Comparison of Air Traffic Management related operational and economic performance

U.S. - Europe

January 2024

This report is a joint publication of the Air Traffic Organization of the FAA (FAA-ATO System Operations Services) and of the EUROCONTROL Aviation Intelligence Unit (AIU) on behalf of the European Commission in the interest of the exchange of information.

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

The objective is to make a factual high-level comparison of Air Traffic Management (ATM) performance between the U.S. and Europe based on a set of comparable performance indicators, developed jointly, and reviewed over time.

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EXECUTIVE SUMMARY

KEY MESSAGES

INTRODUCTION

- This report is the eighth in a series of comparisons between the U.S. and Europe.
- The objective of the work conducted by the U.S. Air Traffic Organization (FAA-ATO) Office of Performance Analysis and the EUROCONTROL Aviation Intelligence Unit (AIU) is to compare, understand, and further improve air traffic management (ATM) performance in both systems.
- The report looks at the operational and economic ATM performance in both systems since the outbreak of the pandemic in 2020. Where appropriate, it also follows up on longer term trends and differences in ATM performance between the U.S. and Europe, identified in previous reports.
- Russia's invasion of Ukraine in February 2022 and the unfolding effects of the war also influenced the analyses in this report. While most European traffic is not directly affected by the resulting airspace closures, there are substantial direct operational and economic impacts on several States in the region.
- To ensure comparability based on a common set of data sources with a sufficient level of detail and coverage, the operational comparison of Air Navigation Service (ANS) performance was limited to flights to or from the main 34 airports for IFR traffic in the U.S. and in Europe which account for approximately 68% and 65% of the controlled flights in Europe and the U.S., respectively.

ORGANISATION OF ATM

- For the interpretation of the results, it is useful to start with a summary of the organization of ATM in the U.S. and in Europe.
- While both systems are operated with similar technology and operational concepts, a significant distinguishing factor is that the U.S. airspace is handled by a single air navigation service provider (ANSP) while Europe is managed by close to 40 different service providers.
- In 2022, the U.S. controlled notably more flights operating under instrumental flight rules (IFR) with less controllers and less en-route control centres.
- Despite the efforts of the Single European Sky Initiative to reduce fragmentation and to better organise European airspace according to traffic flows rather than national boundaries, many issues in Europe revolve around the level of fragmentation and its impact on ATM performance in terms of operations and costs.

FLOW MANAGEMENT TECHNIQUES

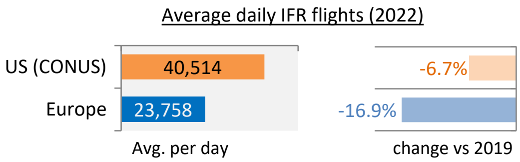
- To minimize the effects of ATM-related constraints, the U.S. and Europe use comparable methodologies to balance demand and capacity but both systems differ notably in the timing (when) and the phase of flight (where) air traffic flow management (ATFM) measures are applied.
- In Europe, a lot of emphasis is put on strategic planning and a large part of the demand/ capacity management measures are applied months in advance. Unlike in the U.S. where only 3 airports have schedule limitations, traffic at major European airports is usually

already regulated (in terms of volume and concentration) in the strategic phase through an airport scheduling process.

- With no or very limited en-route spacing or metering in Europe, the focus in Europe is on anticipating demand/ capacity imbalances in en-route centres or at airports and, if necessary, to solve them by delaying aircraft at the origin airports on the ground (allocation of ATFM take-off slots).
- In the U.S., the emphasis is more on the tactical traffic management in the gate-to-gate phase to maximize system and airport throughput under prevailing conditions on the day of operations. The approach is supported by the en-route function and less en-route capacity constraints than in Europe. This enables delay to be absorbed through path stretching in the en-route airspace and to achieve the metering required by TMAs and airports.
- Hence, many issues in the U.S. appear to be attributable to the effects of capacity variation between most favourable and least favourable conditions at airports, with demand levels near visual airport capacity and self-controlled by airlines.
- The way imbalances between capacity and demand are managed along the trajectory of a flight has an impact on airspace users (predictability, fuel burn), the utilisation of capacity (en-route, airport), and the environment (additional CO_2 emissions).
- Both systems try to optimize the use of available capacity in a safe and efficient manner.
- The comparison of performance based on a set of harmonised indicators provides insights for a more holistic assessment of ATM in both regions, including the identification of future research areas.

TRAFFIC

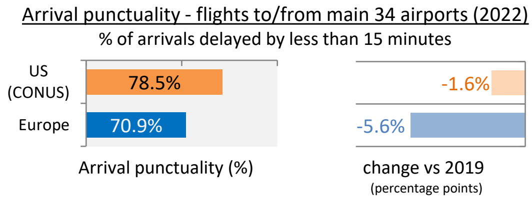
- In terms of controlled traffic, there was a notable decoupling between the U.S. and Europe as of 2003.
- While traffic continued to increase in Europe, the U.S. experienced a decline until 2016, after which traffic began to rise again until the onset of the pandemic in March 2020.
- Between 2003 and 2019, traffic in Europe grew by +31% (+2.5 million flights) while flights in the U.S. CONUS area decreased by -7% (-1.2 million flights) during the same period.
- In 2003, the U.S. managed more than twice the traffic of Europe. However, by 2019, this margin had diminished to approximately 50% more flights in the U.S.
- Following the outbreak of the COVID-19 pandemic in the first quarter of 2020, traffic on both sides of the Atlantic dropped dramatically. Compared to 2019, traffic in the U.S. decreased in 2020 by -33% with Europe showing an even higher drop of -56% vs 2019.
- After passing the low point in April 2020, traffic in the U.S. increased continuously whereas in Europe traffic remained at a low level until summer 2021 when it began to recover again. In 2022, traffic in the U.S. was still -6.7% below 2019 levels while in Europe traffic remained -16.9% below 2019 levels.



- The notable difference in the initial traffic reduction and in the recovery paths can be attributed primarily to the predominantly domestic traffic in the U.S. (80% of flights), which rebounded more quickly than the largely intra-European traffic which was subject to a multitude of national travel restrictions.

PUNCTUALITY

- "Punctuality" is a widely used industry standard to measure the service quality of air transport. It is expressed as the percentage of flights arriving (or departing) within 15 minutes of their published schedule time.
- In 2019, 80.1% of flights in the U.S. arrived within 15 minutes of their scheduled time, compared to 76.5% in Europe.
- As the pandemic began in early 2020, both systems experienced an uptick in punctuality due to the decrease in traffic. In 2020, nearly 90% of flights at U.S. airports arrived at their destinations within 15 minutes of their scheduled time, compared to 87% in Europe.
- As traffic began to rebound, punctuality levels began to deteriorate again on both sides of the Atlantic. In the U.S., arrival punctuality consistently worsened from 2020 through mid-2023, falling below the levels observed in 2019. Meanwhile, in Europe, arrival punctuality initially experienced a moderate decline in 2021 but then reached its all-time lowest point in the summer of 2022.



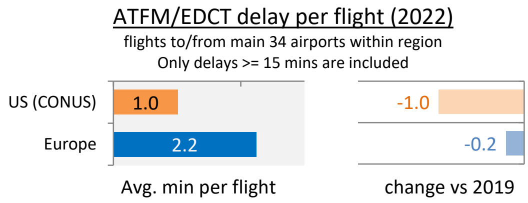
- Despite European traffic levels remaining notably below those of 2019, it became evident that several service providers were ill-prepared to scale up their operations to meet the rapidly increasing demand. The subpar performance in Europe did not stem from a single area (such as airports, airlines, or air traffic control) but rather resulted from deficiencies across multiple actors, primarily associated with staff shortages.
- While punctuality provides valuable first insights, the involvement of many different stakeholders and the inclusion of time buffers in airline schedules limit the analysis from an air traffic management point of view.

OPERATIONAL ANS PERFORMANCE

- The analysis of ATM-related operational performance aims to better understand and quantify constraints imposed on airspace users through the application of air traffic flow measures and therefore focuses more on the efficiency of operations by phase of flight, compared to an (unconstrained) theoretical optimum.
- It is worth noting that a certain level of flight inefficiency is necessary or even desirable for a system to be run efficiently without underutilization of available resources (capacity efficiency).
- Hence, the theoretical optimum cannot be achieved at system level when operational trade-offs, environmental or political restrictions, or other performance affecting factors such as weather conditions are considered.
- The goal should be to minimize overall direct (fuel, etc.) and strategic (schedule buffer, etc.) costs and the impact on environment whilst maximizing the utilization of available capacity.

ANS-RELATED DEPARTURE RESTRICTIONS (ATFM/EDCT DELAYS)

- Both the U.S. and Europe report ATM-related delay imposed on departing flights at the gate (ATFM/EDCT delays).
- In 2022 both regions show an improvement compared to 2019. However, the ATFM/EDCT delay per flight in Europe was more than twice as high as in the U.S., with fundamental differences in underlying drivers and the constraining locations.

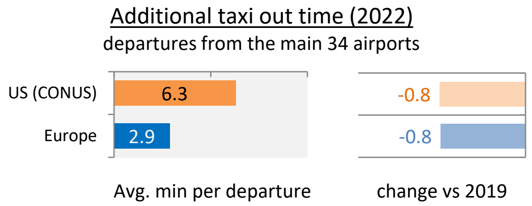


- It is worth pointing out that 2018 and 2019 were particularly bad years with exceptionally high ATFM delays in Europe after a continuous degradation of performance since 2013, mainly because of growing en-route capacity constraints.

- In the U.S. most ATFM/EDCT delays in 2022 were due to airports (66%) while in Europe most delays (75%) were attributed to en-route facilities.
- By far the main reason for delays in the U.S. in 2022 was adverse weather (76%) with a high share originating from airports.
- In Europe, the main causes in 2022 were ATC capacity/staffing related constraints (44%), followed by adverse weather (29%) and "Other" reasons (mainly due to ATC system upgrades and the war in Ukraine).

TAXI-OUT EFFICIENCY

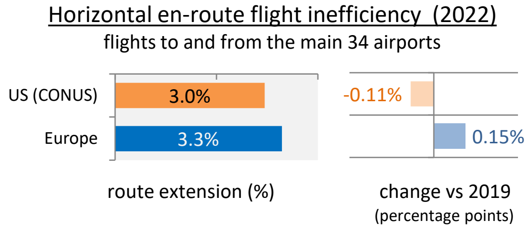
- Following the COVID-19 related traffic reduction, additional taxi-out time in the U.S. initially showed a substantial reduction but increased again in line with the traffic recovery and ultimately reached a level comparable to the pre-pandemic period.
- In Europe, a similar trend was observed. However, in line with the slower traffic recovery, average additional taxi out time remained low until 2022 when it started to increase again to almost reach pre-pandemic levels.



- In 2022, taxi-out efficiency was still better than in 2019 on both sides of the Atlantic.
- Nonetheless, average additional taxi-out time in the U.S. is roughly twice the additional taxi-out time in Europe. This disparity primarily arises from differences in flow control policies, with the U.S. adopting a more tactical approach, and the absence of scheduling caps at most U.S. airports.

HORIZONTAL EN-ROUTE FLIGHT EFFICIENCY

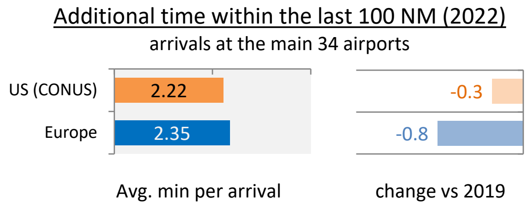
- Overall, the level of horizontal en-route flight inefficiency in both regions was at similar levels in 2022 with a slightly better performance in the U.S.



- The significant decrease in traffic following the COVID-19 outbreak briefly led to a temporary improvement of horizontal en-route flight efficiency in both Europe and the U.S. Nevertheless, as traffic began to recover, flight efficiency deteriorated again, returning to pre-pandemic levels on both sides of the Atlantic.
- Between 2019 and 2022, horizontal en-route flight inefficiency in the U.S. slightly reduced, while it increased in Europe during the same period, partly because of the impact of the war in Ukraine.

FLIGHT EFFICIENCY WITHIN THE LAST 100NM

- Prior to the pandemic, Europe had a significantly higher average additional time within the last 100 nautical miles, which was notably influenced by London Heathrow as a distinct outlier.
- With traffic levels in Europe still notably lower in 2022, the level of inefficiency due to airborne holding and metering was similar in both regions.

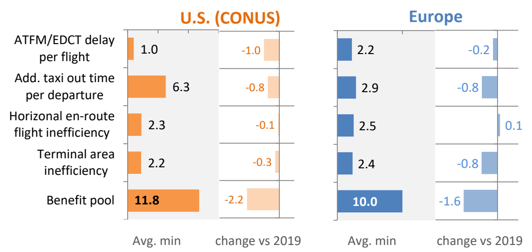


- Compared to 2019, both the U.S. and Europe show an improved performance in 2022, albeit at lower traffic levels at most airports.

ANS-RELATED PERFORMANCE – Overview

- As there are many trade-offs between flight phases, the aggregation of the results enables a high-level comparison of the theoretical maximum "benefit pool" actionable by ATM in both systems.
- It is important to emphasize that the "benefit pool" is based on a theoretical optimum which, due to inherent necessary (safety) or desired (capacity) limitations, is not achievable at system level.
- Overall, the relative distribution of the ATM-related inefficiencies associated with the different phases of flight is consistent with the differences in flow management strategies described throughout the report.
- In Europe ATM-related departure delays (ATFM/EDCT) at the gate are much more frequently used than in the U.S., which leads to a higher average delay and a higher share of traffic affected. Consequently, flights in Europe are 5 times more likely to be held at the gate than in the U.S. because of en-route capacity constraints.
- In the U.S. the additional taxi-out time is twice as high as in Europe, mainly because of the more tactical focus to maximise throughput under prevailing conditions on the day of operations.

Theoretical maximum benefit pool actionable by ATM (2022)



- Overall, the total benefit pool in 2022 was higher in the U.S. than in Europe, but with traffic levels in the U.S. notably closer to pre-pandemic levels.
- To get a more complete picture of ANS performance in each region, there is a need to also consider capacity utilization together with the observed "benefit pool".

ANS COST-EFFICIENCY

- Between 2011 and 2019 traffic grew considerably in both the SES States (+19.3%) and in the U.S. (+8.7%); even so, the U.S. still controlled 84% more flight-hours than SES States in 2019. In the meantime, the ATM/CNS provision costs for the ANSPs in the SES States increased slightly (+2.1%), while the U.S. FAA-ATO reduced its cost-base by -11.2% primarily reflecting a decrease in total support costs, partly due to a change in accounting methodology. Consequently, the ATM/CNS provision costs per flight-hour reduced considerably for both the SES States (-14.4%) and the U.S. (-18.4%) over this period.
- Cost-efficiency metrics in both the SES States and the U.S. were significantly impacted by the sharp decline in flight hours controlled brought about by the implementation of stringent travel restrictions aimed at mitigating the spread of COVID-19.
- The influence of the COVID-19 pandemic on the total number of IFR flight-hours logged in 2021 had a notably more pronounced effect on the SES States, where there was a decrease of -44.6% compared to 2019, as opposed to the U.S., which saw a decrease of -19.9% compared to 2019.
- Both the SES States and the U.S. implemented cost-containment measures reducing the ATM/CNS provision costs between 2019 and 2021 by -7.0% and -1.8% respectively.
- The total ATM/CNS provision costs per flight-hour experienced a significant rise on both sides of the Atlantic after the onset of the COVID-19 pandemic in 2020. However, in the U.S., the increase was notably less pronounced than in the SES States, with a difference of +22.6% compared to +67.9%, respectively. This contrast can be mainly

attributed to the considerably smaller reduction in traffic in the U.S.

- In 2021, the total ATM/CNS provision costs in the U.S. were 47% higher than those in the SES States, but it's important to note that the U.S. also managed more than double the number of IFR flight-hours compared to the SES States. This was achieved with approximately 10.2% fewer ATCOs in OPS (FTE) than in the SES States, who worked, on average, longer than their European counterparts.
- As a result, the average U.S. ATCO was some 1.5 times more productive (in terms of IFR flight-hours controlled per ATCO-hour on duty) than the controllers in the SES States.

EMERGING THEMES

- 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.
- Given the key elements affecting performance in the two systems, further work in the following areas could provide useful insights for performance improvement in both systems.

ANS OPERATIONAL PERFORMANCE

- <u>Magnitude and Effect of Traffic Flow Initiatives</u>: More work is needed to determine how to minimize the impact of flow measures on airspace users and the environment in each flight phase while maximizing the use of scarce airport and en-route capacity.
- <u>Quantify capacity utilization</u>: A better understanding of tactical capacities at airports but also in en-route centres would strengthen the comparison and enable a more complete assessment of flow management together with capacity utilization.
- <u>Factors affecting en-route flight efficiency</u>: Future reports could provide some initial evaluations of those factors impacting en-route flight efficiency in each region (trade-offs, special use airspace, TMA entry points, weather impact, etc.).
- <u>Vertical flight efficiency</u>: More work is required to improve the assessment of vertical flight efficiency that can be attributed to ATM in the comparison report, and to develop commonly agreed indicators for the measurement of those inefficiencies.

ANS COST-EFFICIENCY

- <u>Improve staffing comparisons</u>: Get a deeper understanding of the role of the FAA "developmental" and Certified Professional Controllers In-Training (CPC-ITs) vs. a European equivalent may be necessary to advance other measures, such as cost based or productivity measures. Furthermore, a better understanding of working arrangements in each region (rostering practices, contractual working hours, overtime, leave, training) would be beneficial in future comparison reports.
- <u>Support cost analysis</u>: In view of the large share in the total ATM/CNS costs (70%+), it would be useful to better understand the main support cost drivers in the U.S. and in Europe, including a better understanding of the treatment of facilities and equipment as part of the total operating costs in each region to ensure an accurate comparison in this cost category.

CONTENTS

1 Introduction & Context

This report is the eighth in a series of joint comparisons between the U.S. and Europe [1] [2]. It represents the fifth edition under the Memorandum of Cooperation (NAT-I-9406A) between the United States and the European Union (EU). The work is managed by the joint Performance Analysis Review Committee (PARC) under the Memorandum.

Building on commonly agreed metrics from the previous operational [1] and cost-efficiency [2] comparison reports, the objective of the joint work conducted by the U.S. Air Traffic Organization (FAA-ATO) [1] and EUROCONTROL on behalf of the PARC is to compare, understand, and further improve air traffic management (ATM) performance in both systems.

The outbreak of the COVID-19 pandemic in early 2020 resulted in an unprecedented reduction of air traffic around the globe - with significant effects on the entire aviation industry. Air Navigation Services (ANS) had to adjust operationally and economically as quickly as possible to the reduced demand, whilst ensuring a safe and reliable service to those flights still operating. A first evaluation of the economic and operational impact of the COVID-19 outbreak on the two ATM systems in the U.S. and in Europe was provided in a special report in December 2021 [3].

As shown in this special report in 2021, the impact of the pandemic on air traffic was notably different in the U.S. and in Europe due to differences in market composition. The analysis showed that international traffic was much more affected because of the various measures implemented by governments to fight the pandemic. Hence, the impact on air traffic in the U.S. was notably lower because of the large domestic market share (80%) in comparison to Europe (30%).

The recovery phase also showed different patterns. While in the U.S. traffic recovered continuously after the outbreak of the pandemic in March 2020, in Europe recovery was generally slower but with notably high growth rates in summer.

This report looks at the operational and economic ATM performance in both systems since the outbreak of the pandemic in 2020. Where appropriate, it also follows up on longer term trends and differences in ATM performance between the U.S. and Europe identified in previous reports.

Russia's invasion of Ukraine in February 2022 and the unfolding effects of the war also influenced the analyses in this report.

The closure of Ukraine's airspace to commercial traffic was amplified by reciprocal airspace bans for Russian and many Western operators. This resulted in a cut of many important east-west airways between Europe and Asia for many Western carriers.

While most of the European traffic is not directly affected by the airspace closures, flights originating in Europe or Eastern Asia that previously travelled through Russian airspace need to divert, which adds travel time and fuel burn and in turn lowers flight efficiency. Additionally, there is a direct operational and economic impact on the adjacent Air Navigation Service Providers (ANSPs).

