

# US/ Europe comparison of ATM-related operational performance

An initial harmonized assessment by phase of flight

John Gulding, David Knorr, Marc Rose, James Bonn  
Performance Analysis and Strategy  
FAA  
Washington DC, USA

Philippe Enaud, Holger Hegendoerfer  
Performance Review Unit  
EUROCONTROL  
Brussels, Belgium

**Abstract**—Air Navigation Service Providers (ANSPs) are continually seeking to improve operations. Measures derived from operational databases are a key component to assessing performance and recommending improvements. This paper examines several key performance indicators derived from comparable operations databases for both EUROCONTROL and the Federal Aviation Administration (FAA). This research effort developed a comparable population of operations data and harmonized assessment techniques for developing reference conditions for assessing performance. In the end, measures that address efficiency, punctuality and predictability are presented that can compare high level performance between the two systems by phase of flight.

**Keywords:** Air Traffic Performance Analysis, Key Performance Indicators (KPIs)

## I. INTRODUCTION

As in any industry, global comparisons and benchmarking including data analysis can help drive performance and identify best practices in Air Traffic Management (ATM). Over the years, various groups have looked to estimate the amount of inefficiency that can be addressed by improvements in the ATM system. Public numbers include the 1999 Intergovernmental Panel on Climate Change (IPCC) report which defined a potential 6%-12% inefficiency in the system due to ATM. In its conclusion, it draws on analysis that is over 10 years old. This interest in ATM efficiency has led ANSPs to develop methods of examining their own operational data to determine benefit pools for their system.

In 2003, the Performance Review Commission (PRC) in collaboration with the FAA carried out a comparison of economic performance (productivity and cost-effectiveness) in selected US and European en-route centers [1], in order to measure economic performance in a homogenous way and to identify systemic differences which would explain the significantly higher level of unit costs observed in Europe. The corresponding methodology has now been adopted by International Civil Aviation Organization (ICAO) [2].

In 2003, FAA presented a paper at the 5th USA/Europe Air Traffic Management Research and Development Seminar that examined flight efficiency by the en-route and terminal phase of flight [3]. It identified the major causal factors that contribute to en-route inefficiency and presented a framework that calculated excess distance outside the terminal environment. Since 2003, FAA has been asked to expand this work to assess gate-to-gate efficiencies that can be used to assess system performance that can be compared to ATM estimates worldwide. This work has led to collaborative efforts with the EUROCONTROL Performance Review Unit on gate-to-gate efficiency as well as measures of other key performance indicators such as predictability.

This paper provides a comparison of operational performance between the US and Europe Air Navigation systems, and provides updated key system-level figures. It summarizes the preliminary findings of a joint Federal Aviation Administration (FAA/ATO) and EUROCONTROL study due to be published in the first half of 2009.

The initial focus was on the development of a set of comparable performance measures for comparisons between countries and world regions. Where possible, reasons for differences in system performance were explored in more detail in order to provide an understanding of underlying performance drivers or, where necessary, to stimulate more detailed analyses.

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

## II. HIGH LEVEL VIEW OF THE ATM SYSTEMS IN EUROPE AND THE US

TABLE I. shows key high-level figures for the European and the US Air Navigation systems. The surface of continental

airspace is similar in Europe and the US. However, the FAA controls approximately 80% more flights and handles significantly more visual Flight Rules (VFR) traffic with the same number of staff and fewer facilities. The fragmentation of European ANS with 38 en-route ANSPs is certainly a driver behind such difference.

TABLE I. US/EUROPE KEY ATM SYSTEM FIGURES (2007)

Calendar Year 2007	Europe <sup>1</sup>	USA <sup>2</sup>	Difference
<i>Geographic Area (million km2)</i>	11.5	10.4	-10%
<i>Number of en-route Air Navigation Service Providers</i>	38	1	
<i>Number of Air Traffic Controllers</i>	17 000	17 000	0%
<i>Total staff</i>	56 000	35 000	-38%
<i>Controlled flights (Instrumental flight rules IFR) (million)</i>	10	18	+80%
<i>Share of General Air Traffic</i>	4%	18%	x4.5
<i>Flight hours controlled (million)</i>	14	25	+79%
<i>Relative density (flight hours per area)</i>	1.2	2.4	+97%
<i>Average length of flight (within region)</i>	548 NM	490 NM	-11%
<i>Nr. of en-route centers</i>	66	20	-70%
<i>En-route sectors at maximum configuration</i>	684	955	+40%
<i>Nr. of airports with ATC services</i>	450	503 <sup>3</sup> (280)	+12%
<i>Of which are slot controlled</i>	> 73	3	
<i>Source</i>	Eurocontrol	FAA/ATO	

