to be run efficiently without underutilisation of available resources.
- Due to the stochastic nature of air transport (winds, weather) and the way both systems are operated today (airport slots, traffic flow management), different levels of delay may be required to maximise the use of scarce capacity. There are lessons however to be learned from both sides.
- A clear-cut allocation between ATM and non-ATM related causes 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 the distribution of delay between air and ground and thus on costs to airspace users (see also Figure 3-16 on page 70).
- The approach measures performance from a single airspace user perspective without considering inevitable operational trade-offs, and may include dependencies due to environmental or political restrictions, or other performance affecting factors such as weather conditions.
- ANSP performance is inevitably affected by airline operational trade-offs on each flight. The 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.).
- 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.

3.4.1 ESTIMATED BENEFIT POOL ACTIONABLE BY ATM

By combining the analyses for individual phases of flight in Section 3.3, an estimate of the "improvement pool" actionable by ATM can be derived. It is important to stress that this "benefit pool" represents a theoretical optimum (averages compared to unimpeded times), which is not achievable at system level due to inherent necessary (safety) or desired (capacity) limitations[52].

Moreover, the inefficiencies in the various flight phases (airborne versus ground) have a very different impact on airspace users in terms of predictability (strategic versus tactical – percent of flights affected) and fuel burn (engines on versus engines off).

Figure 3-16 provides an overview of the ATM-related impact on airspace users' operations in terms of time, fuel burn and associated costs.

ATM-related impact on airspace users' operations			Impact on punctuality	Engine status	Impact on fuel burn/ CO_2 emissions	Impact on airspace users' costs
ATM related inefficiencies	At stand	Airport ATFM/EDCT En route ATFM/EDCT	High	OFF	Quasi nil	Time
	Gate-to-gate	Taxi-out phase En route phase Terminal area	Low/ moderate	ON	High	Time + fuel

Figure 3-16: Impact of ATM-related inefficiencies on airspace users' operations

For ATM-related delays at the gate (EDCT/ATFM departure restrictions) the fuel burn is quasi nil but the level of predictability in the scheduling phase for airspace users is low as the delays are not evenly spread among flights. Hence, the impact of those delays on on-time performance and associated costs to airspace users is significant (i.e. "tactical" delays) but the impact on fuel burn and the environment is negligible. It is however acknowledged that – due to the first come, first served principle[53] applied at the arrival airports - in some cases aircraft operators try to make up for ground delay encountered at the origin airport through increased speed which in turn may have a negative impact on total fuel burn for the entire flight.

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

The environmental impact of ATM on climate is closely related to operational performance

[52] 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.

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

which is largely driven by inefficiencies in the 4-D trajectory and associated fuel burn. There is a close link between user requirements to minimise fuel burn and reducing greenhouse gas emissions[54].

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

Previous research [Ref. 32] shows that at system level, the total estimated benefit pool actionable by ATM and associated fuel burn are of the same order of magnitude in the US and Europe (approx. 6-8% of the total fuel burn).

Table 3-2 summarises the current best estimate of the ATM-related impact on operating time. The inefficiency estimate is based on the best available radar trajectories and airline reported surface times available to FAA and EUROCONTROL.

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

Estimated benefit pool actionable by ATM

As outlined in Section 2.1, the two ATM systems differ in terms of average flight lengths (see Figure 2.4 on page 12) and aircraft mix (see Figure 2.7 on page 14).

Those differences would lead to different results, as the "inefficiencies" depend on travelled distance and aircraft type.

For comparability reasons, the calculations in Table 3-2 are based on averages representing a "standard" aircraft in the system.

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

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

Actual fuel burn depends on the respective aircraft mix (including mix of engines on the same type of aircraft, operating procedures) and therefore varies for different traffic samples. For comparability reasons, estimated benefit pool actionable by ATM in Table 3-2 is based on the assumption that the same aircraft type performs a flight of 450NM in the en route phase in the US and the European ATM system (see also grey box for more information).

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

Overall, ATM performance in the US improved at a higher rate than in Europe over the past five years making the two ATM systems comparable in terms of total estimated average additional time in 2012. The distribution of the estimated benefit pool along the phase of flight is consistent with the differences in flow management strategies described throughout the report.

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

Table 3-2: Estimated benefit pool actionable by ATM (2012 vs. 2008)

Estimated benefit pool actionable by ATM for a typical flight (flights to or from the main 34 airports)		**Estimated average additional time (min.)**						**Fuel burn**	**Estimated excess fuel burn (kg)**[55]			
		EUR			US			engines	EUR		US	
		2008	**2012**		**2008**	**2012**			**2008**	**2012**	**2008**	**2012**
Holding at gate per departure (only delays >15min. included)	en route-related (% of flights)	1.4 (5.0%)	0.5 (1.9%)	↓	0.07 (0.1%)	0.08 (0.1%)	↗	OFF	≈0	≈0	≈0	≈0
	airport-related (% of flights)	0.9 (2.8%)	0.6 (2.0%)	↓	1.9 (2.4%)	1.0 (1.4%)	↓	OFF	≈0	≈0	≈0	≈0
Taxi-out phase (min. per departure)		4.6	4.3	↓	6.5	4.9	↓	ON	68	64	98	73
Horizontal en route flight efficiency		2.4[56]	1.9	↓	1.9	1.7	↓	ON	108	86	87	79
Terminal areas (min. per arrival)		2.91	2.85	↓	2.88	2.43	↓	ON	119	117	118	100
Total estimated benefit pool		12.1	10.1	↓	13.3	10.1	↓		296	266	303	252