To allow for consistency in time series analyses, Ukraine was removed from the scope of the analyses in this report.

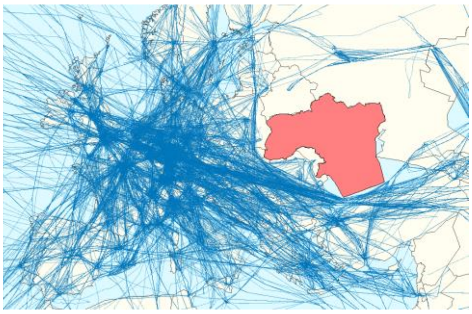


Figure 1-1: Impact of Ukraine war on air traffic

[1] The U.S. Air Traffic Organization (ATO) is the operational arm of the FAA, which applies business-like practices to the delivery of air traffic services.

1.1 REPORT SCOPE

To ensure the comparability of ATM performance, the analysis scope in this report was influenced by the need to identify a common set of data sources with a sufficient level of detail and coverage (see Annex I for more information on data sources).

GEOGRAPHICAL SCOPE

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

Unless stated otherwise, for the purpose of this report, "Europe" is defined as the geographical area where ANS are provided by the EU Member States plus those States outside the EU that are members of EUROCONTROL, **excluding** Oceanic areas, Georgia, the Canary Islands and Ukraine[2].

The overview of the traffic characteristics in the U.S. and in Europe in Chapter 2 includes all airports and all IFR traffic. The more detailed operational 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 IFR traffic in both the U.S. and in Europe[3]. A list of the airports included in this report can be found in Annex II.

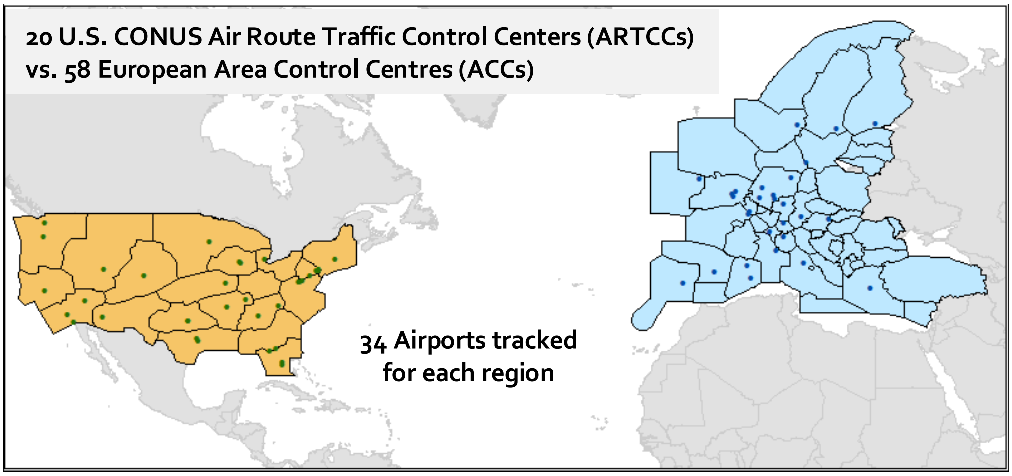


Figure 1-2: Geographical scope of the comparison in the report (2023)

In the economic comparison in Chapter 4, "Europe" corresponds to the 36 ANSPs[4] included in the ATM cost-effectiveness (ACE) benchmarking exercise (see Annex III for the full list of ANSPs).

The "U.S." refers to the 48 contiguous States located on the North American continent south of the border with Canada (U.S. CONUS) **plus** activity for Alaska, Hawaii, Puerto Rico, and Guam.

TEMPORAL SCOPE

The analyses in this report focus mainly on the period between 2018-2022 to contrast the performance of 2022 versus the performance before the pandemic and during the recovery phase. Where useful, comparisons over longer time periods are provided to track trends over time already highlighted in previous reports.

2 Different from previous years, Ukraine was excluded from this report following Russia's invasion in February 2022 and the subsequent closure of airspace to commercial traffic.

3 Although they are within the main 34 airports in terms of traffic in Europe, Istanbul (SAW), Antalya (AYT) and Manchester (MAN) airports were not included in the analysis due to data availability issues.

4 While the latest ACE Benchmarking report [9] includes 38 ANSPs, Sakaeronavigacija, the Georgian ANSP, and BHANSA, the ANSP of Bosnia and Herzegovina, only started to provide data for the years 2015 and 2019 respectively and are therefore excluded from the analysis presented in this report.

1.2 ORGANISATION OF ATM IN THE U.S. AND IN EUROPE

For the interpretation of the results in this report, it is useful to start with a high-level summary of the organisation of ATM in the U.S. and in Europe.

The key difference between both regions is that the European ATM system is composed of many individual Air Navigation Service Providers (ANSP) with different working arrangements and cost structures whereas the U.S. system is operated by a single ANSP using the same tools and equipment, communication processes and a common set of rules and procedures.

Both the U.S. and Europe have established system-wide, centralized traffic management facilities (the ATCSCC[5] and the NM[6] respectively) to manage the ATFM processes at strategic, pre-tactical and tactical level and to ensure that traffic flows do not exceed what can be safely handled by Air Traffic Control (ATC) units while trying to optimize the use of available capacity. The delivery of ATC capacity and the fine-tuning of traffic flows is the responsibility of en-route, terminal and airport ATC facilities.

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

This puts the 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.

In Europe, although Air Traffic Flow Management (ATFM) and Airspace Management (ASM) are coordinated centrally by the NM, at the ATC level the European system is more fragmented, and the provision of ANS is still largely organized by State boundaries.

The NM monitors the traffic situation and proposes flow measures which are coordinated through a Collaborative Decision Making (CDM) process with the local authority. Usually the local Flow Management Positions (FMP), embedded in Area Control Centers (ACCs) to coordinate the air traffic flow management, requests the NM to implement flow measures.

The Single European Sky (SES) initiative of the European Union (EU) aims at reducing the effects of fragmentation. It provides the framework for the creation of additional capacity and for improved efficiency and interoperability of the ATM system in Europe. The second legislative package, adopted in 2009, foresees, inter alia, for the European NM a more proactive role in ATFM, ATC capacity enhancement, airspace structure development and the support to the deployment of technological improvements across the ATM network. Additionally, it made legal provision for an EU wide performance scheme for ANS starting in 2012. The European Commission subsequently made a new reform proposal SES2+ to further improve and advance the Single European Sky. This legislative proposal is currently negotiated between the co-legislators (European parliament and council).

The SES performance scheme places focus on planning and accountability for performance, binding target setting (Safety, Cost-Efficiency, Capacity and Environment), monitoring, incentives and corrective actions at both European and national levels. It is coupled with a charging regime replacing "full cost recovery" by a system of "determined costs" and risk sharing set at the same time as performance targets [4].

Part of the SES initiative also includes the modernisation of the European system as part of the SESAR programme. This comprises research and development of novel operational concepts and technical enablers. The programme received funding from the European Union and is implemented through Common Projects.

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5 Air Traffic Control System Command Center (ATCSCC) in Warrenton, Virginia.

6 Network Manager (NM) in Brussels, Belgium.

Table 1-1 provides a high-level overview of ATM key system figures in the U.S. and in Europe. While the total surface of airspace analyzed in this report is similar for Europe and the U.S., the number of physical ATC facilities differs notably in both ANS systems.

The U.S. has one ANSP and the U.S. CONUS is served by 20 Air Route Traffic Control Centers (ARTCC) supplemented by 26 stand-alone TRACONs providing services to multiple airports (total: 46 facilities). In addition, the U.S. has 134 Approach Control Facilities combined with Tower services.

The ATM system in Europe is more fragmented and operates with more physical facilities than the U.S. The European region comprises 36 ANSPs (and a similar number of different regulators), 58 Area Control Centers (ACC) [7] and 19 stand-alone Approach Control (APP) units (total: 77 facilities).

However, the U.S. controls notably more flights operating under Instrument Flight Rules (IFR) with fewer Air Traffic Controllers (ATCOs) and fewer en-route and terminal facilities (total: 46 facilities).

Year 2021/22	U.S.[8]	Europe [9]	U.S. vs. Europe
Geographic Area (million km^2)	10.4	10.6	
Controlled flights 2022 (IFR) (million)	14.8	8.7	≈ +70%
Share of General Aviation (IFR flights)	19%	4.4%	
Nr. of civil en-route Air Navigation Service Providers	1	36	
Number of en-route facilities	20[10]	58	
Number of stand-alone APP/TRACON units	26[11]	19	
Number of APP units collocated with en-route or TWR fac.	134	250	
Number of airports with ATC services	517[12]	374	
Of which are slot controlled	3 [13]	> 100 [14]	
Number of Air Traffic Controllers (ATCOs in OPS), in FTEs (2021)	11 784[15]	16 552	≈ -29%
Number of OJT/developmental ATCOs, in FTEs (2021)	2 260	1 079	
Total ATCOs in OPS plus OJT/developmental, in FTEs (2021)	14 430	17 631	≈ -18%
Total staff, in FTEs (2021)	31 681	50 945	≈ -38%

Table 1-1: U.S. –Europe ATM key system figures at a glance (2021/22)

Using the definition employed by the ACE and CANSO benchmarking reports which excludes those designated as "on-the-job training" in Europe or as a "developmental" at the FAA, the U.S. operated with some 29% less full-time ATCOs than Europe in 2021. However, the gap narrows notably when developmental and Certified Professional Controllers in Training (CPC-ITs) on the U.S. side and On-the-Job trainees in Europe are also considered.

A further difference between the U.S. and Europe is the share of general aviation traffic which accounts for 19% and 4.4% of total traffic respectively.

7 For Europe, a 59th en-route centre is located in the Canaries, outside of the geographical scope of the study. In the U.S., 3 additional en-route centres are operated by the FAA, outside of the U.S. CONUS.

8 Area refers to CONUS only. Centre count and staff numbers refer to the NAS excluding Oceanic.

9 Area, staff and facility numbers refer to EUROCONTROL States, excluding Georgia, Ukraine, Canary Islands and Oceanic areas. European staff and facility numbers refer to 2021 which is the latest year available.

10 20 en-route centers (ARTCCs) are in the U.S. CONUS, 3 are outside.

11 26 stand-alone TRACONs are in the U.S. CONUS, 1 is outside (Alaska).

12 Total of 514 facilities of which 264 are FAA staffed and 250 federal contract towers. European airports as included in the ACE benchmarking report.

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

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

15 This value reflects the CANSO reporting definition of a fully trained ATCO in OPS and includes supervisors. It is different than the total controller count from the FAA Controller Workforce Plan which does not include supervisors. The number of ATCOs in OPS does not include 1 400 controllers reported for contract towers. The number of ATCOs in OPS including Oceanic is 11 958.

To improve comparability, the analysis of operational ANS performance in Chapter 3 is limited to IFR flights either originating from or arriving to the main 34 airports in each region. Notwithstanding the large number of airports in each region, only a relatively small number of airports account for the main share of traffic. The main 34 airports account for approximately 68% and 65% of the controlled flights in Europe and the U.S., respectively. The traffic mix of this sample is more comparable as this removes a large share of the smaller piston and turboprop aircraft (see also analysis in Figure 2-6 on page 12).

A further significant difference worth pointing out is the low number of airports with schedule or slot limitations in the U.S. compared to Europe, where most of the airports are slot-coordinated.

1.2.1 FLOW MANAGEMENT TECHNIQUES

To minimize the effects of ATM-related constraints, the U.S. and Europe use a comparable methodology to balance demand and capacity[16]. This is accomplished through the application of an "ATFM planning and management" process, which is a collaborative, interactive capacity and airspace planning process, where airport operators, ANSPs, Airspace Users (AUs), military authorities, and other stakeholders work together to improve the performance of the ATM system.

This CDM process allows AUs to optimize their participation in the ATM system while mitigating the impact of constraints on airspace and airport capacity. It also allows for the full realization of the benefits of improved integration of airspace design, airspace management and air traffic flow management (ATFM). The process contains several equally important phases: ATM planning, ATFM execution (strategic, pre-tactical, tactical) including the fine tuning of traffic flows by ATC through Traffic Management Initiatives (TMIs).

Figure 1-3 provides an overview of the key players involved and the most common ATFM techniques.

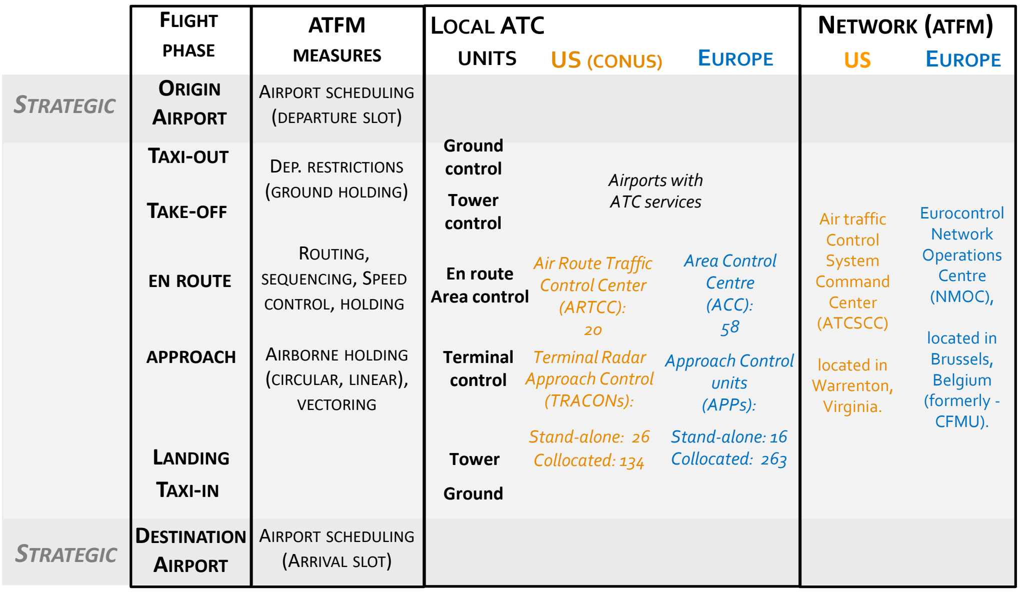

Figure 1-3: Organization of ATFM (Overview)

The two ATFM 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 and a large part of the demand/capacity management measures are applied months in advance. Traffic at major airports is usually regulated (in terms of volume and concentration) in the strategic phase through the airport capacity declaration

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

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

In addition, demand in Europe is managed in pre-tactical phases (allocation of ATFM take-off slots). The European system operates airport streaming on a local and distributed basis with the NM mainly protecting the en-route segments from overload.

In the U.S., the emphasis is on the tactical traffic management in the gate-to-gate phase to maximize system and airport throughput under prevailing conditions on the day of operations. Very few airports in the U.S. have schedule limitations. The operations are based on real time capacity forecasts provided by local ATC. Demand levels are self-controlled by airlines and adapted depending on the expected cost of delays and the expected value of operating additional flights. The few schedule constrained airports in the U.S. are typically served by a wide range of (international) carriers and are in high density areas at the U.S. East and West coast.

With more emphasis on the tactical phase, the U.S. system appears to be more geared towards maximizing airport throughput according to the available capacity on the day of operations. The approach is supported by the en-route function and less en-route capacity constraints than in Europe. This enables to absorb path stretching in the en-route airspace and to achieve the metering required by TMAs and airports.

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

<u>Departure restrictions (ground holdings)</u>: In the U.S., Ground Delay Programs (GDP) or Airspace Flow Programs (AFP) are mostly used in case of severe capacity restrictions at airports or en-route when less constraining measures, such as Time-Based Metering or Miles in Trail (MIT) are not sufficient. The Air Traffic Command Center (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. Most of these delays are taken at the gate. A ground stop (GS) is an extreme measure in air traffic management where arrivals to a specific airport are temporarily postponed. The number of departure airports included in the scope of the ground stop can vary based on the severity of the event and international flights are excluded from these programs.

In Europe when traffic demand is anticipated to exceed the available capacity in en-route ACCs or at airports, 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 European Network Manager. The ATFM delay of a given flight is attributed to the most constraining ATC unit, either en-route (en-route ATFM delay) or airport (airport ATFM delay). The NM was initially created in the 1990s to manage the lack of en-route capacity of a fragmented ATC system. Different from the U.S., 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.

En-route flow management (airborne): In the U.S. sequencing programs are used to achieve specified spacing between aircraft using distance (miles) or time (minutes). The most known is called miles in trail (MIT). It describes the number of miles required between aircraft departing from or arriving to an airport, over a fix, navaid, 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. En-route caused restrictions are small compared to airport driven flow restrictions in the U.S.

MIT restrictions are commonly employed in the U.S., where the responsibility for maintaining a traffic flow at or below the restricted level can be transmitted upstream, sometimes resulting in restrictions even at the departure airport. Consequently, MIT restrictions can ultimately impact aircraft on the ground. When an aircraft is preparing for take-off from an airport to join a traffic flow under an active MIT restriction, it requires specific clearance for take-off. ATC releases the aircraft only when it can seamlessly integrate into the sequenced flow. These delays, managed by the Traffic Management System (TMS), primarily occur during the taxi-out phase, with limited impact at the gate.

The measures have a considerable effect on the workload of ATCOs by optimizing 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 U.S. is more and more transitioning to Time-Based Metering (TBM) due to gained spacing efficiencies. TBM 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 to adjust the time at which the aircraft arrive in a specific airspace or at an airport.

Arrival flow management (airborne): In both the U.S. and the European system, the terminal area around a congested airport is used to absorb delay and to keep pressure on the runways to ensure the maximum use of available capacity. Traffic management Initiatives (TMIs) generally recognize maximizing the airport throughput as paramount.

With Time Based Metering (TBM) systems in U.S. 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.

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

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

2.1 AIR TRAFFIC EVOLUTION IN THE U.S. AND IN EUROPE

Figure 2-1 shows the evolution of IFR traffic in the U.S. and in Europe between 2003 and 2022. The U.S. CONUS airspace is slightly smaller than the European airspace, but the U.S. controlled in 2022 notably more IFR flights with considerably less en-route facilities.

Historic trend (pre-COVID-19):
In 2003, the number of IFR flights in the U.S. CONUS area was more than twice the traffic in Europe. As of 2004, a notable decoupling in terms of traffic evolution is visible with traffic in Europe continuing to grow while U.S. traffic started to decline to reach its lowest level in 2016, before increasing again until the start of the COVID-19 pandemic in early 2020. The effect of the economic crisis starting in 2008 is clearly visible on both sides of the Atlantic. Overall, traffic in Europe grew by +30.9% (+2.5 million flights) between 2003 and 2019 while flights in the U.S. CONUS area declined by -7.1% (-1.2 million flights) during the same period.