Figure 1. shows the traffic density in US and European en-route centers measured in flight hours per square kilometer for all altitudes. Europe’s densities would increase relative to the US if only upper flight levels were considered (the propeller GA aircraft in the US would be excluded)<sup>4</sup>. Detailed comparisons on complexities were beyond the scope of this report.

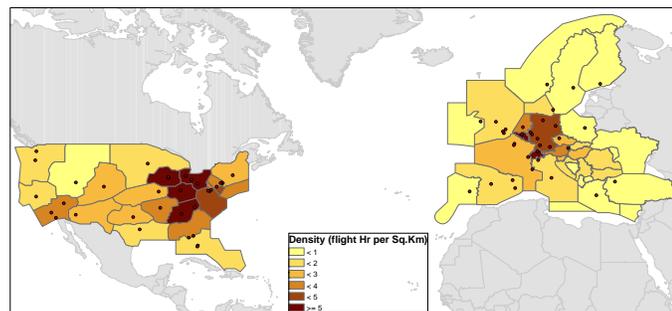


Figure 1. Traffic density in US and European en-route centers

- 1 Eurocontrol States plus the Estonia and Latvia, but excluding oceanic areas and Canary Islands.
- 2 Area, flight hours and center count refers to CONUS only. The term US CONUS refers to the 48 contiguous States located on the North American continent south of the border with Canada, plus the District of Columbia, excluding Alaska, Hawaii and oceanic areas.
- 3 All facilities of which 280 are FAA staffed and 223 contract towers.
- 4 New York Center shows as less dense due to the inclusion of a portion of coastal/oceanic airspace, if this portion were excluded, NY would be the Center with the highest density.

Figure 2. shows annual traffic growth in the US and Europe between 1999 and 2008. Until 2004, growth rates evolved in similar ways on both sides of the Atlantic, but there is a notable difference since then. In Europe, air traffic continued to grow at around 4% per annum while it decreased significantly in the US.

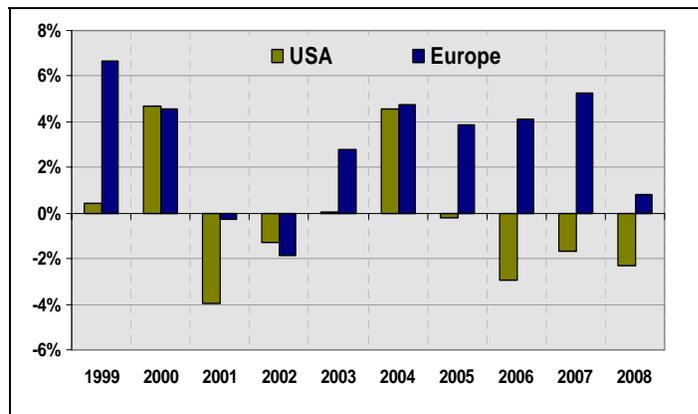


Figure 2. Annual air traffic growth in the US and in Europe

An important difference between the US and Europe is the share of general aviation (18% and 4% respectively). In order to ensure comparability of data sets, the scope of the analysis was limited to controlled commercial (IFR) flights from or to the 34 most important airports in the US (OEP34 ) and Europe (see TABLE II. ).

Traffic to/from the main 34 airports represents some 69% of all IFR flights in Europe and 64% in the US. The share of general aviation to/from the main 34 airports is more comparable with 4% in the US and 1.6% in Europe. If only scheduled airlines are considered, IFR traffic to/from the main 34 airports is 77% for Europe and 86% for US.

TABLE II. SOME KEY AIPIORT DATA FOR (34 MAIN AIRPORTS)

Main 34 airports in 2007	Europe	US	Difference US vs. Europe
<i>Average number of annual movements per airport ('000)</i>	267	441	+65%
<i>Average number of annual passengers per airport (million)</i>	25	32	+28%
<i>Passengers per movement</i>	94	72	-23%
<i>Average number of runways per airport</i>	2.5	4.0	+60%
<i>Annual movements per runway ('000)</i>	108	110	+2%
<i>Annual passengers per runway (million)</i>	10.0	8.0	-20%

Average seat size per scheduled flight differs in the two systems with Europe having a higher percentage of flights using “Large” aircraft than the US. Average seat size per scheduled flight over time is shown in Figure 3.