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

For the US, a remarkable improvement of taxi-out efficiency and a substantial reduction of airport related EDCT (gate) delays can be observed between 2008 and 2012. The notable reduction in the gate to gate phase (mainly taxi-out efficiency) not only considerably reduced the additional time but also additional fuel burn.

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

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

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

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

4 CONCLUSIONS

This report represents the third in a series of operational performance reports between the FAA and Europe. The first report provided trends through 2008 while the current report focuses on changes that have occurred from 2008-2012. This section summarises the high level conclusions for the key fundamental changes that have occurred including those that are most believed to affect performance.

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

4.1 Staffing and Infrastructure

The method of reporting air traffic controller counts has changed over the assessment period as both groups learned more about the different classifications and how best to make the comparison. One key point in making this comparison is to use the ATCOs in operation definition employed by the EUROCONTROL ACE and CANSO benchmarking reports. Under this definition, full time equivalent (FTE) ATCOs are defined as participating in an activity that is either directly related to the control of traffic or is a necessary requirement for ATCOs to be able to control traffic. Such activities include manning a position, refresher training and supervising on-the-job trainee controllers, but do not include participating in special projects, teaching at a training academy, or providing instruction in a simulator. This count does not include controllers designated as “on-the-job training” in Europe or as a “developmental” at the FAA. Using this definition, full time ATCOs grew for both Europe and the US from 2008-2012. However, the US tends to operate with 23 percent less full time ATCOs than Europe in both 2008 and 2012.

This percentage narrows to 10% less ATCOs when FAA developmental controllers are considered. According to the FAA controller workforce plan, a “developmental” controls live traffic with an ability to staff a limited subset of the positions at a facility. FAA controller workforce staffing levels make adjustments based on planned retirements and training requirements for developmentals which can range from 2-3 years. Although there are undoubtedly less total ATCOs in the US than in Europe, more work is needed to compare European “on-the-job training” controllers with FAA developmentals in order to draw firmer conclusions on the staffing comparisons in both systems.

For the ATM system, Europe continues to operate with more physical facilities than the US. The European study region comprises 37 ANSPs (and a similar number of different regulators) and 63 Area Control Centres (ACC). In contrast, the US has one ANSP and 20 Air Route Traffic Control Centres (ARTCC). The US has 162 Terminal Radar Approach Control Facilities (TRACONs) and Combined Facilities servicing a number of airports each, compared to Europe’s 260 Approach control units (APPs). Some TRACONs in the US are so large in terms of size of airspace and service provided that they could be compared to some of the lower airspace en route ACCs in Europe.

Hence, in Europe many issues revolve around the level of fragmentation and its impact on ATM performance in terms of operations and costs. Although there are a number of initiatives aimed at reducing the level of fragmentation (development of FABs under Single European Sky initiative), ATM is still largely organised according to national boundaries which is reflected by the considerably higher number of en route centres than in the US and a diversity of flight data processing systems.

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

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

4.2 External Interdependencies (Demand, Capacity and Weather)

In terms of traffic growth, there was a notable decoupling in 2004 when the traffic in Europe continued to grow while US traffic started to decline. At system level, European traffic continued to grow by 13.9% between 2004 and 2008. From 2008 to 2012, traffic decreased in both systems with Europe declining by 5.3% and the US by 10.5% as a consequence of the economic crisis.

However, not all US airports experienced a decrease. The US airports experiencing notable increases from 2008 to 2012 include San Francisco (SFO), Charlotte (CLT), Miami (MIA), and Reagan National (DCA). During the more recent period from 2010 to 2012, the New York area airports also saw moderate increases in addition to Los Angeles (LAX), Las Vegas (LAS), and Houston (HOU).

In Europe, there is a stronger emphasis on strategic planning. Traffic at major airports is usually regulated in terms of volume and concentration months before the actual day of operations. On the day of operations, the primary means for resolving en route and airport capacity shortfalls is the application of departure restrictions (ATFM slots) to delay aircraft on the ground at the various origin airports. The support of the en route function is limited and rarely extends beyond the national boundaries. 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.

In the US, demand levels at most US airports are self-controlled by airlines and adapted depending on the expected cost of delays. As a result, the ATM system appears to be more flexible and geared towards maximising airport throughput but is more susceptible to service disruptions (such as weather) which potentially results in major delays and cancellations. Furthermore, the US system appears to have fewer en route capacity problems and fewer constraints due to Special Use Airspace and therefore, the capability to absorb large amounts of time through speed control and path stretching. This allows ATC greater flexibility in using en route airspace to achieve the metering required by terminal manoeuvring areas (TMA) and airports. Whereas in Europe departure restrictions are used as a primary means for en route and airport capacity shortfalls, in the US they are only used as a last resort when the less constraining flow measures are insufficient. 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 miles in trail spacing.