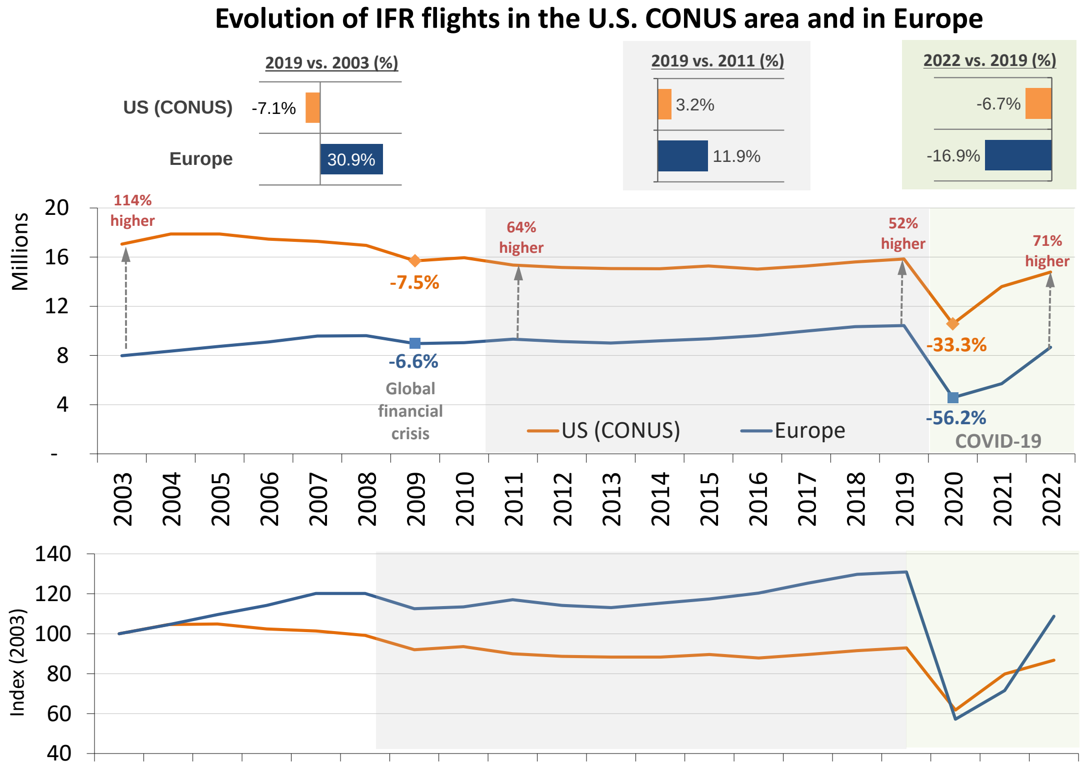

Figure 2-1: Evolution of IFR traffic in the U.S. CONUS area and in Europe (yearly)

COVID-19 pandemic:
Shortly after the World Health Organization (WHO) declared COVID-19 a pandemic in mid-March 2020, air traffic dropped dramatically on both sides of the Atlantic because of the travel restrictions imposed by many countries to fight the pandemic. Consequently, in 2020, there was a -33% reduction in U.S. traffic compared to 2019, equivalent to some 5.3 million less flights. Meanwhile, European air traffic experienced an even more substantial decline, with a -56% reduction in 2020 compared to 2019, resulting in 5.9 million fewer flights.

The annual figures hide to some extent the full dynamics of the COVID-19 crisis. The analysis in Figure 2-2 shows the evolution of the 7-day moving average of daily flights in the U.S. CONUS area and in Europe between 2019 and 2023 (up to end July).

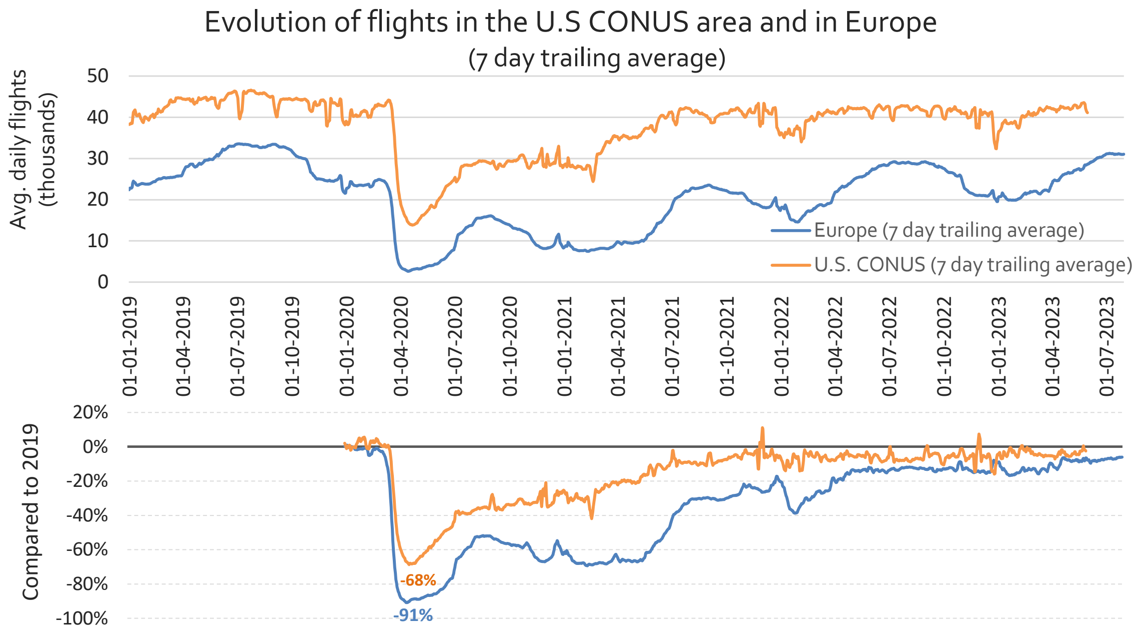

Figure 2-2: Evolution of IFR traffic in the U.S. CONUS area and in Europe (2019-2023)

A first interesting observation is the notably higher seasonal variation in Europe compared to U.S in 2019 which was not affected by the pandemic (top left in Figure 2-2). Flight counts in Europe show a clear increase in summer (+15% vs average), mainly because of notably increased holiday traffic to destinations in southern Europe. In the U.S., the seasonal variation is more moderate and skewed by the high summer traffic in northern states offsetting the high winter/spring traffic in the south.

Following the shock in March 2020, the 7-day average reached its lowest point in Europe in mid-April 2020 when traffic was 91% below the level of 2019. In the U.S., the lowest point was also in mid-April when traffic was 68% below the comparable traffic level in 2019.

After passing the low point in April 2020, traffic in the U.S. increased continuously whereas in Europe traffic declined again after an initial surge in summer 2020 and remained at a low level until summer 2021. Despite substantial growth in the second half of 2021, traffic recovery in Europe in 2021 reached only just above half the level of 2019. As for 2022, European traffic continued its rebound from the impact of the COVID-19 pandemic, reaching approximately 83% of the 2019 traffic level, while in the U.S., traffic levels in 2022 rebounded even further, achieving 93% of the 2019 levels.

As highlighted in the special report published on the impact of the COVID-19 pandemic on the U.S. and European ANS systems [3], the notably higher traffic reduction in Europe was mainly linked to the differences between the U.S. and Europe in terms of market composition and the timing and severity of the measures implemented to fight the COVID-19 pandemic.

Domestic traffic was less affected than international traffic on both sides of the Atlantic. However, the domestic market share in the U.S. is above 80% whereas in Europe domestic flights within States only account for approximately 30% of all flights. Hence, the high share of international or cross-border traffic in Europe affected by travel restrictions implemented by European States clearly played a role in the higher initial traffic reduction in 2020 but was also a factor for the slower recovery rate observed from 2020 onwards.

The recovery from the pandemic was not equally distributed among the network, as illustrated in the map in Figure 2-3.

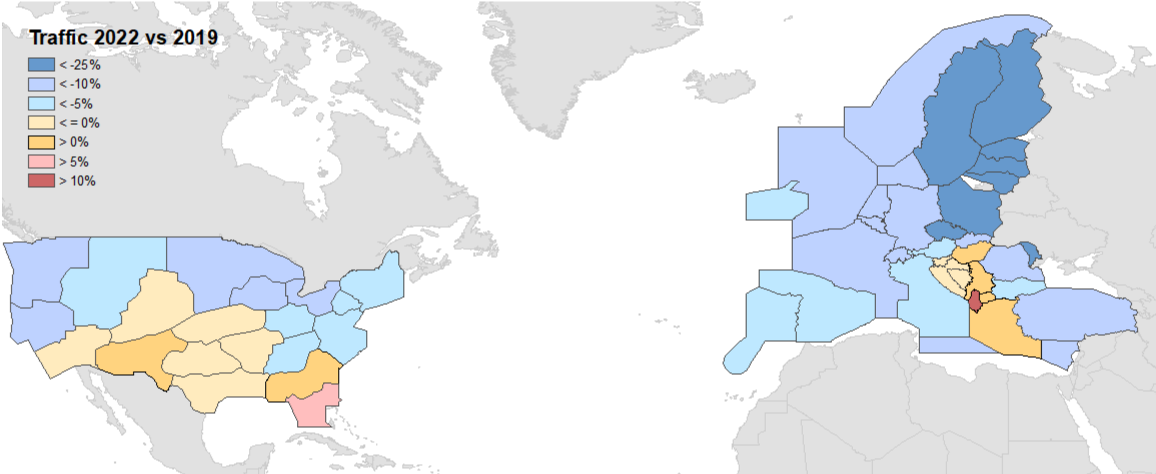

Figure 2-3: Evolution of IFR traffic in the U.S. and in Europe (2022 vs. 2019)

Europe shows a contrasted picture with wide variations between 2022 and 2019. This is partly due to differences in COVID-19 recovery patterns but also due to changes in traffic flows because of the war in Ukraine. Because of a substantial recovery of holiday traffic, typical holiday destinations in southern Europe generally showed a better recovery in 2022 with some states such as Albania and Greece even exceeding 2019 traffic levels.

The impact of the Ukraine war and the airspace closures issued by Western countries and Russia affected traffic flows and overflights in several countries. Some Nordic States have lost substantial traffic, whereas States south of Ukraine show higher traffic levels from flights circumnavigating around closed airspace.

The U.S. is a more homogenous and mature market with a large share of domestic traffic which shows a different behavior. The most noticeable shift in the U.S. is the increase in traffic over pre-pandemic levels in the southeast. The major international airports in the northeast were slower to recover.

2.2 AIR TRAFFIC DENSITY

Figure 2-4 shows the traffic density in the U.S. and in Europe measured in annual flight-hours per square kilometer for all altitudes in 2022. For Europe, the map is shown at Flight Information Region (FIR) level because the display by en-route center would hide the centers in lower airspace.

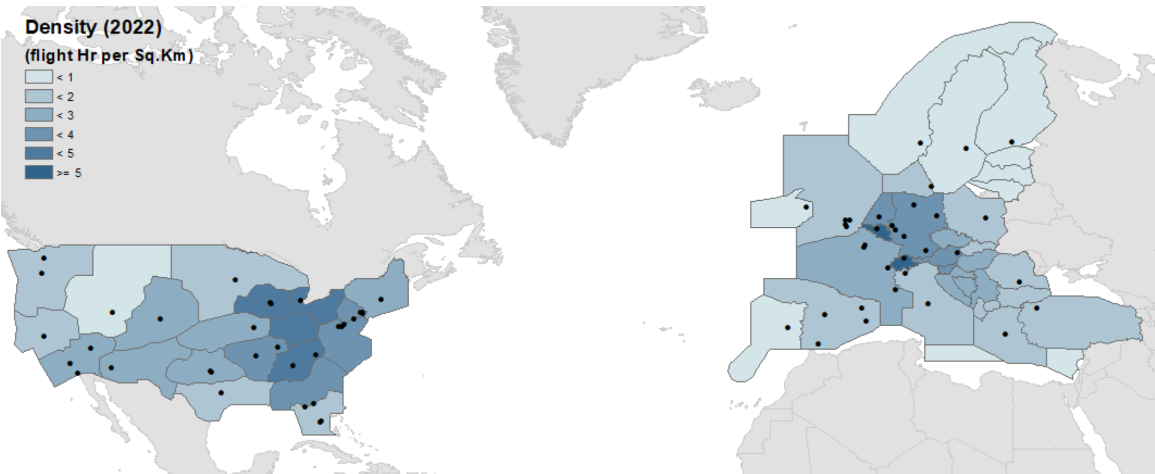

Figure 2-4: Traffic density in the U.S. and in Europe (2022)

In Europe, the "core area" comprising the Benelux States, Northeast France, Germany, and Switzerland is the densest and most complex airspace. The area includes major European hubs, and it is also the crossing point between traffic from Northern Europe to the Southwest and traffic from Central Europe to the West.

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

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

2.3 SEASONAL VARIABILITY

Seasonality and variability of air traffic demand can be a factor affecting ATM performance. If traffic is highly variable, resources may be underutilized during off-peak times but scarce at peak times.

Figure 2-5 compares the seasonal variability (relative difference in traffic levels with respect to the yearly averages) in the U.S. and in Europe for 2022.

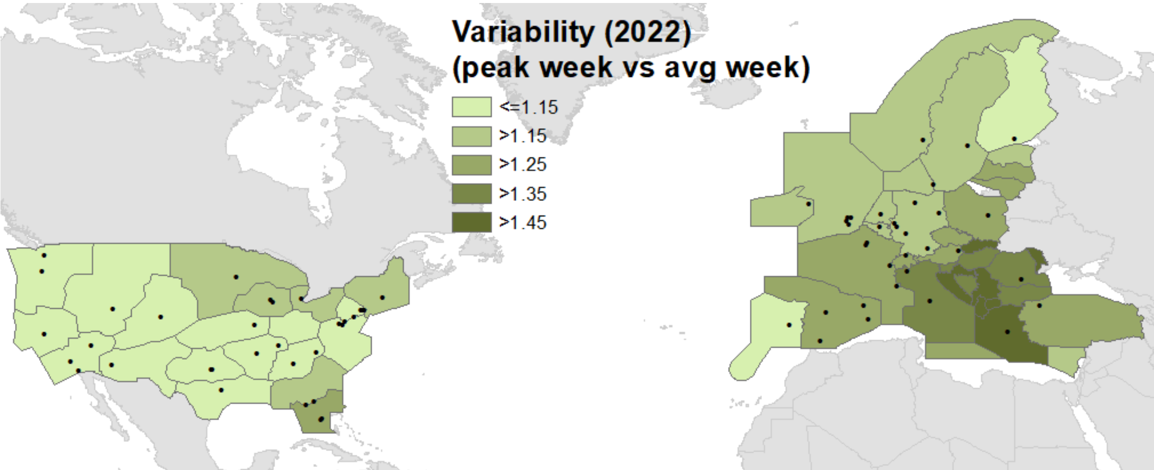

Figure 2-5: Seasonal traffic variability in the U.S. and in Europe (2022)

As was the case before the pandemic, a very high level of seasonal variation in Europe is observed for the holiday destinations in Southern Europe where a comparatively low number of flights in winter contrast sharply with high demand in summer. Additionally, the shift of traffic flows following the outbreak of the war in Ukraine in February 2022 contributed to the variation of traffic in certain areas adjacent to the region.

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

2.4 AIRCRAFT MIX

As shown in Table 1-1, the share of general aviation is notably higher in the U.S. and, although outside the scope of this study, the U.S. also handles notably more Visual Flight Rules (VFR) traffic.

Figure 2-6 shows the distribution of physical aircraft classes for all flights and at the main 34 airports in each region.

If all traffic is considered, the U.S. shows a notably higher share of smaller piston and turboprop aircraft.

Even though the average aircraft size is still notably smaller in the U.S., the samples are more comparable when only flights to and from the 34 main airports are considered.

The higher share of larger aircraft in Europe is also confirmed by the evolution of the average number of seats per scheduled passenger flight in Figure 2-7. For 2022, the average number of seats per scheduled flight is +26% (+34 seats) higher in Europe for traffic to or from the main 34 airports.

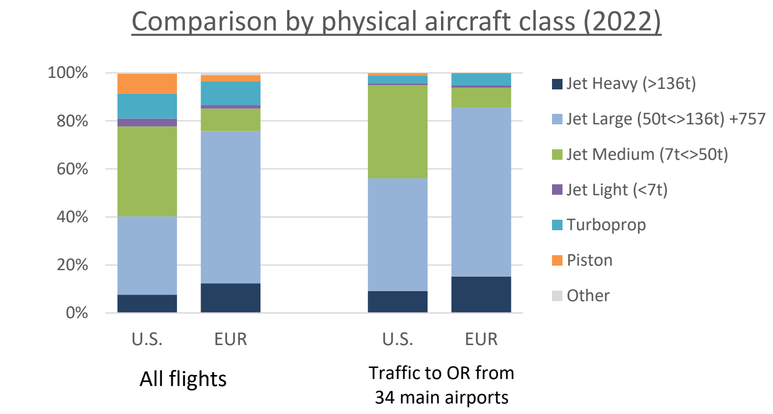

Figure 2-6: Comparison by physical aircraft class (2022)

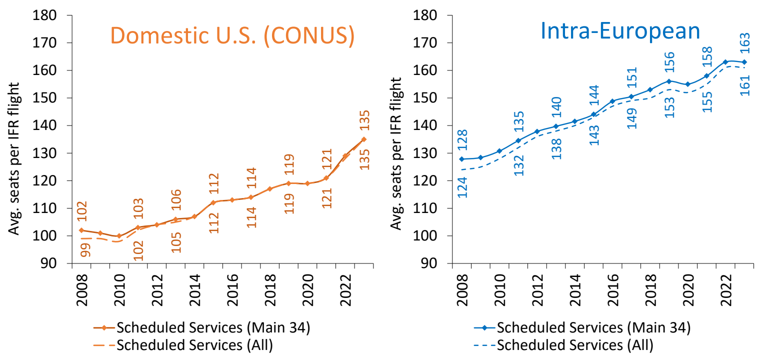

Figure 2-7: Average seats per scheduled flight (2008-2023)

The noticeable variation in aircraft size between the two regions is connected to the distinct approaches adopted by airlines, influenced by factors such as demand, market competition, and other considerations. A growing number of European low-cost carriers opt for a high-density, one-class seating arrangement, in contrast to the typical two-class configuration favored by U.S. carriers. Furthermore, given the limited number of slot-restricted airports in the U.S., airlines have the flexibility to increase service frequency by employing smaller aircraft, which helps them capture a larger market share and cater to high-yield business travelers.

In contrast to Europe, where the average number of seats per flight consistently rose between 2008 and 2022, the United States experienced a more modest growth rate in the number of seats per aircraft during the same period. However, this suggests the potential to accommodate more passengers with relatively minor increases in operations. The substantial increase in average seat numbers in the U.S. since 2013 can be primarily attributed to industry consolidation, resulting in fewer flight frequencies but the utilization of larger aircraft. Additionally, the significant upswing in the U.S. from 2014 to 2015 can be traced to alterations in airlines' regional fleets, which included a sharp reduction in 45-50 seat jets in favor of larger 65-75 seat aircraft on select routes.

2.5 OPERATIONS AT THE MAIN 34 AIRPORTS

Figure 2-8 shows the average daily IFR departures at the main 34 airports[17] in the U.S. and in Europe. The average number of daily IFR departures is considerably higher in the U.S., compared to Europe.

On both sides of the Atlantic, the highest decrease compared to 2019 is observed in April 2020. At the 34 main U.S. airports, departures in April 2020 were -69% lower than in April 2019. In Europe, the decrease in April 2020 was with 91% notably higher at the main 34 airports.

As mentioned before, the notably lower decrease in the U.S. is linked to the stronger domestic market in the U.S. which was less affected than international traffic. U.S. hubs with stronger international traffic (e.g. Atlanta, Chicago, and San Francisco) were subject to a higher traffic reduction within the U.S. during the pandemic.