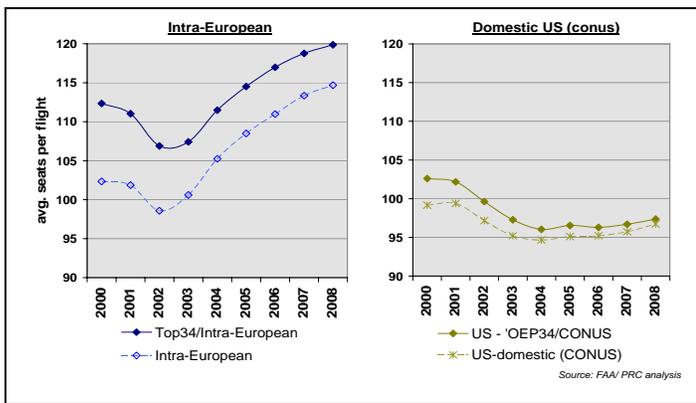


Figure 3. Average seats per scheduled flight

### III. AIR TRAFFIC FLOW MANAGEMENT TECHNIQUES

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

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

- Airline scheduling is capped to “declared capacity” at major European airports, while it is unrestricted at most US airports. For this report, capacity constraints existed at New York LaGuardia, Chicago O’Hare (ORD), and Washington National (DCA). During Fiscal Year 2008, additional capacity constraints were established at JFK and Newark (EWR) airport while the constraint at Chicago O’Hare expired with the addition of the new runway. The level of demand in the US is decided by airlines depending on the expected cost of delays / predictability and the expected value of operating additional flights.
- At many European airports, there is a higher proportion of Instrument Meteorological Conditions (IMC). These airports are generally scheduled to IMC airport capacity.
- The first two points lead to more variable difference between available airport capacity and demand in the US, and ATFM issues tend to concentrate at major airports there.
- While both Air Navigation systems are operated with similar technology and operational concepts, there is one service provider in the US, all US Centers use the same automation systems and they actively cooperate on flow management. In Europe, there are 38 en-route service providers, with little obligation or incentives to cooperate on flow management (e.g. sequencing traffic into major airports of other States) and operating their own systems, which may affect the level of coordination in ATFM and ATC capacity. ATFM issues principally originate from en-route capacity shortfalls in Europe, which is not the case in the US.

- Additionally, in many European States, civil Air Navigation Service Providers (ANSPs) co-exist with military ANSPs. This can make ATC operations and airspace management more difficult. Moreover, the majority of military airspace in the US is located outside the core areas, while in Europe military airspace is organized at State level and there is a high density of both civil and military activity in the core area. More study is needed here to measure the share of flights entering military airspace when great circle routes are used.
- Convective weather/ thunderstorms in the summer are more severe and wide-spread in the US (lower latitude) and may require ground holds and large reroutings of entire traffic flows.

The two ATFM systems differ notably in the timing (when) and the phase of flight (where) ATFM measures are applied. There are trade-offs between flow management policies. Holding at the gate with engines-off lowers environmental impact and taxiway/airspace congestion, while taxi/airborne holding is more responsive to changing circumstances, and therefore makes better use of available airport capacity.

In Europe, the majority of ATFM measures are applied in the strategic (airport capacity declaration) or pre-tactical phases (allocation of ATFM take-off slots). In the US, ATFM measures are applied in the pre-tactical (take-off slots, or other ground delay) and tactical phases, depending on actual traffic situation.

#### A. Ground based flow management

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

In the US, ground delay programs are mostly used in case of severe capacity restrictions at an airport when less constraining ATFM measures, such as Miles in Trail (MIT) are not sufficient. The Air Traffic Command Center applies Estimated Departure Clearance Times (EDCT) to delay flights prior to departure. Most of these delays are taken at the gate but some occur during the taxi phase.