The capacity declaration process at European airports arguably results in schedule limitations closer to IMC capacity while in the US, where demand levels are controlled by airlines and capacity is managed more tactically, the airports operate closer to VMC capacity. The impact of the respective air traffic management systems on airport capacity utilisation in the US and in Europe is not quantified in this report, but would be a worthwhile subject for further study. However, benchmarking the two systems would require a common understanding of how capacity and throughput is measured for comparable airports.

In this report update, FAA and EUROCONTROL included a new side-by-side comparison of capacity and throughput in the two systems. The initial assessment revealed several noteworthy differences in how capacity is set and in turn, how operations are scheduled to respond to a capacity restriction.

In Europe, the declared airport capacity is a limit typically set as early as six months before the day of operations through a coordination process involving the airport managing body, the airlines, and local ATC providers to best achieve a compromise of maximising airport infrastructure utilisation and maintaining an acceptable quality of service. In the US, ATC capacities reflect tactical, real time values based on number of operations scheduled, available runway configuration, and weather, among other considerations.

Overall, the average airport arrival capacity appears to be higher in the US compared to Europe. In the US and Europe, airports with one or two active runways show similar levels of peak arrival capacity. However for airports with three or more active runways, the peak arrival capacity at US airports appear to be much higher than at European airports with the same number of active runways. In addition, there are five US airports having five active runways or more that cannot be compared directly to a European equivalent.

Capacity variation tends to be a key indicator of airports that show the most room for performance improvements. For the study period from 2008 to 2012, despite overall falling traffic levels in the US, many facilities managed to call a higher average declared capacity, which may in part be tied to improved weather or changing airport infrastructure. Memphis (MEM), Cleveland (CLE), and St. Louis (STL) experienced the greatest decline in traffic from 2008 to 2012, but all three airports experienced increases in average arrival rates called at the facility. Airports such as Baltimore (BWI) and Fort Lauderdale (FLL) saw drastic drops in capacity due to runway closures and reconstruction projects in 2012. San Francisco (SFO) and Charlotte (CLT) showed both growth in IFR traffic and airport capacity from 2008 to 2012.

Overall, the US experienced improved weather conditions in terms of ceiling and visibility from 2010 to 2012. From 2010 to 2012, there was a slight increase in IMC operations in the northeast affecting the New York area airports and Philadelphia (PHL). Better weather along with falling demand influenced improvements in US performance described in the next section. However, it remains difficult to proportion the share of these improvements to the known causal influence of weather, capacity or ATM improvements.

4.3 Operational Performance Measures

In large part, operational improvements were observed on both sides of the Atlantic between 2008 and 2012. However, this improvement has to be seen in the context of declining traffic levels as well as several of the other external dependencies described above.

On-time performance improved from 2008-2012 for both US and Europe. Although performance evolved differently over the past years, arrival punctuality in 2012 is at a similar level (≈83%) for both the US and Europe. This improvement varies by airport with the most improved US airports being New York La-Guardia (LGA), New York JFK (JFK), Miami (MIA), Chicago O'Hare (ORD), and Atlanta (ATL). Factors contributing to an improvement in on-time performance include the implementation of schedule limitations in the New York area airports, runway improvement projects that result in improved capacity, improved Air Traffic Service (ATS), policy, and airline practice. In Europe, Dublin (DUB), Milan Linate (LIN), Rome Fiumicino (FCO), and Athens (ATH) show the highest improvements compared to 2008. On-time performance is the 'end product' of complex interactions involving many stakeholders and arrival punctuality is influenced by propagated delay from previous flight legs and performance of previous flight phases.

As punctuality measures are affected by time buffers in the schedule, the evaluation of ATM-related operational service quality is further assessed by phase of flight to better understand the ATM contribution and differences in traffic management techniques between the US and Europe. Inefficiencies have a different impact on airspace users (fuel burn, time) depending on the phase of flight (terminal area, cruise, or ground) and the level of predictability (strategic or tactical).

The use of departure ATFM restrictions or EDCT ground delays to balance capacity with demand differs between the US and Europe. Whereas in Europe ATFM restrictions are used as a primary means for en route and airport capacity shortfalls, in the US ground delays due to en route constraints are rarely required and airport related ground delays are only applied when less constraining flow measures such as MIT are insufficient. Despite a reduction from 5% in 2008 to 1.9% in 2012, flights in Europe are still almost 20 times more likely to be held at the gate for en route constraints than in the US where the percentage remained constant at 0.1%. For airport related delays, the percentage of delayed flights at the gate is more comparable in the US (2%) and in Europe (1.4%). However the delay per delayed flight in the US is more than twice as high as in Europe.