Average daily IFR departures at the main 34 airports

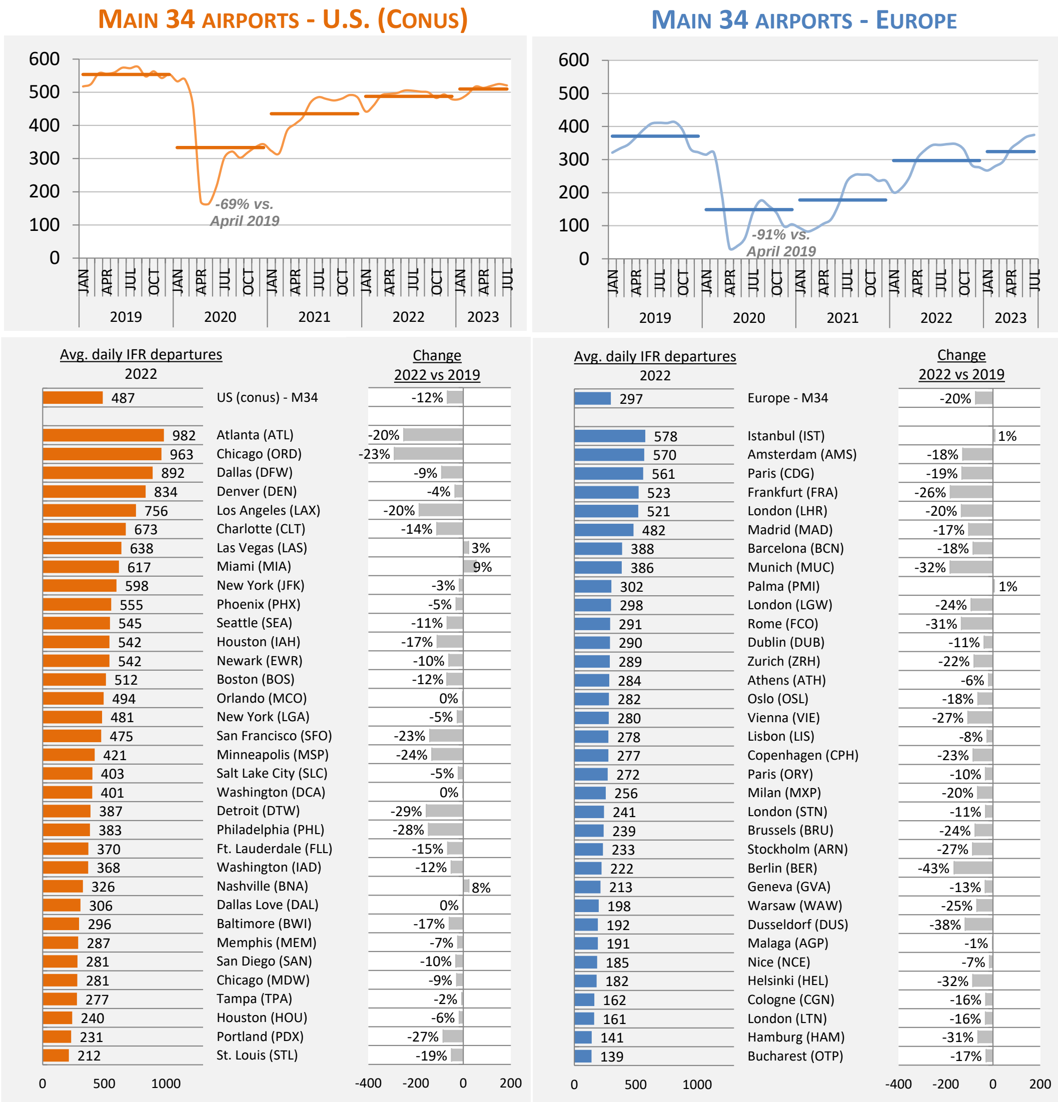

Figure 2-8: Evolution of IFR traffic at the main 34 airports

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[17] Prior to the transfer of operations to the New Istanbul airport on 06 April 2019, traffic at Istanbul Ataturk airport has been included. Before the transfer of traffic to Berlin Brandenburg airport in October 2020, traffic at Berlin Tegel airport has been considered in the analysis.
The analysis relates only to IFR flights. Some airports – especially in the U.S. – have a significant share of additional VFR traffic which has not been considered in the analysis.

3 Comparison of operational ANS performance

3.1 INTRODUCTION AND BACKGROUND

This chapter evaluates ANS operational performance in the U.S. and in Europe, based on commonly agreed indicators used in international benchmarking studies and in the ICAO Global Air Navigation Plan (GANP) context [1]. More information about the GANP indicators is available online on the GANP Portal – KPI Overview.

To ensure comparability based on a common set of data sources with a sufficient level of detail and coverage, the operational comparison of ANS performance was limited to flights to or from the main 34 airports for IFR traffic in the U.S. and in Europe which account for approximately 68% and 65% of the controlled flights in Europe and the U.S., respectively. As shown in the previous section, those samples are more comparable in terms of traffic as it removes a large share of the smaller aircraft (general aviation traffic), particularly in the U.S.

3.2 APPROACH

Before moving to the analysis of ANS-related operational performance, it is useful to look at the On-time Performance (OTP) in the U.S. and in Europe. OTP is a widely used industry standard to measure the reliability and service quality of air transport. Different from the analysis of ANS related[18] operational performance in the second part of the chapter, OTP compares published airline schedules to actual departure and arrival times.

OTP is influenced by complex interactions between airlines, airport operators and Air Navigation Service Providers (ANSPs), from the planning and scheduling phases up to the day of operation. Based on experience and the level of predictability of operations, airlines may include time buffers in their schedule to maintain a satisfactory level of OTP and schedule integrity. On the day of operations, OTP is influenced by airline and airport related delays, extreme weather, security issues, late arriving aircraft but also by the way ANS mange the traffic.

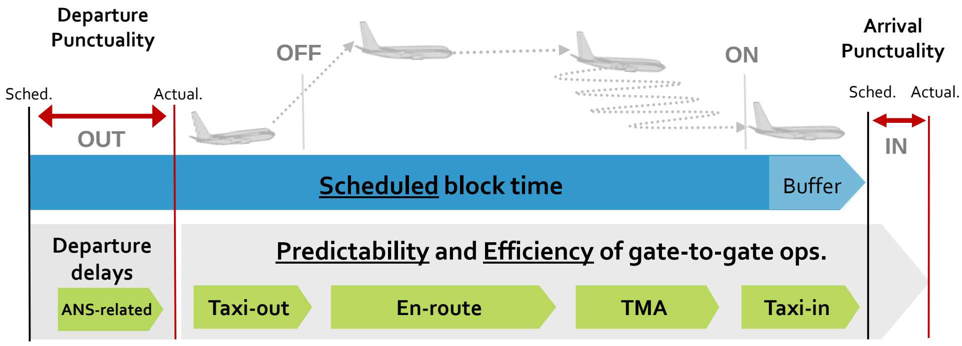


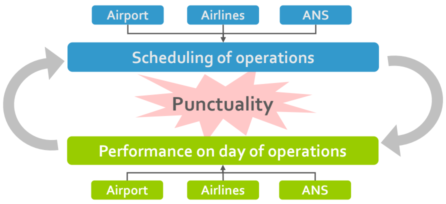
Figure 3-1: On time performance and ANS related performance

Although OTP is a valid indicator from a passenger point of view and provides first insights into the level of air transport performance, the understanding of ANS related operational performance requires a more sophisticated analysis of actual operations by flight phase without time buffers included in airline schedules to compensate for expected travel time variations.

The analysis of ANS related operational performance based on established indicators is provided in Chapter 3.4.

[18] In this report, "ANS-related" means that ANS has a significant influence on the operations.

3.3 ON-TIME PERFORMANCE (OTP)



The OTP analysis in this report considers flights that departed/arrived within 14 minutes and 59 seconds of their scheduled departure/arrival time as "on-time" or "punctual". Cancelled and diverted flights are not included.

Figure 3-2 shows the arrival punctuality at the 34 main airports in the U.S. and in Europe. Some seasonal patterns are visible on both sides of the Atlantic. Whereas the winter performance is mostly affected by weather related delays at airports, the summer is affected by higher demand and resulting congestion but also by convective weather in the en-route airspace.

In 2019, arrival punctuality in the U.S. (80.1%) was almost 4 percentage points higher than in Europe (76.5%). With the start of the COVID-19 pandemic in 2020, punctuality improved in both systems because of the substantial drop in traffic. In the U.S., almost 90% of the flights at the main 34 airports reached their destination within 15 minutes of their scheduled arrival time in 2020 (Europe 87%).

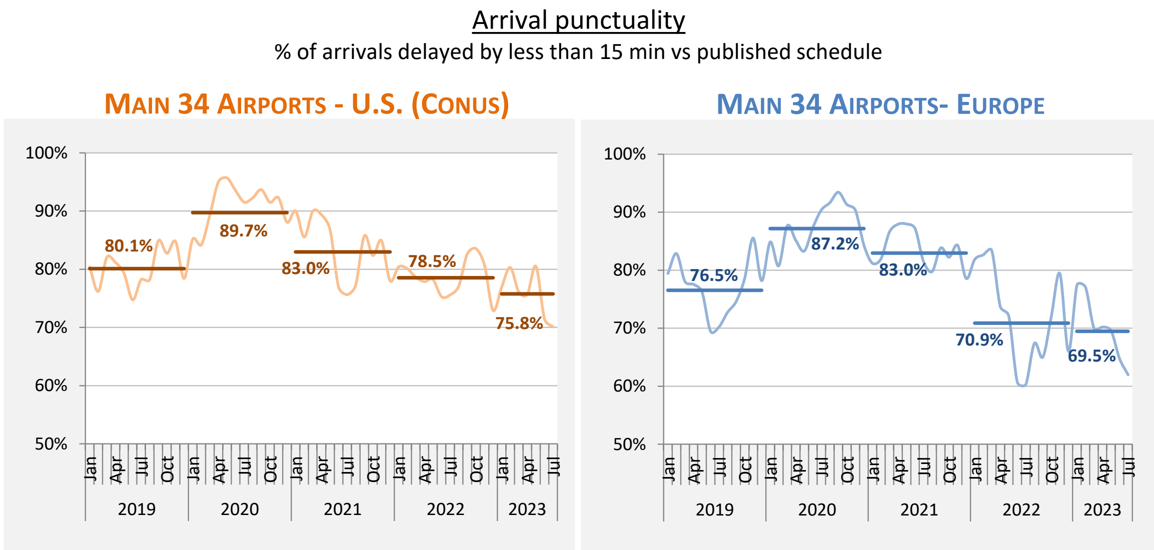


Figure 3-2: Arrival punctuality at the main 34 airports in the U.S. and in Europe (aggregated level)

As traffic began to rebound, punctuality levels started to decline once more on both sides of the Atlantic. In the U.S., arrival punctuality consistently worsened from 2020 through mid-2023, falling below the levels observed in 2019. In Europe, arrival punctuality initially saw a moderate decline in 2021 but then reached its all-time low in the summer of 2022. During this period, it became evident that several service providers were not ready to scale up their operations to meet the rapidly increasing demand.

Especially during the summer of 2022, this lack of preparedness resulted in unacceptably high delays for passengers and numerous flight cancellations due to insufficient staff availability to handle services, even though traffic remained below the 2021 levels. In July 2022, just 60% of flights at the 34 main airports arrived within 15 minutes of their scheduled times. Although there was an improvement in performance during the first quarter of 2023, punctuality in Europe once again suffered a significant decline with the onset of the 2023 holiday season.

The poor performance in Europe was not driven by a deterioration of performance in one single area but by shortcomings at various levels, mainly related to staff shortages (airports, airlines, ATC). Although a degradation of ANS performance contributed to the poor overall performance in Europe, the main contributing factors were airline and airport related delays linked to passenger and ground handling. The delays grew with each turnaround as the day progressed leading not only to lower punctuality levels but also to an increase in average departure delay throughout the day.

Figure 3-3 shows a breakdown of the arrival punctuality at the main 34 airports in both regions, including a comparison vs. 2019 when traffic levels at most airports were higher. It is worth pointing out that poor arrival punctuality at an airport does not automatically mean that the airport was the root cause of the problem of performing poorly. Although airports can act as delay amplifier when there are local capacity constraints (runway, ground handling, etc.), arrival punctuality is mainly affected by delay accumulated on previous flights legs at different locations throughout the network.

Arrival punctuality

% of arrivals delayed by less than 15 min vs published schedule

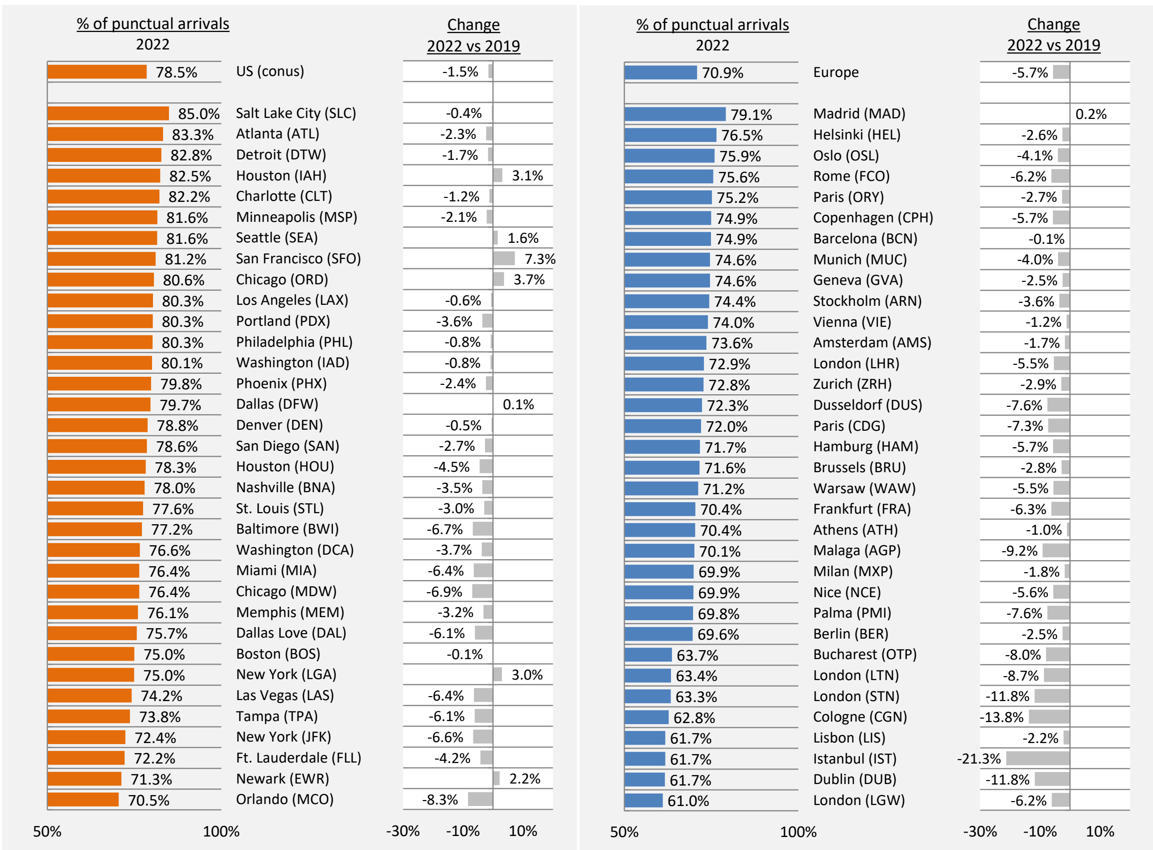


Figure 3-3: Arrival punctuality at the main 34 airports in the U.S. and in Europe (2022 vs. 2019)

As can be expected, the observed performance is not homogenous across airports. In Europe[19], arrival punctuality at the main 34 airports in 2022 ranged from 79.1% at Madrid (MAD) to 61.0% at London Gatwick (LGW) airport.

Many of the U.S. airports with lower traffic levels than 2019 saw an increase in punctuality while operating in a less constrained environment such as EWR (+2.2%), LGA (+3%), ORD (+3.7%), and SFO (+7.3%). While the Florida airports MCO (-8.3%), MIA (-6.4%), and TPA (-6.1%) saw a decrease in punctuality as traffic levels to the southeast exceeded pre-pandemic levels.

[19] Please note that the transfer of operations to the new Istanbul airport took place on 6 April 2019. Therefore, the analysis does not include the first 4 months of 2019.

3.4 ANS- RELATED OPERATIONAL PERFORMANCE

This section analyses ANS-related performance at the main 34 airports in the U.S. and in Europe in more detail. The analysis is based on the joint work in the previous comparison reports. The specific indicators used in this section were developed using common procedures on comparable data from both the FAA-ATO and EUROCONTROL. The indicators are aligned and compatible with the KPIs listed in the ICAO Global Air Navigation Plan (GANP) [5]which can be used to assess the benefits of the global implementation of Aviation System Block Upgrades (ASBUs).

To better understand the impact of ATM and differences in management techniques, the analysis is broken down by phase of flight. As illustrated in Figure 3-4, inefficiencies in the different flight phases have different impacts on aircraft operators and the environment. The U.S. and Europe currently use different strategies for absorbing necessary delay in the various flight phases. Whereas some Traffic Management Initiatives (TMIs) have an impact on flights at the gate, other TMIs impact on the gate-to-gate phase which may generate additional fuel burn and CO_2 emissions (see also Chapter 1.2.1). However, 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 by far exceed the fuel cost.

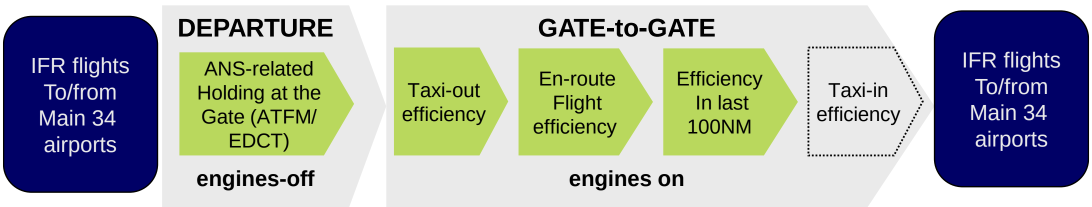


Figure 3-4: Measures of operational efficiency by phase of flight

The goal is to minimize overall direct (fuel, etc.) and strategic (schedule buffer, etc.) costs and the impact on environment whilst maximizing the utilization of available capacity. Hence, not all inefficiencies are to be seen as negative. A certain level is necessary or even desirable if a system is to be run efficiently without underutilization of available resources. As adverse weather and other factors will continue to impact ANS capacities in the foreseeable future, there is a benefit in better understanding the interrelations between variability, efficiency and capacity utilisation.

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

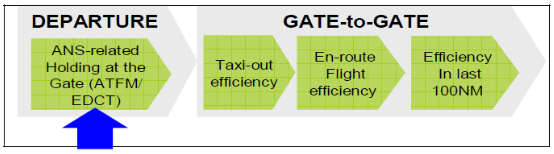
- Some of the efficiency indicators in this report compare actual performance to an ideal (uncongested or unachievable) situation which is not realistic at system level when operational trade-offs, environmental or political restrictions, or other performance affecting factors such as weather conditions are considered;

- A clear-cut allocation between ANS and non-ANS related causes is often difficult. While ANS is often not the root cause of the problem (weather, etc.) the way the situation is handled can have a significant influence on performance (i.e. distribution of delay between air and ground, use of scarce capacity, etc.) and thus on costs to airspace users;

- ANS 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 optimize their operations based on time and costs can vary depending on their needs and requirements (fuel price, business model, etc.); and,

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

3.4.1 ANS-RELATED DEPARTURE RESTRICTIONS (ATFM/EDCT DELAYS)



This section reviews ANS-related departure delays in the U.S. and in Europe.

Both the U.S. and Europe report ATM-related delay imposed on departing flights through Traffic Management Initiatives (TMIs)[20] to achieve required levels of safety as well as to balance demand and capacity most effectively. Reducing gate/surface delays (by releasing too many aircraft) at the origin airport when the destination airport's capacities are constrained potentially increases airborne delay (i.e. holding or extended final approaches). Applying excessive gate/surface delays on the other hand, risks underutilization of capacity and thus increase overall delay.

As described in Chapter 1.2.1, holdings at the gate are in Europe commonly used to handle en-route and airport constraints already prior to departure. Aircraft subject to ATFM restrictions are held at the gate at the departure airport according to an ATFM slot, allocated by the European Network Manager.

In the U.S., ground delay programs are mostly used in case of severe capacity restrictions when less constraining flow measures in the gate-to-gate phase are not sufficient. The Air Traffic Command Center (ATCSCC) applies Estimated Departure Clearance Times (EDCT) to delay flights prior to departure.

The resulting delays are calculated with reference to the times in the last submitted flight plan (i.e., not the departure times in airline schedules). For the U.S., this is an estimated take-off time based on the time an aircraft enters FAA control (calls ready) plus a nominal taxi-out time. Most of these delays are taken at the gate but some delays due to local en-route departure and MIT restrictions occur also during the taxi phase (see Chapter 3.4.2).

To stay consistent with previous U.S./EU comparison reports, <u>only ATFM/EDCT delays equal or greater than 15 minutes were included in the analyses</u>.

Table 3-1 compares ATM-related departure restrictions at the gate, imposed in the two ATM systems due to en-route and airport constraints. As can be expected, the share of flights affected by departure restrictions at origin airports differs considerably between the U.S. and Europe.