#### B. Airborne Flow Management

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

In the US, in order to ensure maximum use of available capacity in en-route centers and arrival airports, traffic flows are controlled through Miles in Trail (MIT) and Time Based Metering (TBM). Flow restrictions are passed back from the arrival airport to surrounding centers and so on as far as necessary. MIT 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. These Traffic Management System (TMS) delays are predominantly taken in the taxi-out phase and to a limited extent at the gate.

Due to the stochastic nature of air transport (weather, technical failures, etc.) and the way both systems are operated today (technology, organization, etc.), a certain level of delay is required to maximize the use of scarce capacity (particularly airport capacity). Both ATM systems handle traffic flows differently and lessons can be learnt from both sides.

### C. Terminal Management Area

In both the US and European systems the terminal area around a congested airport is used to absorb delay and keep pressure on the runways. Traffic Management initiatives generally recognize maximizing the airport capacity/throughput as paramount,

## IV. COMPARISON OF OVERALL AIR TRANSPORT PERFORMANCE

This section provides a high level analysis of operational air transport performance in the US and in Europe. The next section assesses delays per phase of flight.

### A. On-time performance (Punctuality)

Figure 4. compares the industry-standard indicators for punctuality, i.e. arrivals or departures delayed more than 15 minutes versus schedule.

After a continuous decrease between 2004 and 2007, on-time performance in Europe and in the US would appear to have improved in 2008. However, this improvement needs to be seen in a context of lower traffic growth (and in the case of the US lower overall traffic) as a result of the global financial and economic crisis, and increased schedule padding in the US as shown in Figure 5. below.

The gap between departure and arrival punctuality is significant in the US and quasi nil in Europe. This can be linked with different flow management and airport capacity allocation policies.

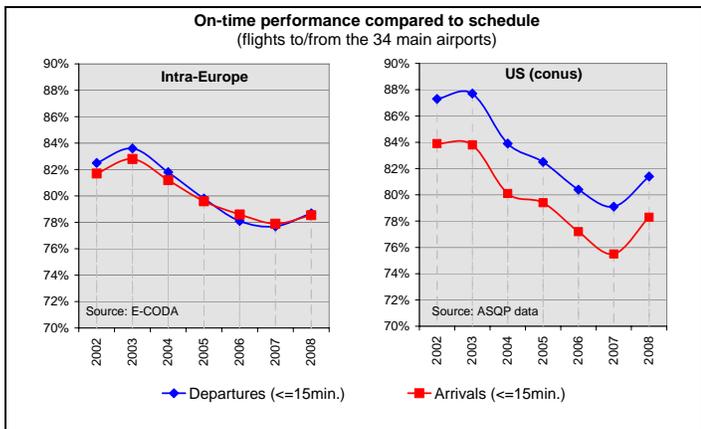


Figure 4. On-time performance (2002-2008)

### B. Trends in airline scheduling

Trends in airline scheduling provide a first insight on the level of predictability at scheduling phase.

Figure 5. shows the evolution of airline scheduling times in Europe and the US. The analysis compares the scheduled block times for each flight of a given city pair with the long term average for that city pair over the full period (2000-2008).

Between 2000 and 2008, scheduled block times remained stable in Europe while a clear increasing trend is visible in the US. These increases may result from adding block time to improve on-time or could be tied to a tightening of turn-around-times. The US has seen a redistribution of demand in already congested airports (e.g. JFK) which is believed to be responsible for growth of actual and scheduled block times.

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

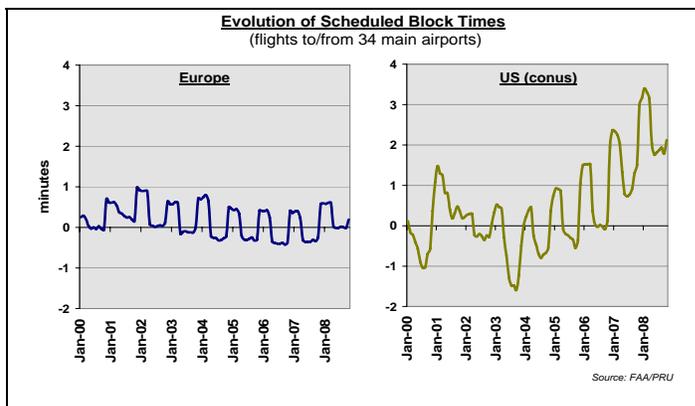


Figure 5. Scheduling of air transport operations (2000-2008)

### C. Evolution of average times by flight phase

Figure 6. shows trends in the duration of the individual flight phases in Europe and the US. The analysis compares actual times for each city pair with the long term average for that city pair over the full period (2003-2008).