Most of the airport related delays in the US are caused by weather and are highly concentrated at five airports: Newark (EWR), San Francisco (SFO), Philadelphia (PHL), New York (LGA), and Chicago (ORD). Although making up over 82% of the total EDCT delays, four of these top five airports with the exception of San Francisco experienced the most substantial decreases in EDCT delay from 2008 to 2012. Overall, average EDCT delays to the 34 main US airports decreased by 50% in 2012 compared to 2008. The US airports with the greatest system impact in reducing average EDCT delays from 2008 to 2012 are ATL, ORD, JFK, LGA, PHL, and EWR. The airport responsible for adding the most to EDCT delay was SFO. In Europe, most airport ATFM delay is also weather related but delays are more evenly spread across airports with London (LHR), Frankfurt (FRA), Amsterdam (AMS) and Zurich (ZRH) being the most constraining ones.

Surface measures studied in this report include taxi-out efficiency and taxi-in efficiency, which both can be measured as the average additional time beyond an unimpeded reference time. At a high level, seasonal patterns are visible with different cycles in the US and Europe. Whereas in Europe the additional times peak during the winter months (most likely due to weather conditions), in the US the peak is in the summer which is most likely linked to congestion. On average, additional times in the taxi-out phase appear to be higher in the US, but from 2008 to 2012, US performance improved by 25% whereas performance in Europe remained largely unchanged with only a minor improvement of 3%. The US airports with the greatest reduction in additional taxi-out time are ATL (-34%), JFK (-49%), EWR (-42%), and ORD (-26%). However, LAX (+37%) and SFO (+17%) experienced increases in additional taxi-out time. In 2012, the gap in additional taxi-out time narrows considerably between the US (4.86) and Europe (4.25). On the arrival side, the additional time in the taxi-in phase is slightly higher in the US than in Europe but remains relatively stable over time in both systems.

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

For the en route phase, a horizontal flight efficiency measure is used to compare the actual flight trajectory length to a benchmark achieved distance for each flight. In 2012, the level of total horizontal en route flight inefficiency for flights to or from the main 34 airports in Europe was 2.98% compared to 2.73% in the US, with Europe having 0.25% greater en route inefficiency. For both the US and Europe, flight inefficiency decreases relative to the flight distance. At the airport level, direct route extension (A-D) in NM for US flights are longer on average than in Europe, but as a percentage (A-D/H), US flights are less inefficient due to the US having longer flight lengths. For the US, many of the direct flight inefficiencies can be traced to separating traffic in larger metroplex airspace (New York and Atlanta) as well as the need to coordinate with and avoid Special Use Airspace (SUA). Therefore, many of these calculated inefficiencies are most likely not a recoverable part of the estimated benefit pool. Future assessments may directly compute the flight inefficiency due to SUA.

For the terminal arrival phase, flight efficiency in the last 100 NM before landing aims to estimate the level of inefficiencies due to airborne holding, metering, and sequencing of arrivals. At system level, the additional time within the last 100 NM was similar in 2008 but is lower in the US in 2012. In Europe, London Heathrow (LHR) has by far the highest level of additional time within the last 100 NM. This is followed by Madrid (MAD) and Frankfurt (FRA) which show less than half the level observed at London Heathrow. Although consistent with decisions taken during the airport capacity declaration process regarding average holding in stack, it is remarkable that London (LHR) alone accounted for 20% of the total additional time observed at the main 34 European airports in 2012.

The US shows a less contrasted picture with many airports improving between 2008 and 2012. As a whole, the average additional time within the last 100 NM decreased by nearly 16% in the US from 2008 to 2012. Although the US airports with the highest level of inefficiencies remain those in the greater New York area, the New York airports (JFK, LGA, EWR), Atlanta (ATL), and Philadelphia (PHL) also saw the greatest improvements in terminal arrival efficiency from 2008 to 2012. One of the main differences of the US air traffic management system is the ability to maximise airport capacity by taking action in the en route phase of flight, such as in trail spacing whereas in Europe, most of the sequencing and holding is done at lower altitudes around the airport and additional delays beyond what can be absorbed around the airport are taken on the ground at the departure airports.

Although the US saw an overall improvement in operational performance, this can be expected given the favourable conditions that have occurred from 2008-2012. Ceiling and visibility weather indicators point to less impact from weather and this is largely reflected in the higher capacity rates observed. Overall demand is also down putting less stress on the system than in 2008. It is therefore not clear if the improved performance levels will be sustained if traffic begins to increase or if weather degrades. While technologies, concepts, and procedures have helped to further optimise safety, add capacity, and increase efficiency (e.g. Reduced Vertical Separation Minima, RNAV) over the past years, it will remain challenging to maintain the same level of efficiency while absorbing projected demand increases over the next 20 years.