Only ATFM/EDCT/TMI delays > = 15 min. are included.		**EUROPE**			**U.S. (CONUS)**		
		2017	**2019**	**2022**	**2017**	**2019**	**2022**
	IFR flights (M)	**5.3 M**	**5.5 M**	**4.6 M**	**8.4 M**	**8.8 M**	**7.7 M**
Total delays >=15min. (ATM/TMI)	% of flights delayed >=15 min.	5.3%	7.5%	7.0%	3.4%	3.2%	1.9%
	delay per flight (min.)	1.5	2.1	2.1	2.1	2.0	1.0
	delay per delayed flight (min.)	29	29	30	61	63	52
Airport related delays >=15min. (ATM/TMI)	% of flights delayed >=15 min.	2.5%	2.6%	1.6%	2.4%	2.3%	1.1%
	delay per flight (min.)	0.8	0.8	0.5	1.7	1.7	0.7
	delay per delayed flight (min.)	31	31	33	71	74	63
En route related delays >=15min. (ATM/TMI)	% of flights delayed >=15 min.	2.8%	4.8%	5.4%	1.0%	0.9%	0.9%
	delay per flight (min.)	0.8	1.3	1.6	0.4	0.3	0.3
	delay per delayed flight (min.)	27	27	29	36	34	39

Table 3-1: ATFM/EDCT departure delays (overview)

Flights in Europe are more than 5 times more likely to be held at the gate for en-route constraints than in the U.S. where the share of flights was just below 1% in 2022.

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

For airport related delays the percentage of flights delayed at the gate is only slightly lower in the U.S. than in Europe but the delay per delayed flight is about twice as high in the U.S. which is consistent with the use of departure holdings at the gate in the U.S. only as a last resort.

Figure 3-5 shows the average ATFM/EDCT delay by charged facility (en-route, airport) for traffic to and from the main 34 airports between 2018 and July 2023 at an aggregated level.

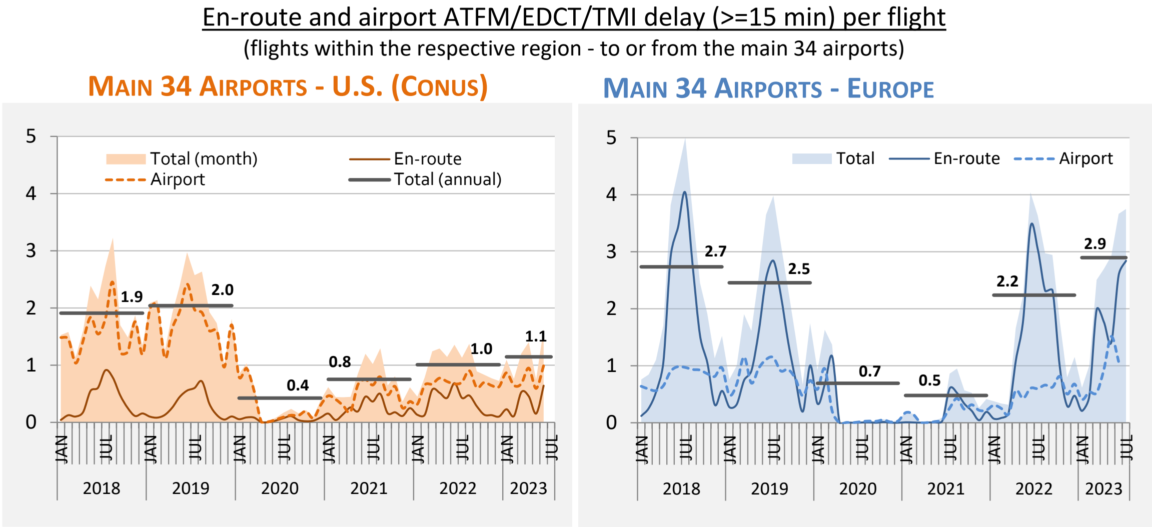


Figure 3-5: Average ATFM/EDCT delay per flight at the main 34 airports (aggregated view)

The ATFM related average holding time at the gate is much higher in Europe and shows a clear seasonal pattern - peaking in summer when traffic levels are highest. It is worth pointing out that 2018 and 2019 were particularly bad years with exceptionally high ATFM delays in Europe after a continuous degradation of performance since 2013, mainly because of growing en-route capacity constraints in a limited number of ACCs in the core area which impacted the entire European network in 2018/19.

Virtually no ATFM/EDCT delay was reported in both regions in 2020, following the unprecedented COVID-19 related drop in traffic. With traffic recovering again, ATFM/EDCT delays started to rise again on both sides of the Atlantic but stayed in the U.S. well below the levels observed before the pandemic.

In Europe, with traffic continuing to recover further, it became obvious that the European ATM network was not ready to support the traffic levels served in 2019. ATFM delays were recorded at notably lower daily traffic levels in summer 2022 than in 2018 or in 2019 which is an indication that ANSPs were unable to deploy as much capacity to handle traffic demand as they had been able to deploy prior to the COVID-19 pandemic.

ATFM/EDCT departure delays can be further broken down by attributed delay cause (ATC capacity, staffing, weather, etc.). Figure 3-6 shows a breakdown of the ATFM/EDCT delays by facility (en-route vs. airport) and by attributed delay cause to get a better understanding of the underlying drivers in each region.

It confirms again the already highlighted difference between U.S. and Europe in terms of attribution of delays between en-route facilities and airports. In the U.S. most ATFM/EDCT delays in 2022 were due to airports (66%) while in Europe most delays (75%) were attributed to en-route facilities.

By far the main reason for delays in the U.S. in 2022 was adverse weather (76%) with a high share originating from airports (53.3%). In Europe, the main cause in 2022 was ATC capacity and staffing constraints (including ATC industrial actions) accounting for 44% closely followed by adverse weather

(29%) and "Other" reasons (24%). The high share of "Other" delay in Europe was mainly due to 'special events' such as the implementation of various ATC capacity projects (requiring capacity reductions during the implementation phase) and to airspace restrictions associated with the war in Ukraine.

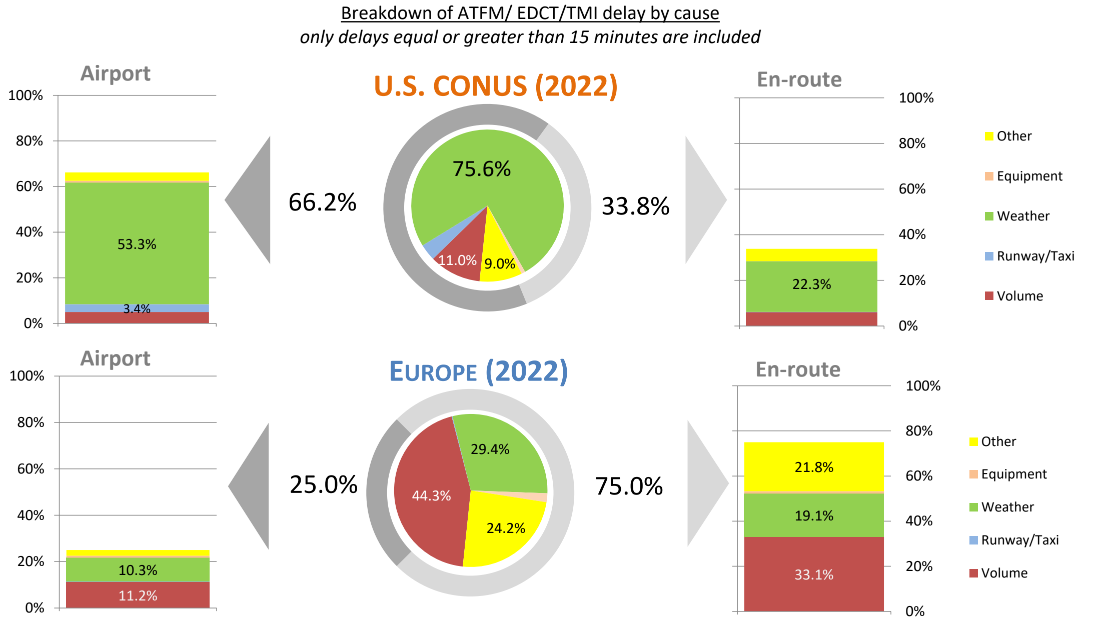


Figure 3-6: Breakdown of ATFM/EDCT delay by cause and facility

Unlike in Europe, only few airports in the U.S. have schedule limitations and the ATM system is more geared towards maximizing system and airport throughput under prevailing conditions on the day of operations. Hence, many issues in the U.S. appear to be attributable to the effects of capacity variation between most favorable and least favorable conditions, particularly in a highly dense airspace such as the Greater New York area. Thus, a large part of the EDCT delays in the U.S. originate from only a limited number of airports (EWR, LGA, JFK, ORD, BOS, SFO, and LAX), mainly due to adverse weather (wind, thunderstorms, and low ceilings).

This is also confirmed by the analysis of the arrivals at the main 34 airports in the U.S. and in Europe in Figure 3-7. Whereas in Europe the ATFM/EDCT delays are more equally distributed between en-route and airport facilities but also between airports, in the U.S., the delays in 2022 were mainly due to New York La Guardia (LGA) and Newark (EWR) airport.

In Europe, high ATFM delays for arrivals can be observed at London Gatwick (LGW), Lisbon (LIS), Cologne (CGN), Amsterdam (AMS), and Berlin (BER). A large part of the delay is related to en-route ATFM delays.

With traffic slower to return to Newark (EWR), San Francisco (SFO), and New York La Guardia (LGA) in 2022 the ATFM delay attributed to these airports remained well below the 2019 levels. While the Florida airports had a slight increase in enroute delay coinciding with increased traffic volume.

More analysis is needed to evaluate how the moderation of demand with "airport slots" in Europe impacts on the significant difference in ATFM/EDCT delay attribution between the U.S. and Europe.

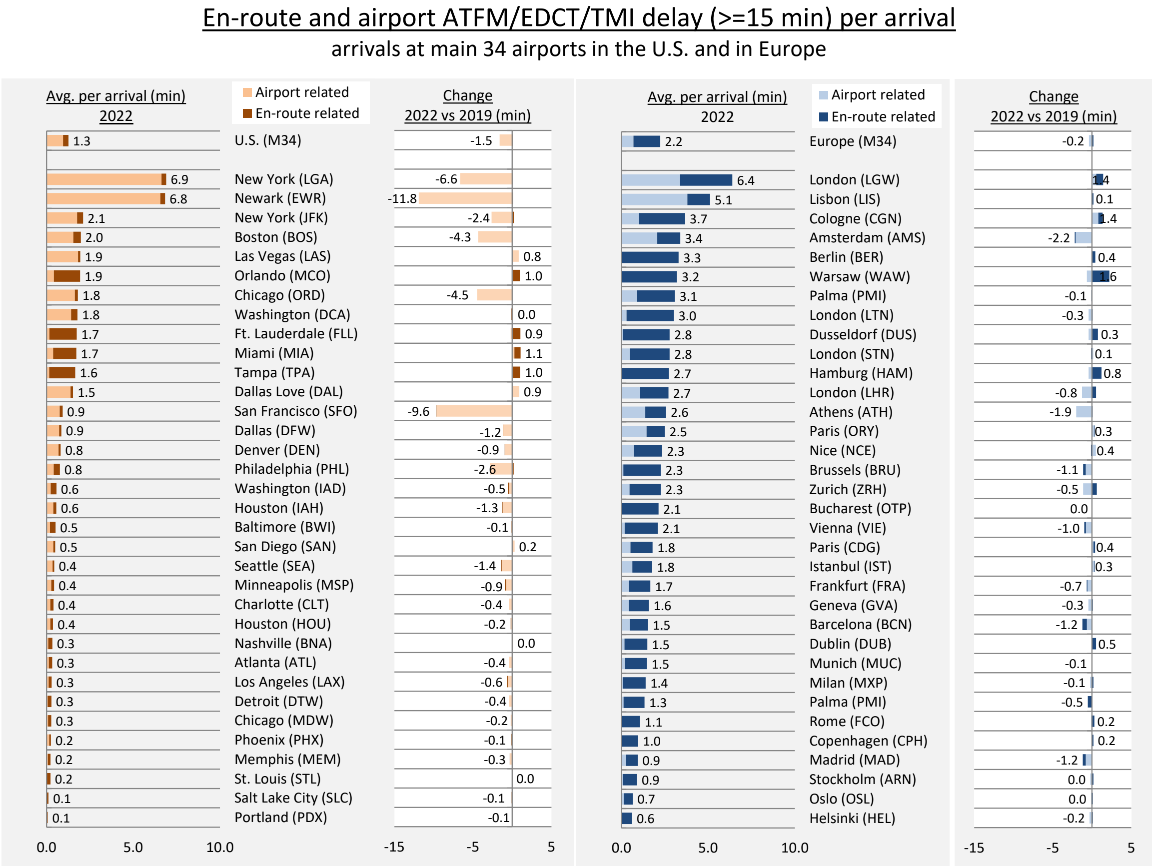
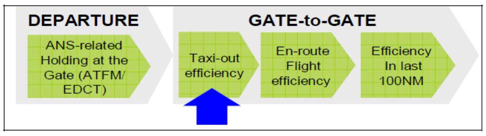


Figure 3-7: Average ATFM/EDCT delay per flight at the main 34 airports

3.4.2 TAXI-OUT EFFICIENCY



This section analyses inefficiencies in the taxi out phase. The measure is influenced by several factors such as take-off queue size (waiting time at the runway), distance to runway (runway configuration, stand location), downstream restrictions, aircraft type, and remote de-icing to name a few. Of these causal factors, the take-off queue size is considered to be the most important one.

In the U.S., the additional time observed in the taxi-out phase also includes TMS 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.

The analysis is in line with the proposed GANP KPI02 methodology to determine the additional taxi out time. The methodology 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 computed as the 20th percentile of the gate-runway combinations at the analyzed airports over the entire analysis period.

Figure 3-8 shows the result for the U.S. and Europe at aggregated level between 2018 and mid-2023.

Seasonal patterns are visible on both sides of the Atlantic – but with different cycle. Whereas in Europe the additional times peak during the winter months (most likely due to weather conditions and de-icing), in the U.S. the peak is in the summer which is most likely linked to congestion.

There was a substantial reduction in additional taxi-out time in the U.S. in early 2020, corresponding to the decrease in traffic due to the onset of the pandemic. However, this additional taxi-out time gradually rebounded and eventually returned to a level comparable to the pre-pandemic period.

In Europe, a comparable decline in the average additional taxi-out time occurred after the pandemic outbreak. In line with the slower traffic recovery in Europe, average additional taxi-out time remained relatively low until 2022 when it began to rise again to almost reach pre-pandemic levels by the first half of 2023.

Additional time in the taxi out phase
(minutes per departure)

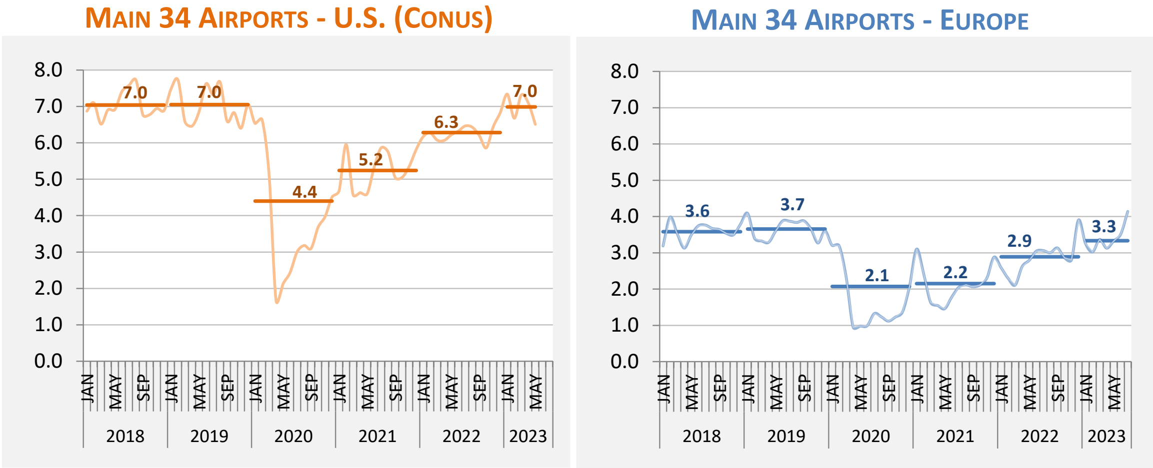


Figure 3-8: Additional times in the taxi-out phase (aggregated view)

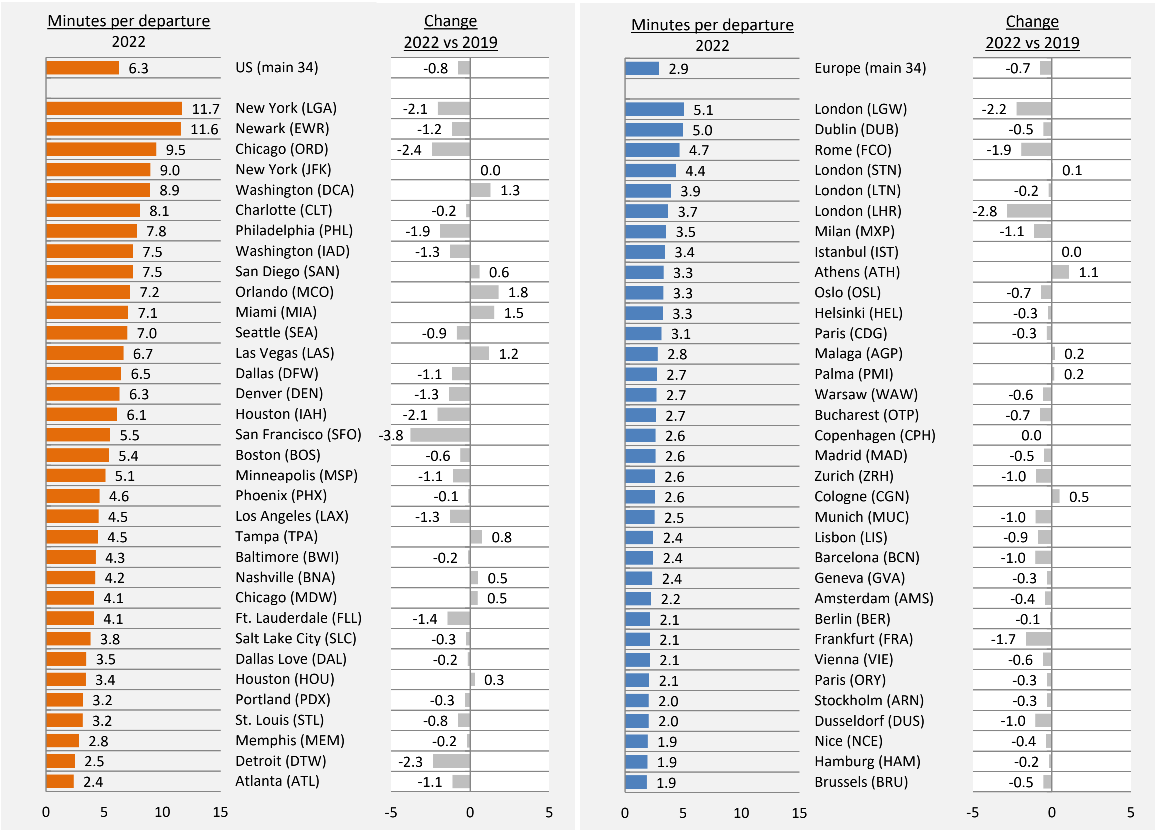


Figure 3-9: Additional times in the taxi-out phase (2022 vs. 2019)

Figure 3-9 shows a breakdown of additional taxi-out time by airport in 2022, including a comparison vs. 2019. Particularly in the U.S., the high-level result is driven by contrasted situations among airports and, to a large extent, influenced by the performance at the airports in the New York metropolitan area and Chicago where average additional taxi out times above 10 minutes were observed.

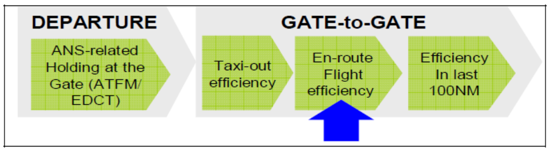
Many of the U.S. airports that had lower daily departure traffic than 2019 levels also had a decrease in taxi out delay, for example: New York La Guardia (LGA) (departures -23%), Newark (EWR) (departures -10%), Chicago (ORD) (departures -23%), San Francisco (SFO) (departures -23%).