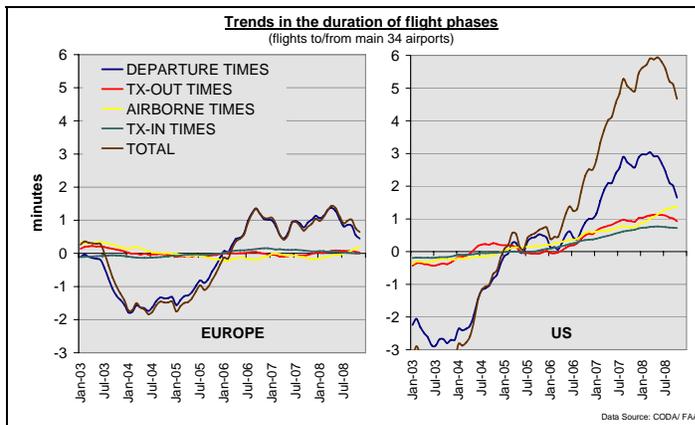


Figure 6. Trends in the duration of flight phases (2003-2008)

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

#### D. Predictability/ Variability of operations by flight phase

Predictability is measured in Figure 7. from the flight perspective (i.e. airline view) as the difference between the 80th and the 20th percentile for each flight phase. Figure 7 shows that in both Europe and the US, arrival predictability is mainly driven by departure predictability.

With the exception of taxi-in times, variability in times for all flight phases is higher in the US as are the seasonal impacts of delays. Increased variability in the US is overall, heavily driven by weather. Over the last 5 years, increased variability in the US is driven by increased flights at congested airports. The higher variability by phase of flight in the US is based on the operation of the ATM system.

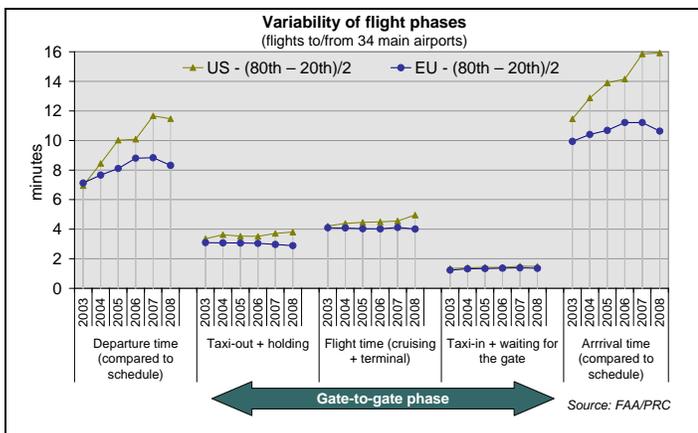


Figure 7. Variability of flight phases (2003-2008)

US airports schedule flights closer to visual metrological conditions (VMC) such that when low visibility is experienced delays are higher. In the summer, the US has more convective weather which also impacts variability. Airline scheduling and weather drive the need for a flexible system that can absorb delays in all phases of flight further driving up the variance of flight times in the US.

#### V. COMPARISON OF ANS CONTRIBUTION TOWARDS AIR TRANSPORT PERFORMANCE

This section focuses particularly on the ANS contribution towards overall air transport performance as measured in the previous section of this chapter (punctuality, variability, average times). In order to account for differences in fuel burn, the following section is broken down by phase of flight. The section concludes with an overview of the estimated ANS contribution in individual flight phases.

Before looking at the ANS contribution in more detail, the following points should be borne in mind:

- Not all ‘delay’ is to be seen as negative. A certain level of ‘delay’ is necessary and sometimes even desirable if

a system is to be run efficiently without underutilization of available resources (e.g. airport capacity).

- A clear cut allocation between ANS and non-ANS related causes is often difficult. While ANS is not always the root cause of the problem (weather, delay embedded in scheduling etc.), the way the situation is handled by ANS can have a significant influence on overall performance (i.e. distribution of delay between air and ground) and thus on costs to airspace users.
- Some indicators measure the difference between the actual situation and an ideal (unachievable) situation where each aircraft would be alone in the system and not be subject to any constraints. This is for example the case for horizontal flight efficiency which compares actually flown distance to the great circle distance.