By combining the analyses for individual phases of flight, an estimate of the improvement pool actionable by ANS can be derived. It is important to stress that the overall results represent a theoretical optimum which is – due to inherent safety and capacity limitations - not achievable at the system level. It should also be noted that there are other flight components not considered which may also lead to improved fuel efficiency. Some of these, such as preferred flight speed are not fully under the control of ATM. Examining the change in the improvement pool from 2008-2012, it is estimated that fuel inefficiency may have been reduced by a large percentage in the US and Europe. For example, in the US, the taxi-out phase is estimated to have improved by 25%.

5 EMERGING THEMES AND NEXT STEPS

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

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

In the US, impacts to performance are highly linked to capacity variation at airports with demand levels that are near the upper range of the declared capacity of the facility. For most airports, demand levels are self-controlled by airlines and adapted depending on expected cost of delays. The more dynamic approach encourages high airport throughput levels but is more susceptible to service disruptions (such as weather) which potentially result in major delays and cancellations. The focus is on the mitigation of weather effects in order to maintain high system throughput. Demand management policies at some of the most constraining US airports helped in improving performance between 2008 and 2012.

This report was limited in the detail of common performance analysis that could assess the effects of fragmented airspace and capacity variation between the two systems. This is largely due to the maturity of the databases that would be required to develop complimentary measures. However data availability and the ability to automate the assessment of large scale systems continue to improve. The adoption of new technology may also give rise to new measures. For example, in the US, a new technology called the Collaborative Trajectory Options Program (CTOP), which will allow airspace users to file a preferred set of flight plans, may improve the ability to develop measures on efficiency against User Preferred Trajectories.

Given the key elements affecting performance in the two systems and the projected improvements in data availability, EUROCONTROL and FAA intend to jointly advance a common performance assessment capability in the following areas.

1. <u>Improve Controller and Staffing Comparisons:</u> This operational benchmark report makes basic high level comparisons on the staffing and facilities required to accommodate a given level of traffic at a given level of performance. This effort indicates that a deeper understanding of the role of the FAA “developmental” controller vs. a European equivalent may be necessary to advance other measures, such as cost based or productivity measures. At present, international benchmarks make these comparisons using the ACE and CANSO definition of the full time ATCO in operation (ATCO in OPS).

2. <u>Improve Facility Level Comparisons:</u> This series of benchmark reports has consistently noted that Europe operates with more ANSPs, en route centres and more approach facilities than the US. Similar to airport activity, this report could begin reporting other facility activity that could be useful for system comparisons. This would include US staffing and flight activity for centres and TRACONs benchmarked to their closest European equivalent. This may include recent work in Europe on developing Functional Airspace Blocks which would be compared to similar areas and activity in the US.

3. Quantify the Magnitude and Effect of Traffic Flow Initiatives: When an imbalance between capacity and demand occurs (en route or at airports), the way the resulting “extra” time 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). For instance, it is noted frequently in this report that the relatively lower values for ATFM delay due to airspace constraints in the US compared to Europe may be due to the use of traffic flow procedures such as miles or minutes in trail. More work is needed to determine how to minimise the impact of flow measures on airspace users and the environment while maximising the use of scarce capacity.

4. Quantifying Capacity Variation: This report provided FAA and EUROCONTROL’s first view of airport arrival capacities and how they relate to peak throughput at the airports. The sources of the two groups are different with Europe using strategic peak arrival capacities used in the demand coordination process and the US using tactical called rates that are used as part of traffic flow management. For the US, these rates are recorded and allow for a US assessment of capacity variation which is a strong indicator of variation in other performance indicators. If comparable tactical capacities were available in Europe, it would be possible to strengthen this comparison and to assess if differences in the operating environment lead to greater capacity variation (less predictability).

5. En route Measures that Utilise the Flight Plan: The European Single European Sky Performance Scheme contains a measure of flight plan against a benchmark achieved distance to determine if airlines are filing shorter distances over time. Future reports could include similar or complementary measures that assess efficiency using the airline filed flight plan. This may also improve a common understanding of interdependencies in the system.

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

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

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

9. Weather impact on performance: EU/US benchmarking continues to report weather condition between the two systems and assess their potential impact on performance. As both groups have access to METAR data, future reports may include more common

side-by-side comparisons of basic trends in ceiling/visibility as well as a broader set of weather events that can be shown to affect performance.

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

11. Impact of variability induced by airlines and airports and ATM on system performance: In an environment with limited capacities, any deviation from the flight plan or schedule potentially results in time penalties (i.e. delay) or an underutilisation of available resources if provisions for capacity and demand variations are made in advance. More research is needed to understand required flexibility levels of system users and what level of “delay” is necessary to maximise the use of capacity.