In Europe, overall taxi-out performance at the main 34 airports in 2022 was still slightly below the level of 2019, but with less traffic than in 2019. The highest average additional taxi-out times in 2022 were observed at London Gatwick (LGW), Dublin (DUB), Rome (FCO) and the three other London airports (STN, LTN, LHR). The most significant improvements compared to 2019 were observed at London Heathrow (LHR), London Gatwick (LGW), Rome Fiumicino (FCO), and Frankfurt (FRA).

Overall, additional taxi-out times appear to be notably higher in the U.S which is mainly due to the difference in flow control policies (more tactical focus) and the absence of scheduling caps at most U.S. airports (see Chapter 1.2.1). At an aggregated level, the average additional taxi-out time in the U.S. is roughly twice the additional time observed in Europe.

Although the impact of ANSPs on total additional time is limited when runway capacities are constraining departures, in Europe, Airport Collaborative Decision Making (A-CDM) initiatives try to optimize the departure queue by managing the pushback times. The aim is to keep aircraft at the stand to reduce additional time and fuel burn in the taxi-out phase to a minimum by providing only minimal queues and improved sequencing at the threshold to maximize runway throughput. The resulting inefficiencies would show as ATC related departure delays at the gate.

3.4.3 HORIZONTAL EN-ROUTE FLIGHT EFFICIENCY



This section analyses inefficiencies in the horizontal en-route flight phase. The analysis is in line with the proposed GANP KPI05 methodology to determine the actual en-route extension. The flight efficiency in the terminal maneuvering areas (TMA) of airports is addressed in the next section.

It is acknowledged that flight efficiency also has a vertical component which is also important in terms of additional fuel burn and environmental impact. The horizontal en-route flight efficiency (HFE) indicator in this report does not measure this vertical component and there is scope for further improvement in future reports. Such additional work on vertical flight inefficiencies and potential benefits of implementing Continuous Descent Operations (CDO) will form a more complete picture.

The efficiency of a flight in the en-route phase is affected by a considerable number of factors involving different stakeholders. Not all those factors are under the direct control of ANS (adverse weather, segregated airspace, etc.) but ANS has a role to play in reducing the constraints to a necessary minimum while maximizing the use of airspace and ensuring safe separation of flights.

In view of external factors such as adverse weather and necessary (safety) as well as desired (capacity) trade-offs, there will always be a certain level of flight inefficiency which is important to bear in mind for the interpretation of the results.

The HFE indicator in this report compares the actual flown trajectory with the shortest distance between flight origin and destination using the Great Circle Distance (GCD). “En-route” is defined as the portion between a 40 NM radius around the departure airport and a 100 NM radius around the arrival airport. Where a flight departs or arrives outside the respective airspace, only that part inside the airspace is considered. Flights with a great circle distance (G) shorter than 60NM between terminal areas were excluded from the analysis.

It is acknowledged that such a distance-based approach does not necessarily correspond to the "optimum" trajectory when meteorological conditions or economic preferences of airspace users are considered for specific flights. However, when used at the strategic level, the indicator will point to areas where horizontal flight efficiency is increasing or decreasing over time.

Figure 3-10 shows the average horizontal en-route flight efficiency of flights to or from the main 34 airports in the U.S. and Europe. Only flights taking off and landing within the respective region were considered in the analysis (i.e. transatlantic flights are excluded). An "inefficiency" of 5% means for instance that the extra distance over 1 000 NM was 50 NM.

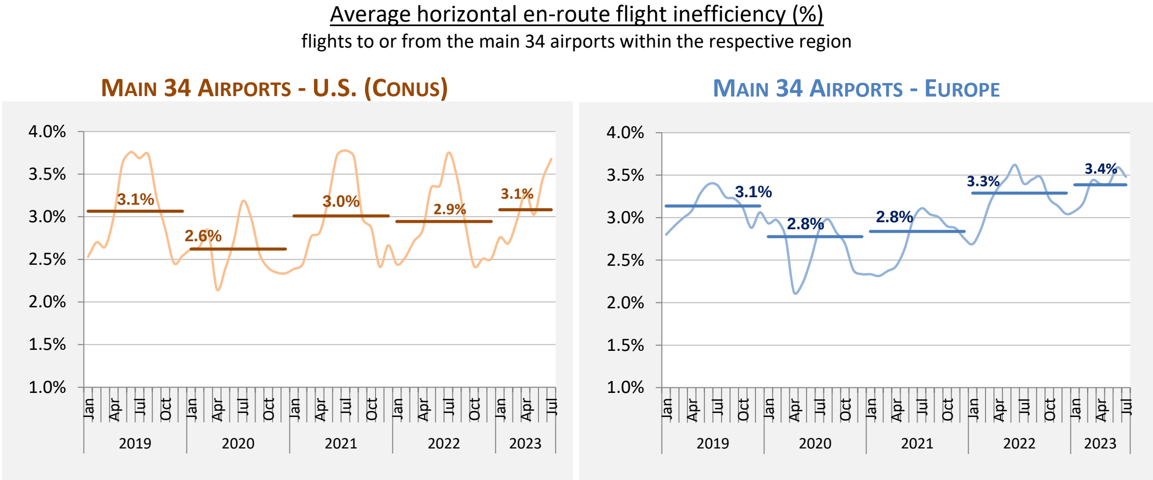


Figure 3-10: Horizontal en-route flight efficiency

Overall, the level of horizontal en-route flight efficiency in both regions seems similar. Both regions show seasonal patterns with lower flight efficiency in summer, which is mainly due to adverse weather (particularly in the U.S.) and congested airspace (particularly in Europe).

The sharp decline in traffic that occurred after the onset of COVID-19 in March 2020 led to a temporary and brief improvement in horizontal en-route flight efficiency in both Europe and the U.S. However, as traffic began to recover, flight efficiency deteriorated again, returning to levels similar to those seen before the pandemic on both sides of the Atlantic.

In Europe, virtually from one day to the next the flow measures implemented to manage the en-route capacity crisis (re-routing, level-capping) in 2019 were no longer necessary and therefore removed. Yet, as traffic continued to rebound throughout 2022, the implementation of new measures to alleviate congestion in ACCs and the effects of the war in Ukraine led to a decline in horizontal en-route flight efficiency resulting in efficiency levels falling below those observed in 2019.

In recent years, the ongoing adoption of Free Route Airspace (FRA) across Europe has yielded significant advantages. FRA provides airlines with a more adaptable framework in contrast to a rigid route structure, offering increased options and opportunities to curtail fuel consumption and emissions. Despite these regional efforts, there is room for further enhancements, primarily stemming from the fragmented nature of European airspace design, which remains the responsibility of individual states. While local efficiency has improved through FRA implementation, there is a need to shift attention toward cross-border initiatives to fully harness the broader network-wide benefits.

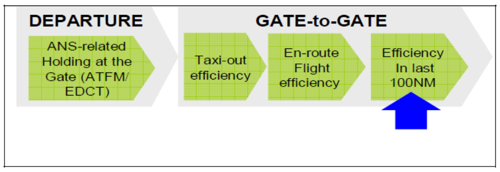
In the U.S., horizontal en-route flight efficiency also includes some path stretching due to Miles in Trail (MIT) restrictions (compare Chapter 1.2.1). While many of the heaviest travelled city pairs in the U.S. such as San Francisco to Los Angeles or Chicago to the New York area achieve direct routing for most flights, some important city pairs are affected by special activity airspaces on the East and the West Coast impacting negatively on flight efficiency. Also, the 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) due to high traffic and the presence of major airports located close together. Over time, flight paths have moved further away from the New York area. The excess distance is needed to manage workload and maintain safety.

While there are economic and environmental benefits in improving flight-efficiency, there are also inherent limitations on both sides of the Atlantic. Trade-offs and interdependencies with other performance areas, including safety, capacity, environment, shared civil/military airspace and airspace user preferences (such as selecting routes due to weather conditions, wind-optimized routes, or other factors like variations in route charges), need to be considered.

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

3.4.4 FLIGHT EFFICIENCY WITHIN THE LAST 100NM

This section analyses the level of inefficiencies due to airborne holding and metering that occur during the arrival/descent phase. The analysis is in line with the proposed GANP KPI08 methodology to determine additional time in the terminal airspace.



To capture tactical arrival control measures (sequencing, flow integration, speed control, spacing, stretching, etc.) irrespective of local ATM strategies, a standardized Arrival Sequencing and Metering Area (ASMA) with a 100 nautical mile radius around each airport was used. To prevent the need for continuous adjustments to the entry fix and runway pairing, approach sectors were designated for each airport, allowing for modifications to approach fixes within specified limits. Because of the multitude of variables at play, it is challenging to pinpoint the direct contribution of the Air Navigation Service (ANS) toward the additional time within the last 100 nautical miles.

The transit times within the 100 NM ASMA ring are affected by several ATM and non-ATM-related parameters including, but not limited to, flow management measures (holdings, etc.), airspace design, airports configuration, aircraft type environmental restrictions, and in Europe, to some extent, the objectives agreed by the airport scheduling committee when declaring the airport capacity.

The “additional” time is used as a proxy for the level of inefficiency within the last 100 NM. It is defined as the average additional time beyond the unimpeded transit time computed as the 20th percentile of each approach sector, runway combination and aircraft class combination over the entire analysis period.

Figure 3-11 shows the evolution of average additional time within the last 100 NM for the U.S. and Europe at aggregated level between 2018 and mid-2023.

At system level, average additional time within the last 100 NM was higher in Europe before the pandemic which was to some extent driven by London Heathrow[21] which was a clear outlier in Europe.

Similar to what was observed in the case of other operational performance indicators, there was a marked enhancement during the period of reduced traffic due to the pandemic, followed by a steady decline as traffic levels continued to recover.

[21] The performance at London Heathrow was consistent with the decision taken during the airport scheduling process to accept a 10 minute average holding delay to maximise the utilisation of the scarce runway capacity.

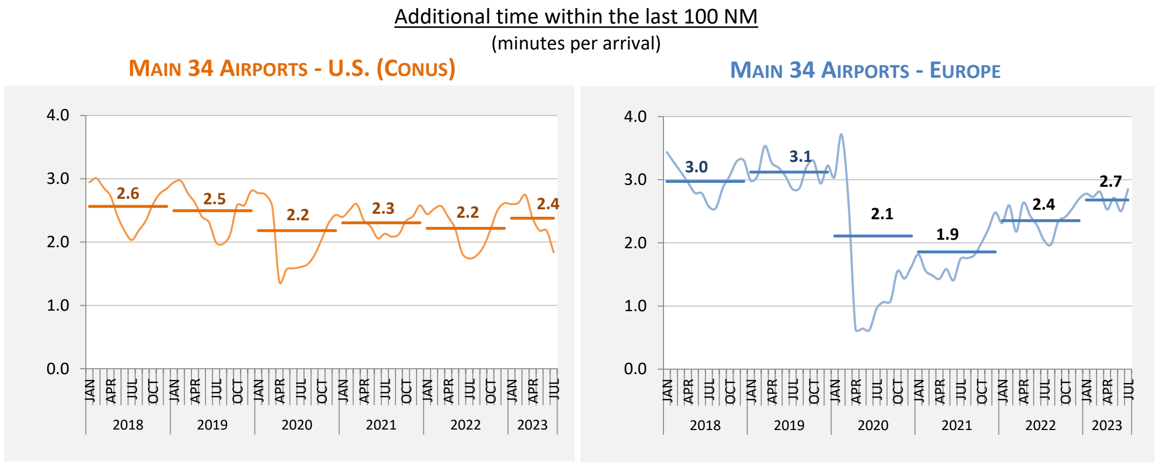


Figure 3-11: Additional time within the last 100 NM (aggregated view)

Figure 3-12 shows the additional time within the last 100NM at the main 34 airports in both regions, including a comparison of the performance vs. 2019.

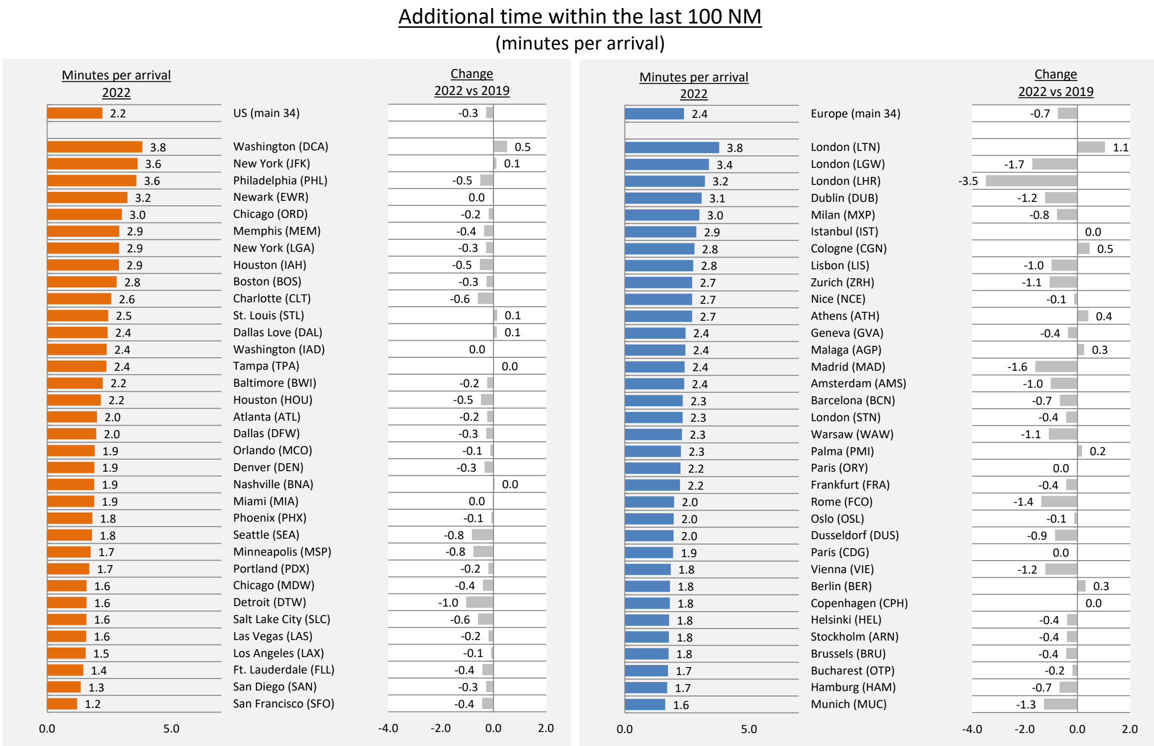


Figure 3-12: Additional time within the last 100 NM (2022 vs. 2019)

In the U.S., similar to taxi-out performance, there is still a notable difference for the airports in the greater New York area, which show the highest level of additional time within the last 100 NM. The New York airspace is highly constrained with the terminal areas of Newark (EWR), New York (JFK), and La Guardia (LGA) overlapping closely.

In Europe, many of the major airports were still well below the traffic levels of 2019 which positively influenced performance. London Heathrow shows an average improvement of 3.5 minutes in 2022 compared to 2019.

Due to the large number of variables involved, the direct ATM contribution towards the additional time within the last 100 NM is difficult to determine. One of the main differences of the U.S. air traffic management system is the ability to maximize airport capacity by taking action in the en-route phase of flights, such as path stretching to achieve the in-trail spacing required as described in section 1.2.1.

3.4.4.1 Arrival management in the U.S. and in Europe

Both the U.S. and Europe focus on safely optimizing arrival management to reduce congestion, enhance efficiency, and minimize environmental impacts. However, the specific strategies, technologies, and regulatory frameworks can differ based on regional characteristics and priorities.

In a constrained environment, ANS must maintain peak throughput as well as manage delay. There is a trade-off between operational efficiency and airport capacity utilization. For instance, to ensure a high airport capacity utilization, London Heathrow (LHR) airport accepts a given amount of holding delay already in their airport scheduling process.

Arrival procedures in Europe vary significantly from airport to airport and recent years have seen a significant number of changes to approach procedures. However, in Europe, the support of the en-route function is limited and rarely extends beyond the national boundaries. As a result, most of the sequencing and holding activities occur at lower altitudes near the respective airports. Any additional delays that cannot be accommodated in the vicinity of the airport are managed on the ground at departure airports through the allocation of ATFM departure slots.

Figure 3-13 illustrates how local ATM strategies affect arrival flows at two major European airports. Whereas at London Heathrow most of the approach operations take place near the airport, at Paris CDG, the sequencing of arrival traffic starts already much further out.

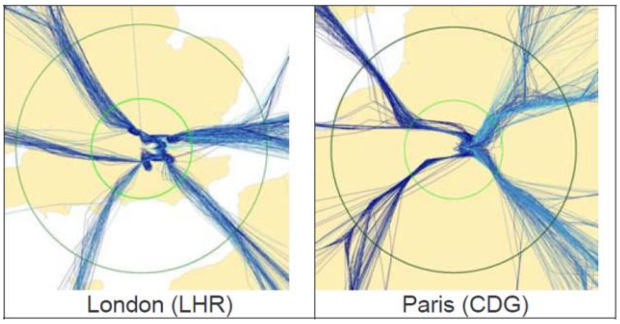


Figure 3-13: Impact of local ATM strategies on arrival flows

To reduce the fuel inefficient time spent in stacks at lower altitudes, NATS and partnering ANSPs have implemented a collaborative ATM procedure called Cross Border Arrivals Management (XMAN) for flights to London Heathrow airport. It has been developed within the Single European Sky ATM Research Programme (SESAR).

ATC instructs the pilot to adjust the aircraft's speed to move some of the anticipated time spent holding at lower altitudes to more fuel-efficient higher altitudes. This will save fuel and carbon dioxide (CO_2) emissions on its approach into London Heathrow.

One of the key questions is therefore what strategy works best for ATM to absorb delay in the most fuel-efficient manner while ensuring the maximization of scarce runway capacity at any point in time.

Considerable focus is being placed on the role of optimal descent profiles to reduce fuel burn. Vertical and horizontal inefficiencies on descent are primarily a function of absorbing necessary time to manage runway capacity constraints. While there are numerous studies published related to the benefits of optimal descent profiles, most reflect benefits during non-congested periods and focus only on vertical flight inefficiencies.

Today, the use of speed control already in the cruise phase for the purpose of absorbing terminal area congestion is limited in both regions. Without an agreed time of arrival, flights usually compete for runway capacity on a first come first served basis. While in some cases this speeding up may benefit the individual airline, the tactical competition for runway resources results in additional delay absorption around the arrival airport and the added terminal area congestion increases fuel burn at system level.

However, ANS management could start well before top of descent to reduce fuel burn. The concept involves shifting the duration spent at lower altitudes to more fuel-efficient higher altitudes. Any surplus time consumed during level flight segments is exchanged for an equivalent surplus time at more fuel-efficient higher altitudes. It's worth noting that long-haul flights hold the greatest potential for fuel savings by implementing speed control during the cruise phase of the journey.

Both NextGen and SESAR have 4-D trajectories as basic tenets, which would implicitly involve speed control. ATM has incentives to reduce congestion around terminal areas beyond saving fuel including reducing the workload associated with merging and spacing, and reducing the safety risk associated with aircraft considering fuel related diversions to alternate airports.

More work is needed to better address and understand the value of speed control in the cruise phase for terminal congestion and potential fuel savings with speed control strategies.

3.5 CONCLUSIONS - OPERATIONAL ANS PERFORMANCE

It is important to note that ANS performance varies within both Europe and the U.S. due to factors such as regional traffic patterns, airport sizes, weather conditions, and investment in infrastructure.

Based on established indicators, the analysis of ATM-related operational performance in this report aims to quantify and monitor constraints imposed on airspace users through the application of air traffic flow measures. Particularly, the focus is on the performance of the two ATM systems since the outbreak of the COVID-19 pandemic in 2020.

Air traffic in both systems was severely affected by the measures put in place to fight the pandemic but with a notably higher impact in Europe. In comparison to 2019, there was a -33% decrease in traffic in the United States in 2020, while Europe experienced a more significant drop of -56%. Fast forward to 2022, traffic in the U.S. still lagged behind 2019 levels by -6.7%, whereas in Europe, traffic (in terms of IFR flights) remained -16.9% below 2019 levels. The notably steeper decline in Europe can be attributed to differences in market composition. The U.S. benefits from a large domestic market, which facilitated a swifter recovery compared to predominantly international flights in Europe. Additionally, the outbreak of the war in Ukraine in 2022 and the resulting economic downturn in several European countries further contributed to the challenges faced by the European aviation sector.