#### A. ANS-related departure/gate holdings

This section reviews ANS-related departure delays in the US and in Europe (ATFM vs. EDCT). Aircraft that are expected to arrive during a period of a capacity shortfall en-route or at the destination airport are held on the ground at their various origin airports. Most of these delays are taken at the gate but some occur also during the taxi phase.

TABLE III. compares ANS-related departure delays attributable to en-route and airport constraints. In the US, en-route related ground delays are much lower per flight, but the delay per delayed flight is significantly higher. Whereas in the US the use of ground delays (EDCT) is the last resort from a pool of management tools, in Europe ground delays (ATFM) are used much more frequently for balancing demand with capacity.

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

	2007	En-route related (EDCT/ATFM)		Airport related (EDCT/ATFM)			
		IFR flights (M)	% of flights delayed	delay per flight (min.)	delay per flight (min.)	% of flights delayed	delay per flight (min.)
US	9.7	0.2%	0.1	53	1.7%	1.1	68
Europe	5.7	7.8%	1.4	18	6.8%	1.4	21

#### B. Taxi-out efficiency

The analysis of taxi-out efficiency in Figure 8. refers to the period between the time when the aircraft leaves the stand and the take off time.

This phase of flight is influenced by a number of factors such as push-back times, congestion, and remote de-icing. The excess time is measured as the average excess time beyond an unimpeded reference time. For the US, the excess time observed in the taxi-out phase also includes TMS delays due to local en route departure and MIT restrictions.

Figure 8. shows a significantly higher average excess time in the taxi-out phase in the US (6.8 minutes per departure) than in Europe (3.7 minutes per departure).

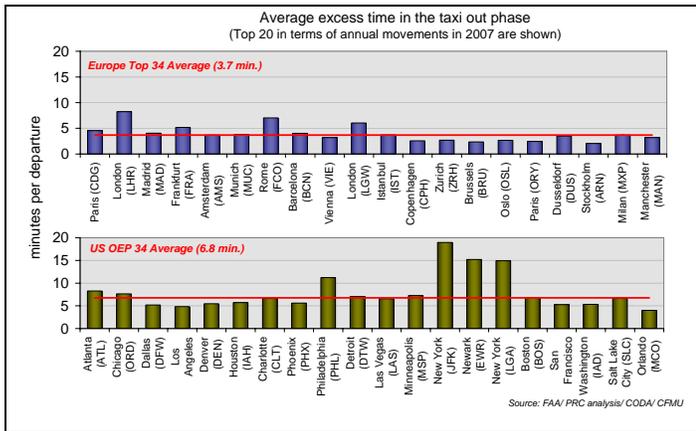


Figure 8. Comparison of excess time in the taxi out phase

Differences in taxi-out times reflect the different flow control policies and the absence of scheduling caps at most US airports. Additionally, the US department of transportation collects and publishes data on on-time departures which adds to the focus of getting off gate on time.

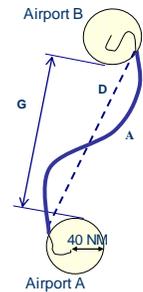
### C. En-route flight efficiency

En-route flight efficiency has a horizontal (distance) and a vertical (altitude) component. The focus of this section is on horizontal en-route flight efficiency, which is of much higher economic and environmental importance than the vertical component [4].

Efficiency or benefit pool calculations that consider full optimal 4-D trajectories must account for aircraft weight and aircraft performance information that is not generally available in the databases used to assess ATM performance. Furthermore, if an ANSP had access to a system that could detect a non-ideal condition, more information would be needed to determine if this was the result of ATC or an operating trade-off made by the user. More research is required to determine the relation of optimized trajectories to the performance indicators described in this paper.

The flight efficiency in the terminal maneuvering areas (TMA) of airports is addressed in the next section of this chapter. It should be noted that whereas in Europe en-route flight efficiency is mainly affected by the fragmentation of airspace, in the US the en-route indicator includes some path stretching due to MIT restrictions which are passed back from airports located in areas with little or no room for aircraft to deviate laterally from the filed route (for example Newark area).