ANNEX I - LIST OF AIRPORTS INCLUDED IN THIS STUDY

Table 3: Top 34 European airports included in the study (2012)

EUROPE	ICAO	IATA	COUNTRY	Avg. daily IFR departures in 2012	2012 vs. 2008
Amsterdam (AMS)	EHAM	AMS	NETHERLANDS	593	-1.7%
Athens (ATH)	LGAV	ATH	GREECE	204	-22.7%
Barcelona (BCN)	LEBL	BCN	SPAIN	396	-9.8%
Berlin (TXL)	EDDT	TXL	GERMANY	231	7.0%
Brussels (BRU)	EBBR	BRU	BELGIUM	298	-13.4%
Cologne (CGN)	EDDK	CGN	GERMANY	167	-12.3%
Copenhagen (CPH)	EKCH	CPH	DENMARK	332	-8.0%
Dublin (DUB)	EIDW	DUB	IRELAND	222	-22.1%
Dusseldorf (DUS)	EDDL	DUS	GERMANY	296	-4.8%
Frankfurt (FRA)	EDDF	FRA	GERMANY	659	-0.7%
Geneva (GVA)	LSGG	GVA	SWITZERLAND	247	2.7%
Hamburg (HAM)	EDDH	HAM	GERMANY	197	-11.1%
Helsinki (HEL)	EFHK	HEL	FINLAND	235	-7.2%
Lisbon (LIS)	LPPT	LIS	PORTUGAL	197	0.0%
London (LGW)	EGKK	LGW	UNITED KINGDOM	337	-6.5%
London (LHR)	EGLL	LHR	UNITED KINGDOM	649	-0.7%
London (STN)	EGSS	STN	UNITED KINGDOM	194	-25.9%
Lyon (LYS)	LFLL	LYS	FRANCE	163	-8.8%
Madrid (MAD)	LEMD	MAD	SPAIN	510	-20.6%
Manchester (MAN)	EGCC	MAN	UNITED KINGDOM	230	-17.0%
Milan (LIN)	LIML	LIN	ITALY	161	-7.3%
Milan (MXP)	LIMC	MXP	ITALY	239	-19.7%
Munich (MUC)	EDDM	MUC	GERMANY	540	-7.9%
Nice (NCE)	LFMN	NCE	FRANCE	195	-0.5%
Oslo (OSL)	ENGM	OSL	NORWAY	322	-0.1%
Palma (PMI)	LEPA	PMI	SPAIN	237	-10.1%
Paris (CDG)	LFPG	CDG	FRANCE	680	-11.1%
Paris (ORY)	LFPO	ORY	FRANCE	320	-0.1%
Prague (PRG)	LKPR	PRG	CZECH REPUBLIC	175	-26.3%
Rome (FCO)	LIRF	FCO	ITALY	429	-9.5%
Stockholm (ARN)	ESSA	ARN	SWEDEN	287	-5.9%
Stuttgart (STR)	EDDS	STR	GERMANY	164	-18.2%
Vienna (VIE)	LOWW	VIE	AUSTRIA	357	-9.7%
Zurich (ZRH)	LSZH	ZRH	SWITZERLAND	357	-0.5%
				318	**-8.8%**

Table 4: US main 34 airports included in the study (2012)

USA	ICAO	IATA	COUNTRY	Avg. daily IFR departures in 2012	2012 vs. 2008
Atlanta (ATL)	KATL	ATL	United States	1259	-5.6%
Baltimore (BWI)	KBWI	BWI	United States	360	-1.6%
Boston (BOS)	KBOS	BOS	United States	481	-5.1%
Charlotte (CLT)	KCLT	CLT	United States	746	3.6%
Chicago (MDW)	KMDW	MDW	United States	327	-6.6%
Chicago (ORD)	KORD	ORD	United States	1194	-0.7%
Cleveland (CLE)	KCLE	CLE	United States	247	-23.1%
Dallas (DFW)	KDFW	DFW	United States	887	-1.0%
Denver (DEN)	KDEN	DEN	United States	844	-1.5%
Detroit (DTW)	KDTW	DTW	United States	585	-7.7%
Ft. Lauderdale (FLL)	KFLL	FLL	United States	338	-10.3%
Houston (HOU)	IHOU	HOU	United States	245	-2.7%
Houston (IAH)	KIAH	IAH	United States	696	-12.9%
Las Vegas (LAS)	KLAS	LAS	United States	567	-12.0%
Los Angeles (LAX)	KLAX	LAX	United States	822	-1.8%
Memphis (MEM)	KMEM	MEM	United States	367	-25.6%
Miami (MIA)	KMIA	MIA	United States	529	4.4%
Minneapolis (MSP)	KMSP	MSP	United States	579	-5.5%
New York (JFK)	KJFK	JFK	United States	552	-8.7%
New York (LGA)	KLGA	LGA	United States	504	-3.3%
Newark (EWR)	KEWR	EWR	United States	564	-5.0%
Orlando (MCO)	KMCO	MCO	United States	415	-11.2%
Philadelphia (PHL)	KPHL	PHL	United States	603	-8.2%
Phoenix (PHX)	KPHX	PHX	United States	612	-8.4%
Portland (PDX)	KPDX	PDX	United States	279	-16.1%
Raleigh-Durham (RDU)	KRDU	RDU	United States	234	-19.1%
Salt Lake City (SLC)	KSLC	SLC	United States	394	-16.6%
San Diego (SAN)	KSAN	SAN	United States	251	-17.2%
San Francisco (SFO)	KSFO	SFO	United States	572	9.6%
Seattle (SEA)	KSEA	SEA	United States	419	-10.7%
St. Louis (STL)	KSTL	STL	United States	259	-22.9%
Tampa (TPA)	KTPA	TPA	United States	247	-20.3%
Washington (DCA)	KDCA	DCA	United States	391	3.6%
Washington (IAD)	KIAD	IAD	United States	460	-13.8%
				524	**-7.0%**