From a passenger point of view, on time performance is generally used as the industry standard to get a first high level understanding of air transport performance. As traffic declined in early 2020, the proportion of flights arriving within a 15-minute window of their scheduled arrival time initially experienced a substantial rise. However, it subsequently began to decline again in both the U.S. and Europe in accordance with the observed patterns of traffic recovery.

In the U.S., arrival punctuality continuously degraded between 2020 and mid-2023 to a level below 2019 (78.5%). In Europe, arrival punctuality first degraded moderately in 2021 but then dropped to the worst level on record in summer 2022, mainly driven by staff shortages in all parts of the aviation industry which made it difficult to accommodate the quickly growing demand in summer.

The more focused analysis of ATM performance by phase of flight compares actual performance to an unconstrained theoretical optimum, which removes possible influences from time buffers included by airlines to maintain schedule integrity.

ANS performance on both sides of the Atlantic showed improvements in all stages of flight immediately following the decline in traffic caused by the pandemic in April 2020. However, performance began to deteriorate again, in line with the traffic recovery patterns observed in the U.S. and Europe.

Consistent with the observations made in previous reports, the relative distribution of the ATM-related inefficiencies by phase of flight reflects the differences in flow management strategies in both systems. The U.S. and Europe currently use different strategies for absorbing necessary delay in the various flight phases.

Overall, the differences in ATM related operational service quality between the two systems appear to originate from different reasons, including, inter alia, regulatory and operational differences, policies in allocation of airport slots and flow management, as well as different weather patterns.

In Europe, a lot of emphasis is put on strategic planning and a large part of the demand/capacity management measures are applied months in advance. Unlike in the U.S. where only 3 airports have schedule limitations, traffic at major European airports is usually already regulated (in terms of volume and concentration) in the strategic phase through an airport scheduling process. With no or very limited en-route spacing or metering in Europe, the focus is placed on anticipating demand/ capacity imbalances in en-route centres or at airports and, if necessary, to solve them by delaying aircraft at the origin airports on the ground (allocation of ATFM take-off slots).

In the U.S., the emphasis is more on the tactical traffic management in the gate-to-gate phase to maximize system and airport throughput under prevailing conditions on the day of operations. The approach is supported by the en-route function and less en-route capacity restrictions than in Europe. As needed, miles in trail (MIT) or minutes in trail (MINIT) are used to apportion traffic into a manageable flow, as well as to provide space for additional traffic (merging or departing) to enter the flow of traffic. Resulting delays are normally manifested as delays in the taxi-out phase or at the gate.

Inefficiencies in the various flight phases (airborne versus ground) have a very different impact on airspace users in terms of fuel burn (engines on versus engines off). For ANS-related delays at the gate (ATFM/EDCT departure restrictions) the fuel burn is quasi nil[22] while in the gate-to-gate phase (taxi, en-route, terminal holdings) the impact in terms of additional time, fuel and associated costs is significant. Hence, the environmental impact of ATM on climate is closely related to operational inefficiencies in the gate-to-gate phase and associated additional greenhouse gas emissions.

By combining the analyses of the individual phases of flight, an estimate of the theoretical maximum "improvement pool" actionable by ANS can be derived. It is important to stress again that this "benefit pool" is based on a theoretical optimum, which is not achievable at system level due to inherent necessary (safety) or desired (capacity) limitations.

In Europe, average ANS-related delays experienced at the gate (ATFM/EDCT) are more than twice as high as in the U.S.

Flights in Europe are 5 times more likely to be held at the gate than in the U.S. because of

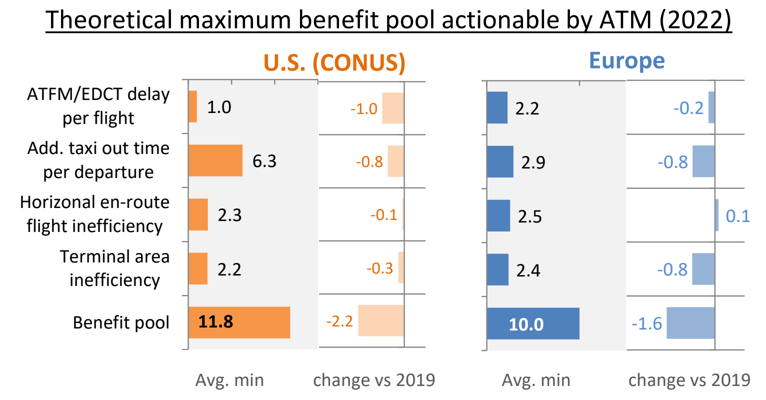


Figure 3-14: Theoretical maximum benefit pool actionable by ATM in the U.S. and in Europe (2022)

[22] It is 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.

en-route capacity constraints. In the U.S. most delays experienced at the gate are related to adverse weather at airports.

This could be associated with the difference in approach: In Europe, the capacity declaration process tends to arrange traffic in closer alignment with Instrument Meteorological Conditions (IMC) capacity. In contrast, in the U.S., where demand levels are regulated by airlines and capacity is managed with greater flexibility, the ATM system seems to be better equipped to adjust throughput in response to current conditions, potentially allowing for operation closer to Visual Meteorological Conditions (VMC) capacity when feasible. The more tactical approach in the U.S. is also visible in the high average additional taxi-out time which in the U.S. is twice as high as in Europe.

Overall, the total benefit pool in 2022 was higher in the U.S. than in Europe, but with traffic levels in the U.S. notably closer to pre-pandemic levels.

To get a more complete picture of ATM performance in each region, it is necessary to also consider capacity utilization in both systems together with the observed "benefit pool".

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 by far exceed the savings in fuel cost. More study is needed to understand the real costs of each strategy.

4 Comparison of ANS cost-efficiency trends (2011-21)

4.1 INTRODUCTION AND BACKGROUND

This analysis is the fourth in a series of factual high-level comparison of ANS cost-efficiency trends between the U.S. and Europe [6], [7], [2] based on a well-established economic performance framework. The factual high-level comparison of ANS cost-efficiency between the U.S. and Europe in this chapter focuses on the continental costs of:

- Air Traffic Management (ATM) and
- Communications, and Navigation and Surveillance (CNS) provision.

It does not address:

- Oceanic ANS,
- services provided to military operational air traffic (OAT), or
- airport landside management operations.

For Europe, results are shown at European and at the SES State level:

- "Europe" corresponds to 36 ANSPs[23] included in the ATM cost-effectiveness (ACE) benchmarking programme;
- "SES States" refers to the 29 ANSPs of the EU27+2 States[24] which are subject to the SES performance and charging scheme regulation in the third Reference Period (RP3, 2020-2024) [4].

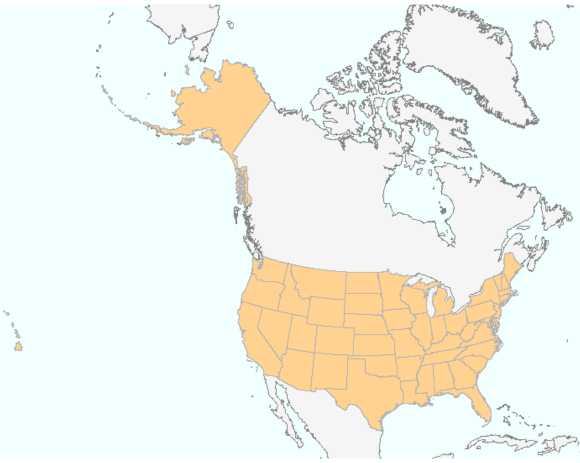


Figure 4-1: U.S. geographic scope included in the economic comparison

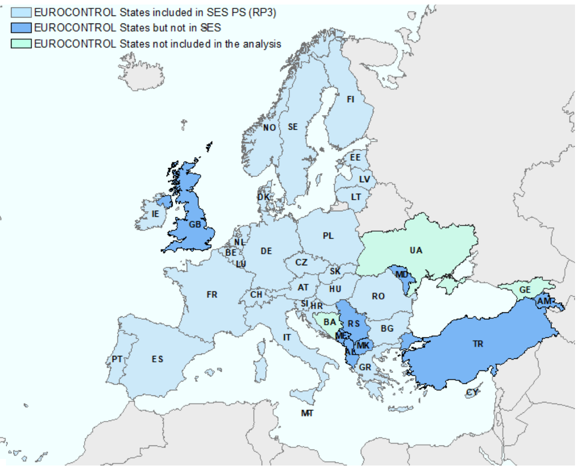


Figure 4-2: European States included in the economic comparison

Since 2012, the EU SES performance scheme places a strong emphasis on various aspects, including performance planning and accountability, the establishment of binding targets (covering Safety, Cost-Efficiency, Capacity, and Environmental aspects), continuous monitoring, incentives, and corrective measures, both at the European and national levels. This scheme is closely linked with a charging regime, which replaced the concept of "full cost recovery" with a system known as

[23] While the latest ACE Benchmarking report [9] includes 38 ANSPs, Sakaeronavigacija, the Georgian ANSP, and BHANSA, the ANSP of Bosnia and Herzegovina, only started to provide data for the years 2015 and 2019 respectively and are therefore excluded from the analysis presented in this Report. See Annex 3 for details.

[24] 27 National ANSPs (EU27) without Luxembourg, plus Norway, Switzerland, and Maastricht Upper Area Control Centre (MUAC) operated by EUROCONTROL. See Annex 3 for details.

"determined costs" and introduced risk-sharing mechanisms in conjunction with the setting of performance targets.

The "U.S." refers to continental U.S. (CONUS), which includes the 48 connected states and District of Columbia located on the North American continent south of the border with Canada plus activity for Alaska, Hawaii, Puerto Rico, and Guam.

Although both figures for the SES States and Europe are shown in the analysis, for sake of simplicity and clarity only the differences between the U.S. and the SES States are highlighted in the figures and commented in the text wherever appropriate.

It is important to highlight that there is a fundamental difference in how ATM/CNS provision is funded in the U.S. and in Europe. Whereas in Europe air navigation services are primarily funded through specific en-route and terminal ANS charges, in the U.S., the Federal Aviation Administration (FAA) is primarily funded by excise taxes deposited into the Airport and Airway Trust Fund (AATF) with additional funding from the General Fund of the U.S. Treasury as necessary. This funding is provided to the FAA by Congress through annual appropriations laws and supplemental funding laws.

The SES performance scheme is coupled with a charging regime which replaces "full cost recovery" with a system of "determined costs" set at the same time as the performance targets. These performance targets are legally binding for EU Member States and are designed to encourage ANSPs to be more efficient and responsive to traffic demand, while ensuring adequate safety levels. The goal is to achieve significant and sustainable performance improvements.

<u>Finally, it should be noted that the analysis in this report is not affected by funding differences as it compares the costs rather than the funding of both systems</u>. However, there may be significant difference in accounting principles and costing methods so steps have been taken to account for these or, at least, note them.

4.2 SCOPE, METHODOLOGY AND INFLUENCING FACTORS

4.2.1 SCOPE OF THE ECONOMIC ANALYSIS

The data used in this analysis represent the latest year for which actual financial data are available for the U.S. and for Europe[25].

- for Europe and the SES States, costs and operational data are sourced from submissions by ANSPs to the Performance Review Unit (PRU) for the ACE benchmarking reports [8] [9] [10], [11];
- for the U.S., costs and operational data provided by the FAA-ATO[26] are consistent with the submission to the CANSO[27] Global Benchmarking Reports [12] which have underlying definitions of cost items and output metrics in line and consistent with those used in the ACE benchmarking programme in Europe.

[25] The U.S. data refers to financial years whereas for Europe the data refers to calendar years.

[26] Only the costs attributable to the U.S. Air Traffic Organization (FAA-ATO), the operational arm of the FAA, were considered in the comparison. The FAA-ATO continental costs represent around two thirds of the total FAA net cost of operations for FY 2021 (US$18.0 billion). The other third relates to costs outside the FAA-ATO (such as airports, certification, aviation research, airspace infrastructure improvements, among other FAA costs that are not associated with the ATO), but also to FAA-ATO costs falling outside the scope of this study (Oceanic services and weather).

[27] The Civil Air Navigation Services Organization.

To ensure the comparability of ANS cost-efficiency, the analysis in this chapter is undertaken on a gate-to-gate basis. This approach accounts for differences in cost allocation practices between the U.S. and Europe in terms of en-route and terminal ANS costs.

To the greatest degree possible, efforts have been made to reach comparability of financial data by excluding "other" or "unique" costs. A summary of the costs that are included and excluded in the comparison is provided in Table 4-1 with a more complete breakdown to follow.

Cost type	U.S.	Europe/SES States
ATM/CNS provision costs	✓	✓
Flow management coordination	✓	✓
Cost of capital	n/a	✘
MET costs (internal/external)	✘	✘
R&D (e.g. NextGen, SESAR, etc.)	✘[28]	✘
ATC provision to military (OAT)	✘	✘
Regulatory costs	*Includes the proportion for the ATO*	✘
Cost for contract towers	✓[29]	✘
Flight Services	✓	✓

Table 4-1: Summary of included and excluded costs

Flow management coordination: Costs for the Air Traffic Control System Command Center (ATCSCC) are included in the U.S. data and similarly the EUROCONTROL Network Manager Operations Centre (NMOC) costs are included in the overall European data. NMOC costs for the SES States have been calculated on a pro-rata basis, allocating the overall European NMOC costs between SES States (85%) and other EUROCONTROL States (15%).

Cost of capital: Due to the differences in the funding process, the cost of capital (interest on debt and remuneration of equity) is not part of the FAA-ATO cost base. For comparison purposes, the cost of capital (some 5% of the European costs) has been removed from the European figures.

MET costs: The costs of meteorological services (MET), airport management and related services have been removed, where possible.

Research & Development: Despite all the efforts to ensure comparability, there are inherent differences in the cost structures of government entities and privately operated entities which are not easily quantified or removed. It should be noted that FAA-ATO funded R&D expenditures are included. However, the FAA is making significant investment into their NextGen program, some of which is not funded by the FAA-ATO and therefore not included in this report.

Regulatory: While regulatory costs are not included in the European data (e.g. costs of National Supervisory Authorities or Civil Aviation Authorities), a small portion of the FAA costs includes regulatory costs, which could not be excluded due to the FAA being a governmental entity. However, the amount is small and does not significantly impact the overall results of the comparison.

Contract towers: are outsourced services by the FAA. Hence, the staff employed in FAA contract towers (including more than 1,400 ATCOs) are not represented in the staff or ATCO-hour figures for FAA-ATO. The total amount of costs related to contract towers (including ATCO employment costs) is reported under and considered as part of the "support costs" in this report.

[28] Excluded if not FAA-ATO funded.

[29] The cost of contract towers for 2021 was some 188 million USD (some 155 million EUR).

Flight Services: The cost of flight services is part of the FAA-ATO continental costs; similarly, costs for Flight Information Services are part of the cost base for European ANSPs.

Where necessary, some minor refinements were made to historic data reported in previous cost-efficiency comparisons to reflect changes in cost allocation systems and to provide the reader with the most accurate picture.

4.2.2 METHODOLOGY AND FRAMEWORK

As was the case in the previous comparison reports [6] [7] [2], the analysis draws heavily on the well-established ATM Cost-Effectiveness (ACE) benchmarking framework [13].

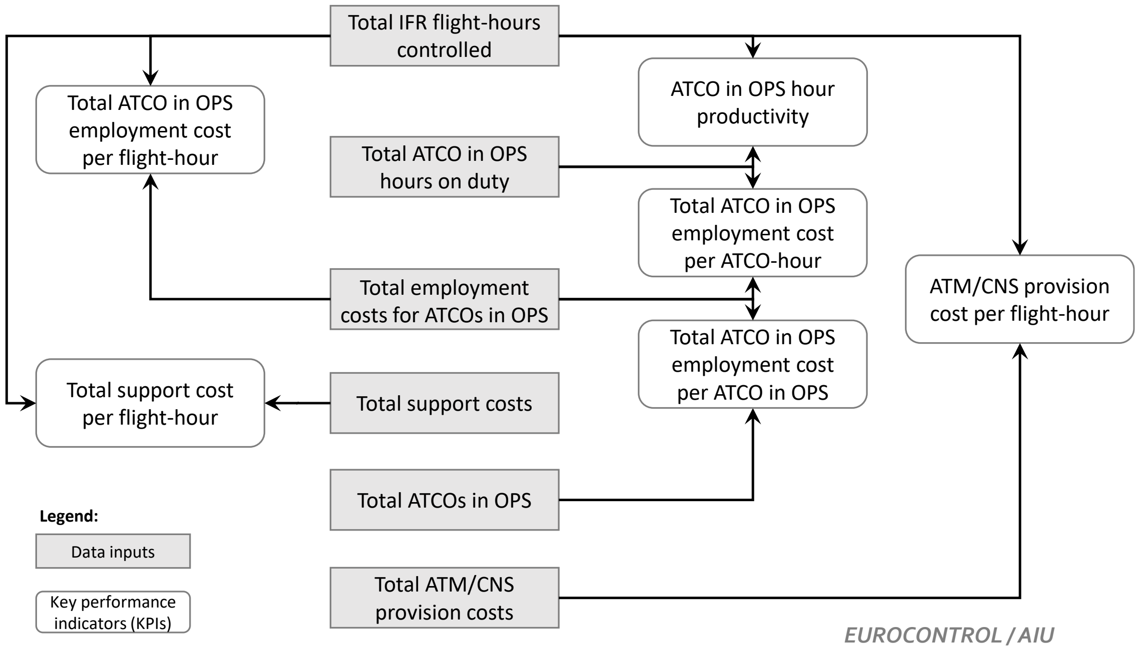


Figure 4-3: Cost-effectiveness analytical framework

Figure 4-3 illustrates the key economic (input/output) metrics that are used for the analysis.

The ATM/CNS provision costs per IFR flight-hour controlled is the key cost-effectiveness indicator, which reflects the ratio of total ATM/CNS provision costs and the output measured in terms of flight-hours controlled. For a better understanding of the drivers, it is further broken down into:

- **Air Traffic Controller (ATCO) in OPS employment costs**[30] **per unit of output** (itself broken down into **ATCO-hour productivity** and **ATCO employment costs per ATCO in OPS**); and
- **Support costs per unit of output** is the ratio of support costs (defined as ATM/CNS provision costs **other** than ATCO in OPS employment costs) to IFR flight-hour. Typically, these include support staff employment costs, operating costs and depreciation/amortization. For FAA-ATO, the support costs also include some operational staff engaged in ATC activities (i.e. traffic management coordinators, controllers, inflight services, developmentals and CPC-IT, ATCOs in contract towers, Oceanic ATCOs as detailed in section 4.2.1).

[30] Only full time certified ATCOs were considered in the specific ATCO in OPS employment costs. Employment costs for developmental controllers, controllers in training (CPC-IT) and contract tower controllers were included in support costs. This distinction is made to facilitate international comparisons and differs from total controller counts reported in the FAA controller workforce plan [23] which includes developmental controllers and controllers in training as part of the total count.

4.2.3 CURRENCY EXCHANGE AND INFLATION EFFECTS

All cost figures in this chapter are expressed in 2021 real terms, i.e. the nominal cost series were deflated using the respective Consumer Price Index (CPI) deflators for the FAA-ATO and the European ANSPs. To enable cost-efficiency comparisons between the U.S. and Europe, there is a need to convert the costs to a common currency. This can be done by one of two ways:

- using currency exchange rates; or
- by means of an artificial currency.

The latter—Purchasing Power Standards (PPS) through the means of Purchasing Power Parities (PPPs) is used and refers to the units needed to purchase a defined basket of consumer goods in each country. More details on the methodology and data used are provided in Annex 4.

The PPS method equalises the purchasing power of two currencies by taking the relative cost of living into account. Depending on the analysis, using PPS can make international comparisons more valid, particularly when directly comparing some cost categories, such as staff costs.

Using the annual currency exchange rates would introduce a bias because of the fluctuations over time (see Figure 4-4). All else equal, the appreciation of the USD would increase the U.S. ANS costs, when expressed in Euro, and therefore narrow the observed gap. Accordingly, the depreciation of the USD would widen the cost-efficiency gap.