The Key Performance Indicator (KPI) for horizontal en-route flight efficiency is en-route extension. It is defined as the difference between the length of the actual trajectory (A) and the Great Circle Distance (G) between the departure and arrival terminal areas (radius of 40 NM around the airport). This is an ideal (and unachievable) situation where each aircraft would be alone in the system and not be subject to any constraints.



Trade-offs and interdependencies in the ATM system such as capacity, safety, weather, noise, and military operations limit potential improvement of route extension

Figure 9. depicts the direct route extension<sup>5</sup> for flights to/from the top 34 airports within the respective region (Intra-Europe, US-CONUS). “Direct route extension” and corresponding fuel burn are approximately 1% lower in the US for flights of comparable lengths.

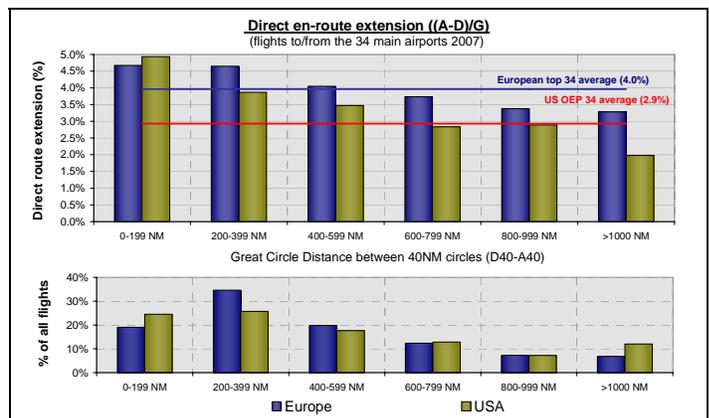


Figure 9. Comparison of direct en-route extension

### D. Arrival Sequencing and Metering Area (ASMA) delays

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

Figure 10. shows the excess time within the last 100NM. It is measured as the average excess time beyond the unimpeded transit time for each airport.

<sup>5</sup> Difference between the actual trajectory (A) and the direct course between the two terminal entry points (D) divided by the Great Circle distance (G).

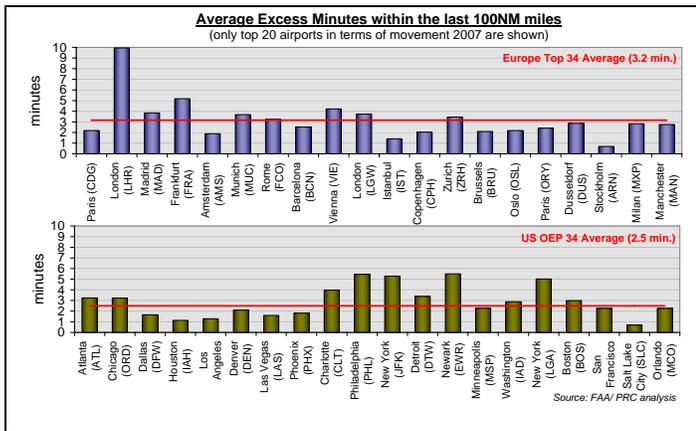


Figure 10. Average excess time within the last 100NM

In view of the stochastic nature of air transport and with the absence of en-route sequencing in Europe, airports like London Heathrow and Frankfurt already include a certain amount of delay in their capacity declaration to ensure a continuous traffic flow. This means there is significant delay absorbed at lower altitudes around the airport in an effort to maximize throughput. Additional delays beyond what can be absorbed around an airport are taken on the ground at departure.

Similarly to US airports which schedule flight closer to VMC capacity, high intensity airports such as London Heathrow and Frankfurt are more vulnerable to adverse weather.

#### VI. ESTIMATED TOTAL BENEFIT POOL ACTIONABLE BY ANS

TABLE IV. shows the estimated total benefit pool actionable by ANS for the traffic to or from the 34 analyzed main airports in Europe and the US.

The benefit pool represent a theoretical optimum. Safety and capacity constraints limit the practicality of ever fully recovering these “inefficiencies”. Furthermore, inefficiencies will grow with demand in the absence of capacity and efficient improvements. Maintaining the same inefficiencies while absorbing projected demand increases over the next 20 years will be very challenging.