ANNEX II - GLOSSARY

AAR	Airport Arrival Acceptance Rates
ACC	Area Control Centre. That part of ATC that is concerned with en route traffic coming from or going to adjacent centres or APP. It is a unit established to provide air traffic control service to controlled flights in control areas under its jurisdiction.
ACI	Airports Council International (http://www.aci-europe.org/)
ADR	Airport Departure Rates
AIG	Accident and Incident Investigation (ICAO)
AIP	Aeronautical Information Publication, sets out procedures used by pilots and air traffic controllers
AIS	Aeronautical Information Service
ANS	Air Navigation Service. A generic term describing the totality of services provided in order to ensure the safety, regularity and efficiency of air navigation and the appropriate functioning of the air navigation system.
ANSP	Air Navigation Services Provider
APP	Approach Control Unit
ARTCC	Air Route Traffic Control Center, the equivalent of an ACC in Europe.
ASM	Airspace Management
ASMA	Arrival Sequencing and Metering Area
ASPM	FAA Aviation System Performance Metrics
ATC	Air Traffic Control. A service operated by the appropriate authority to promote the safe, orderly and expeditious flow of air traffic.
ATCO	Air Traffic Control Officer
ATCSCC	US Air Traffic Control System Command Centre
ATFCM	Air Traffic Flow and Capacity Management
ATFM	Air Traffic Flow Management. ATFM is established to support ATC in ensuring an optimum flow of traffic to, from, through or within defined areas during times when demand exceeds, or is expected to exceed, the available capacity of the ATC system, including relevant aerodromes.
ATFM delay (CFMU)	The duration between the last take-off time requested by the aircraft operator and the take-off slot given by the CFMU.
ATFM Regulation	When traffic demand is anticipated to exceed the declared capacity in en route control centres or at the departure/arrival airport, ATC units may call for "ATFM regulations."
ATM	Air Traffic Management. A system consisting of a ground part and an air part, both of which are needed to ensure the safe and efficient movement of aircraft during all phases of operation. The airborne part of ATM consists of the functional capability which interacts with the ground part to attain the general objectives of ATM. The ground part of ATM comprises the functions of Air Traffic Services (ATS), Airspace Management (ASM) and Air Traffic Flow Management (ATFM). Air traffic services are the primary components of ATM.
ATO	Air Traffic Organization (FAA)
ATS	Air Traffic Service. A generic term meaning variously, flight information service, alerting service, air traffic advisory service, air traffic control service.
Bad weather	For the purpose of this report, "bad weather" is defined as any weather condition (e.g. strong wind, low visibility, snow) which causes a significant drop in the available airport capacity.
CAA	Civil Aviation Authority
CANSO	Civil Air Navigation Services Organisation (http://www.canso.org)
CDA	Continuous Descent Approach

CDM	Collaborative Decision Making
CDR	Conditional Routes
CFMU	See NOC
CO_2	Carbon dioxide
CODA	EUROCONTROL Central Office for Delay Analysis
CONUS	see US CONUS
CTOP	Collaborative Trajectory Options Program
CTOT	Calculated take-off Time
EC	European Commission
ECAC	European Civil Aviation Conference.
EDCT	Estimate Departure Clearance Time. EDCT is a long-term Ground Delay Programme (GDP), in which the Command Centre (ATCSCC) selects certain flights heading to a capacity limited destination airport and assigns an EDCT to each flight, with a 15 minute time window.
ETFMS	Enhanced Tactical Flow Management System
EU	Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxemburg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden and United Kingdom. All these 27 States are also Members of the ECAC.
EUROCONTROL	The European Organisation for the Safety of Air Navigation. It comprises Member States and the Agency.
EUROCONTROL Member States	Albania, Armenia, Austria, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Moldova, Monaco, Montenegro, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, The former Yugoslav Republic of Macedonia, Turkey, Ukraine and United Kingdom of Great Britain and Northern Ireland
FAA	US Federal Aviation Administration
FAA-ATO	US Federal Aviation Administration - Air Traffic Organization
FAB	Functional Airspace Blocks
FDP	Flight data processing
FIR	Flight Information Region. An airspace of defined dimensions within which flight information service and alerting service are provided.
FL	Flight Level. Altitude above sea level in 100-foot units measured according to a standard atmosphere. Strictly speaking a flight level is an indication of pressure, not of altitude. Only above the transition level are flight levels used to indicate altitude; below the transition level, feet are used.
FMP	Flow Management Position
FMS	Flight Management System
FUA Level 1 Level 2 Level 3	Flexible Use of Airspace Strategic Airspace Management Pre-tactical Airspace Management Tactical Airspace Management
GAT	General Air Traffic. Encompasses all flights conducted in accordance with the rules and procedures of ICAO. The report uses the same classification of GAT IFR traffic as STATFOR: 1. Business aviation: All IFR movements by aircraft types in the list of business aircraft types (see STATFOR Business Aviation Report, May 2006, for the list); 2. Military IFR: ICAO Flight type = 'M', plus all flights by operators or aircraft types for which 70%+ of 2003 flights were 'M'; 3. Cargo: All movements by operators with fleets consisting of 65% or more all-freight airframes 4. Low-cost: See STATFOR Document 150 for list.

	5. Traditional Scheduled: ICAO Flight Type = 'S', e.g. flag carriers. 6. Charter: ICAO Flight Type = 'N', e.g. charter plus air taxi not included in (1)
GDP	Ground delay program
General Aviation	All flights classified as "G" (general aviation) in the flight plan submitted to the appropriate authorities.
IATA	International Air Transport Association (www.iata.org)
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules. Properly equipped aircraft are allowed to fly under bad-weather conditions following instrument flight rules.
ILS	Instrument landing System; a lateral and vertical beam aligned with the runway centreline in order to guide aircraft in a straight line approach to the runway threshold for landing.
IMC	Instrument Meteorological Conditions
KPA	Key Performance Area
KPI	Key Performance Indicator
M	Million
MDI	Minimum Departure Interval
MET	Meteorological Services for Air Navigation
MIL	Military flights
MIT	Miles in Trail
MTOW	Maximum Take-off Weight
NAS	National Airspace System
NextGen	The Next Generation Air Transportation System (NextGen) is the name given to a new National Airspace System due for implementation across the United States in stages between 2012 and 2025.
NM	Nautical mile (1.852 km)
NOC	Eurocontrol Network Operations Centre located in Brussels (formerly CFMU)
OEP	Operational Evolution Partnership (a list of 35 US airports that was compiled in 2000, based on lists from the FAA and Congress and a study that identified the most congested airports in the US).
OPS	Operational Services
OPSNET	The Operations Network is the official source of NAS air traffic operations and delay data. The data is used to analyse the performance of the FAA's air traffic control facilities.
Percentile	A percentile is the value of a variable below which a certain per cent of observations fall. For example, the 80th percentile is the value below which 80 per cent of the observations may be found.
PPS	Purchasing power standard
PRC	Performance Review Commission
Primary Delay	A delay other than reactionary
PRU	Performance Review Unit
Punctuality	On-time performance with respect to published departure and arrival times
RAD	Route availability document
Reactionary delay	Delay caused by late arrival of aircraft or crew from previous journeys
Separation minima	The minimum required distance between aircraft. Vertically usually 1,000 ft below flight level 290, 2,000 ft above flight level 290. Horizontally, depending on the radar, 3 NM or more. In the absence of radar, horizontal separation is achieved through time separation (e.g. 15 minutes between passing a certain navigation point).
SES	Single European Sky (EU) http://europa.eu.int/comm/transport/air/single_sky/index_en.htm
SESAR	The Single European Sky implementation programme
Slot (ATFM)	A take-off time window assigned to an IFR flight for ATFM purposes
STATFOR	EUROCONTROL Statistics & Forecasts Service

Summer period	May to October inclusive
Taxi-in	The time from touch-down to arrival block time.
Taxi-out	The time from off-block to take-off, including eventual holding before take-off.
TBM	Time Based Metering
TFMS	Traffic Flow Management System
TMA	Terminal Manoeuvring Area
TMS	Traffic Management System
TRACON	Terminal Radar Approach Control
UAC	Upper Airspace Area Control Centre
US	United States of America
US CONUS	The 48 contiguous States located on the North American continent south of the border with Canada, plus the District of Columbia, excluding Alaska, Hawaii and oceanic areas
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions

ANNEX III - REFERENCES

1 Performance Review Commission and FAA, "A comparison of performance in selected US and European En-route Centres", (MAY 2003).
http://www.eurocontrol.int/documents/comparison-performance-selected-us-and-european-en-route-centres

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

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

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

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

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

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

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

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

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

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

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 FAA Free Flight Performance Metrics Reports 199-2001.

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

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

17 IATA, EUROCONTROL, CANSO European flight efficiency plan, August 2008.

18 Regulation (EC) No 1070/2009 of the European Parliament and of the Council of 21 October 2009 amending Regulations (EC) No 549/2004, (EC) No 550/2004, (EC) No 551/2004 and (EC) No 552/2004 in order to improve the performance and sustainability of the European aviation system.

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

20 Airbus, "Getting to grips with fuel economy", Issue 3 - July 2004.

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

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

23 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.

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

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

26 "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.

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

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

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

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

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

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

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

U.S. Department of Transportation
Federal Aviation Administration
Performance Analysis Office
800 Independence Ave., S.W.
Washington, DC 20591
Tel: 202-527-2845

2013-AJR-887 — Produced by FAA Communications.