TABLE IV. ESTIMATED TOTAL BENEFIT POOL ACTIONABLE BY ANS

Estimated excess time on flights to/from the main 34 airports (2007)		TIME per flight (minutes)		Predictability
		EUR	US	
Gate/ departure holdings	en-route-related	1.4	0.1	Low
	airport-related	1.4	1.1	Low
Taxi-out phase		3.7	6.8	Medium
Horizontal en-route flight efficiency		2.2-3.8	1.5-2.7	High
Terminal areas (ASMA/TMA)		3.2	2.5	Medium
Total estimated excess time per flight		11.9-13.5	12.0-13.2	

It is important to point out that the excess time for the individual flight phase shown in TABLE IV. are different in terms of fuel burn and predictability. The airport diagram

above shows the geometry used in the excess distance calculation and the rationale for reporting a range for the Horizontal en-route flight efficiency. The range in horizontal flight efficiency is due to assumptions on the need to maintain the route structure in the TMA (A-D) or a benefit pool that could improve upon the existing route structure in the TMA (A-G) and provide a more direct flight.

Whereas for ATFM/ EDCT gate delays the fuel burn is quasi nil, those delays are largely unpredictable and not evenly spread among flights (small percentage of flights but high delays).

Excess time in the gate-to-gate phase (taxi-out, en-route, and terminal area) are generally more predictable for airspace users (more evenly spread and smaller delays) but lead to considerably higher fuel burn. A large proportion of these delays are usually built into the airlines’ schedules.

Further work would be needed to better assess the impact of excess time on flight efficiency and predictability. The goal is to minimize overall direct (fuel, etc.) and strategic (schedule buffer, etc.), costs to airspace users whilst maximizing the utilization of available airport and en-route capacity.

#### VII. CONCLUSIONS

The FAA/ATO and the PRC have managed to compare operational ANS performance on both sides of the Atlantic, using consistent data sources and methodologies. Moving forward, we now have a consistent approach to measure operational performance and understand ATM best practices, which may have global applicability.

One observes similar arrival punctuality levels in the US and Europe, albeit with higher variability in delays and related cost in the US.

A breakdown by flight phases reveals strong and weak points on both sides.

- A schedule upwards creep and down-sizing are observed in the US, and not in Europe.
- Departure punctuality is better, but taxi-out delays are longer and associated unit fuel burn higher in the US.
- “Direct route extension” is approximately 1% lower in the US, with corresponding fuel burn benefits;
- While there is no superior performance in terms of arrival transit time in the TMA, London Heathrow is a clear outlier.

These differences possibly originate from different policies in allocation of airport slots and flow management, as well as different weather conditions. The impact on environment, predictability and flexibility in accommodating unforeseen changes may be different. A better understanding of trade-offs would be needed to identify best practices and policies.

Identification and application of best practices could possibly help in significantly raising the level of performance on both sides of the Atlantic in a relatively short term, with today’s technology and operational concepts.

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## AUTHOR BIOGRAPHY

**John Gulding** currently serves as the manager of the Forecast Analysis division for the Office of Performance Analysis and Strategy. He has a Bachelors degree in mathematics from the University of Virginia and a Masters in operations research from George Mason University.

Current duties include producing future traffic scenario used for FAA planning projects such as NextGen and assessments of existing FAA

performance databases in determining potential benefit pools that may be realized through air traffic modernization.

**Dave Knorr** is the FAA/ATO Liaison to the German ATC organization (DFS) and to the CANSO Global Benchmarking Group. Mr. Knorr has a Masters in Engineering Administration and a BS in Mathematics both from Virginia Tech. He has held several management positions at the FAA related operational performance analysis.

**Marc Rose** of MCR is the manager of the Operations Research branch of the SETA-II contract supporting FAA. He has over 20 years experience which includes cost benefit analysis, detailed data analysis, procedures for applying risk to return-on-investment for many FAA projects.

**James Bonn** is a senior operations research analyst in the FAA ATO. Dr. Bonn holds a B.S. in Math from Northern Arizona University, a M.S. in Math from the University of Utah and a Ph.D. in Math from the University of North Carolina at Chapel Hill.

**Philippe Enaud** is a graduate of the Ecole Polytechnique de Paris. In EUROCONTROL, he has worked in the CFMU. He is one of the Deputy Heads of the Performance Review Unit.

**Holger Hegendoerfer** is an independent consultant with more than 10 years experience in the aviation industry. Prior to this, he worked as a senior consultant for KPMG and as a manager in IATA.