To minimise the effects of currency exchange rate fluctuations in the time series analysis, the <u>2011-2021 average exchange rate $1.21: €1 consistently to the entire (deflated) cost series for the U.S was applied</u>.[31]

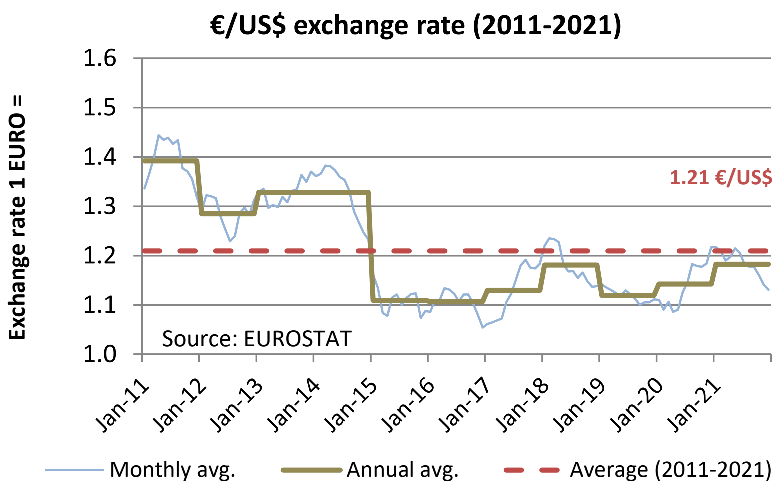


Figure 4-4: Time series of the €/US$ exchange rate

The analysis in this report was therefore carried out primarily using the USD/Euro exchange rate methodology with some supplemental PPS charts (based on EUROSTAT data) and the results are shown and described as considered most appropriate for the respective section.

Accordingly, a <u>PPP exchange rate of 1.40 was used for the U.S. to express figures in PPS</u>, corresponding to the 2011-2021 average PPP exchange rate, which reflects the fact that for every unit spent in the EU27 Area it takes 1.40 to obtain the same unit in the U.S.

[31] The treatment of financial figures for European ANSPs is explained in detail in Annex 4 of the ACE Benchmarking report (May 2023 edition) [9].

4.3 LONG-TERM OVERVIEW

In aviation, a range of outputs are measured to describe performance (flights, passenger, tonne-kilometre revenue, available seat km, etc.). For the analysis in this chapter, the instrument flight rules (IFR) flight-hours controlled are used as they are closely associated with the work provided by ATCOs.

While relevant for the air transport system in general, the use of other output measures such as passenger kilometres might be misleading in the ANS context as larger aircraft would automatically improve ANS performance.

Figure 4-3 shows the evolution of IFR flight-hours controlled in the U.S. and in Europe between 2006 and 2021 with the effects of the economic crisis starting in 2008 and the impact of the COVID-19 pandemic is clearly visible on both sides of the Atlantic.

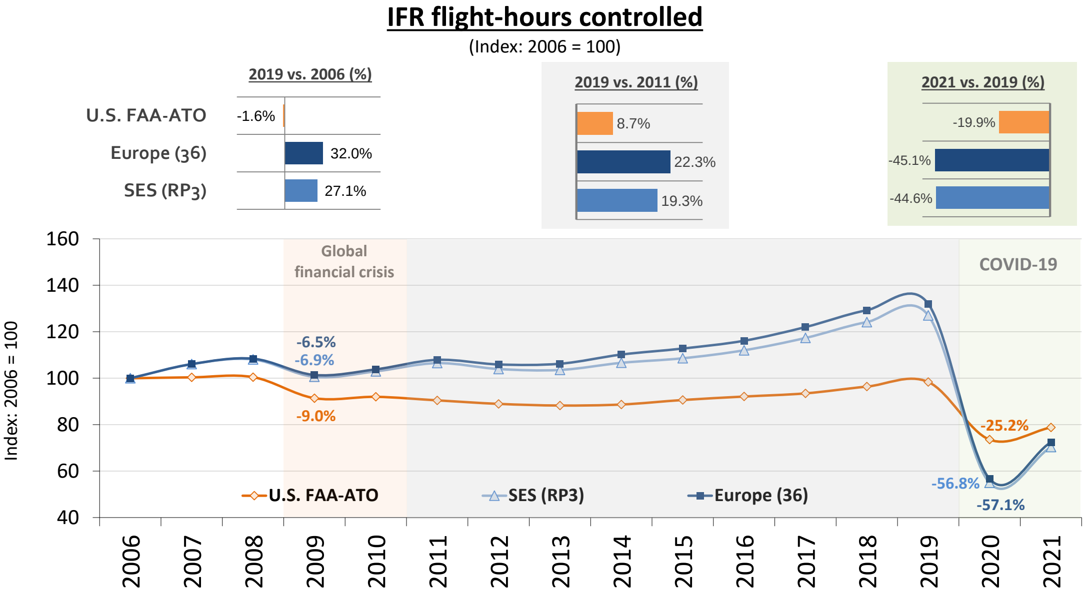


Figure 4-5: Long term trends in IFR flight-hours controlled

In the SES States, the reduced demand for air transport following the fallout of the global financial crisis in 2008 resulted in a -6.9% reduction in flight-hours. While it took six years for the traffic to recover to pre-crisis levels (in 2015), the traffic continued to grow rapidly reaching the highest levels ever recorded in Europe in 2019 (some +27% higher than that in 2006 for SES States). While the U.S. controls significantly more flight-hours than the SES States (1.5 to 2.5 times more depending on the year), the robust traffic growth experienced in Europe as of 2013 significantly reduced the gap (from 138% in 2006 to 84% in 2019).

Traffic levels dropped dramatically on both sides of the Atlantic with the outbreak of the pandemic in 2020. The number of flight-hours in the SES States reduced considerably (-56.8%) following the implementation of lockdowns and other measures primarily targeting the cross-border movement of people between States. While the U.S. also implemented international and state travel restrictions to mitigate the spread of COVID-19, the reduction in flight-hours was less than half of that experienced by the SES States and rebounded faster in the U.S, which is discussed further in Section 4.3.

Figure 4-6 shows the trend in total ATM/CNS provision costs in real terms for the U.S. FAA-ATO and Europe between 2006 and 2021.

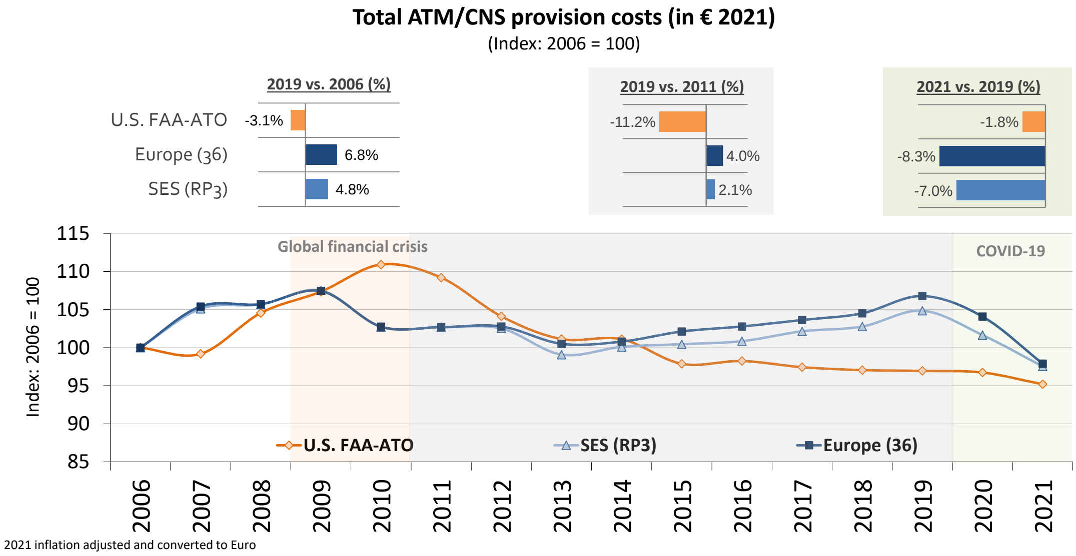


Figure 4-6: Long term trends in total ATM/CNS provision costs

Between 2006 and 2019, total ATM/CNS costs decreased by -3.1% in the U.S. while they increased by +4.8% in the SES States (+6.8% for Europe) during the same period. At the same time, flight-hours controlled decreased by -1.6% in the U.S. while for SES States they increased by +27% (2019 vs. 2006).

The increase in FAA-ATO total ATM/CNS provision cost between 2007 and 2010 is mostly attributable to the increased purchasing associated with NextGen[39] (part of the FAA-ATO support cost category in this report). The decrease in FAA-ATO provision costs between 2011 to 2021 is also driven by the reduction in support costs, which are discussed in detail in section 4.3.

For the SES ANSPs the total provision costs grew by +4.8% between 2006 and 2019 with the notable reduction in the cost base following the financial crisis between 2009 and 2010 predominantly driven by cost containment measures implemented by European ANSPs in response to the lower traffic volumes following the economic downturn. Despite the significant growth in traffic from 2011 to 2019 (+19.3%), the costs in SES ANSPs saw only a marginal increase (+2.1%). This can be attributed in part to the introduction of the SES Performance Scheme, which imposed cost-efficiency targets that exerted pressure on costs through legal obligations within the framework.

Considering the different cycles affecting aviation industry on both sides of the Atlantic, the long-term analysis over the period starting in 2006 offers limited value. For this reason, the 10-year period (2011-2021) is considered for the analysis of cost-efficiency performance of the two systems. To that end, it is recalled that the year 2012 marks the start of the Single European Sky (SES) performance scheme in Europe while in the U.S. the FAA Modernization and Reform Act was passed by Congress in the same year. Both initiatives are expected to have a bearing on cost-efficiency performance.

Due to the magnitude of disruption by COVID-19 pandemic from 2020 onward in both systems, it is difficult to compare performance in 2011 to that in 2021. Therefore, to better capture the distinct cycles observed in the performance of air navigation service providers in the SES States and the FAA-ATO as well as to gain a deeper understanding of the pandemic's impact on the two systems the analysis of the main key performance indicators is divided into two separate periods: (1) 2011-2019 and (2) 2019-2021 throughout this chapter.

4.4 COMPARISON OF ANS COST-EFFICIENCY & PRODUCTIVITY

Figure 4-7 shows a high-level comparison of the total ATM/CNS provision costs in the U.S. and in Europe in 2021. As described in section 4.2.3, for FAA-ATO, the total costs of €9.7 billion are based on the conversion of an amount of US$ 11.8 billion to Euro using the average 2011-2021 exchange rate of US$1.21: €1. In 2021, total ATM/CNS provision costs in the U.S. were 47% higher than in SES States (27% vs. Europe), but the U.S. controlled +166% (+115% vs. Europe) more IFR flight-hours.

Total ATM/CNS provision costs (in M€2021)	U.S. FAA-ATO	EUROPE (36 ANSPs)	SES (RP3)	U.S. vs Europe	U.S. vs SES (RP3)
2021 IFR flight-hours controlled	20.4 M	9.5 M	7.6 M	+115%	+166%
Employment costs for ATCO in OPS	€ 2,214	€ 2,495	€ 2,161	-11%	+2%
Total support costs	€ 7,532	€ 5,198	€ 4,480	+45%	+68%
Total costs	**€ 9,746**	**€ 7,693**	**€ 6,641**	**+27%**	**+47%**

2021 inflation adjusted and converted to Euro

Figure 4-7: Breakdown of ATM/CNS provision costs (€2021)

This data was collected and combined under several different accounting structures that make different assumptions and run under different principles. Some of the differences in accounting practices between the U.S. and Europe include:

- FAA-ATO follows U.S. Generally Accepted Accounting Principles (GAAP) based upon the Federal Accounting Standards Advisory Board (FASAB),[32] while European ANSPs use either International Financial Reporting Standards (IFRS) or local GAAP, which, while similar in principle, differ in terms of accounting of development costs (expensed under GAAP and capitalised under IFRS) and recording of fixed asset values (historical cost under both GAAP and IFRS, but companies are allowed to revalue at fair market price under IFRS).
- genuine differences in the accounting treatment of depreciation: FAA depreciation expenses are calculated using the straight-line method, as in Europe, but different depreciation periods and capitalization amount thresholds may be applied in the U.S. versus in Europe.

As already indicated previously, the financial data used in this chapter is collected from different organisations using different accounting and reporting methodologies. These inherent differences are discussed in more detail throughout the chapter as notable discrepancies arise.

4.4.1 UNIT ATM/CNS PROVISION COSTS

Figure 4-8 shows the evolution of the total ATM/CNS provision costs per IFR flight-hour controlled in the U.S. and in Europe.

The unit ATM/CNS provision costs for the SES States reduced almost continuously (except for a slight increase in 2012) over the entire 2011-2019 period at an annualised rate of -1.9% per annum. This significant cost-efficiency improvement was achieved by maintaining the costs relatively stable (+0.3% p.a.) in the context of significant traffic growth (+2.2% p.a.). This should be seen in the context of the implementation of SES Performance Scheme and the incentive mechanism embedded in the charging scheme which contributed to maintaining a downward pressure on costs during the regulatory Refence Periods (RP1 covering 2012-14 and RP2 covering 2015-19).

The U.S. provision costs per flight-hour were consistently below those in Europe and the SES States between 2011 and 2021. For example, they were 21% lower in 2011, 24% lower in 2019, and 45% lower in 2021 than SES. Between 2011 and 2019, U.S. unit ATM/CNS provision costs reduced continuously

[32] Federal Accounting Standards Advisory Board, *Handbook of Accounting Standards and Other Pronouncements* (FASAB Handbook), as Amended

(-2.5% p.a.), reflecting a combination of significant reduction in ATM/CNS provision costs (-1.5% p.a.) and an increase in IFR flight-hours controlled (+1.1% p.a.). As a result, the gap between the unit cost indicator for SES States and the U.S. increased slightly over this period.

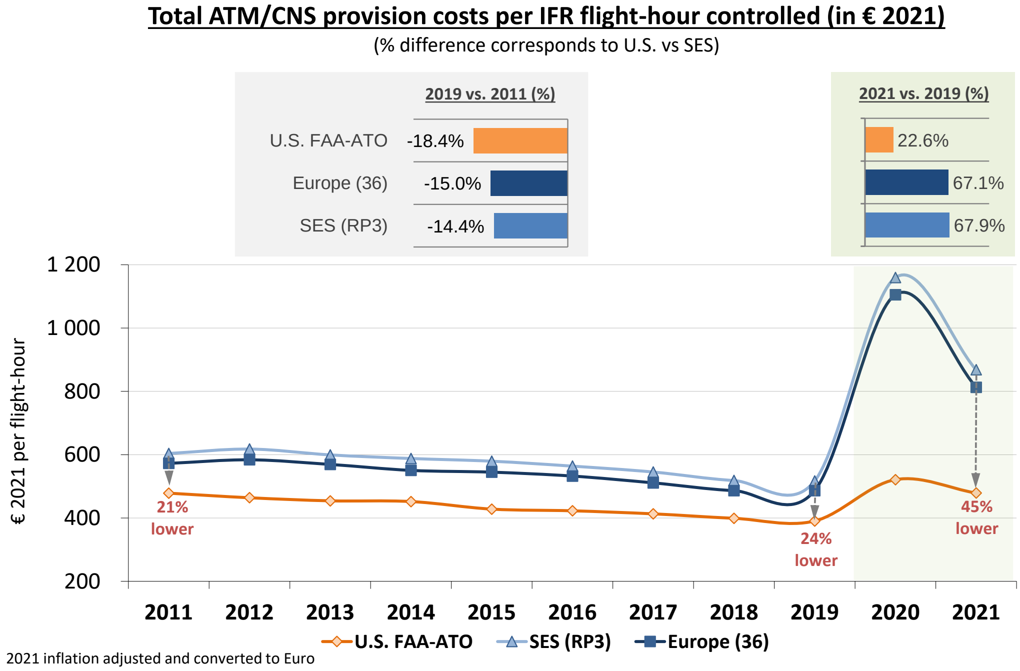


Figure 4-8: Trends in unit ATM/CNS provision costs (2011-2021)

The FAA-ATO handles about twice as many flight-hours as Europe. This factors into the increase of unit costs in 2020, which was not as significant for the U.S. when compared to Europe, mainly due to the lower traffic reduction (-25.2%), and a faster recovery of the U.S. domestic market, reaching around 80% of the 2019 traffic level at the end of April 2021. As already discussed in Chapter 2 of this report, the U.S. has a larger share of domestic flights in proportion to total flights while Europe has a greater share of international flights as a proportion of total flights.

Following the outbreak of the COVID-19 pandemic, the unit costs in the SES States nearly doubled in 2020. While European ANSPs' did enact stringent cost-containment measures in 2020, they resulted in a -3.0% reduction to ATM/CNS provision costs which was not sufficient to compensate for the -56.8% reduction in traffic over the same period. It should also be recognised that some of these measures have a lagging effect (e.g. delay between the implementation of redundancy scheme and departure of staff) or, in some cases, entail higher up-front costs (e.g. redundancy packages) negatively affecting the cost-base in the short term but bringing significant savings in the medium and long terms.

4.4.2 SUPPORT COSTS & STAFF

Total support costs (defined as total ATM/CNS provision costs other than ATCO in OPS employment costs) in the U.S. accounted for around 77.3% of the total ATM/CNS provision costs in 2021, whereas in the SES States the relative share was almost 10% lower (67.5% in 2021).

Employment costs of support staff (defined as staff other than ATCOs in OPS) constitute a significant portion of support costs. However, for FAA-ATO, support staff costs also include those for operational staff that control air traffic but are not fully certified yet, i.e. developmental ATCOs in training and Certified Professional Controllers in Training (CPC-ITs) that transferred from another facility. Additionally, contracted ATCOs in OPS working in small contract towers are also included in support costs but are not reflected in support staff figures.

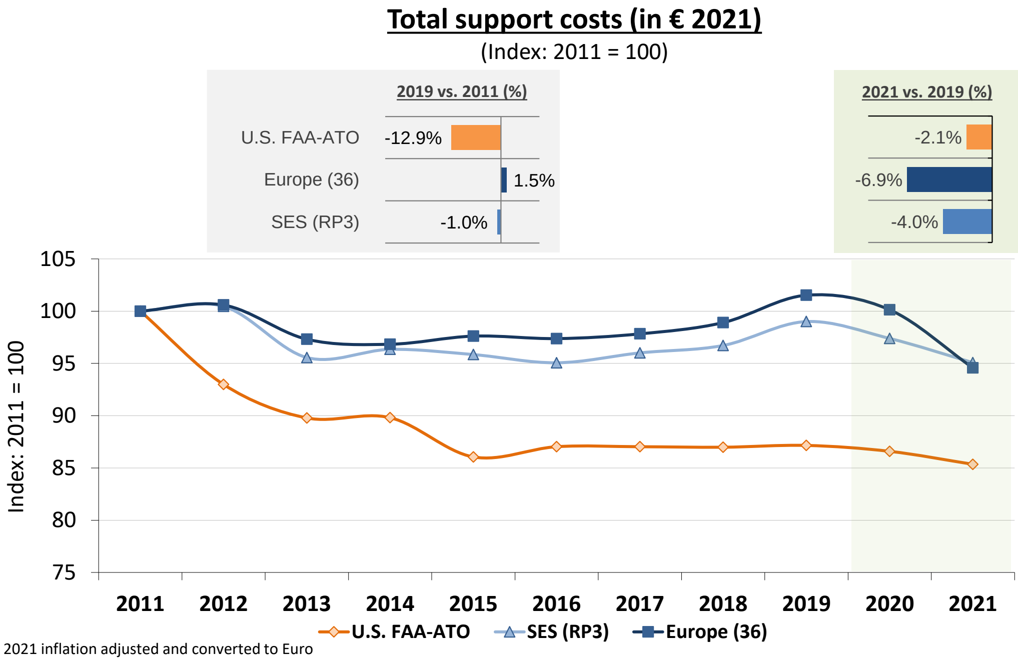


Figure 4-9: Trends in total support costs (2011-2021)

As shown in Figure 4-9, total support costs in the SES States remained relatively stable (-1.0%) between 2011 and 2019. On the other hand, for the FAA-ATO, the trend of reducing support costs between 2011 and 2015 are primarily driven by several factors:

- changes in the accounting treatment for purchasing and expensing equipment instead of capitalised and depreciated and lower cost from asset disposal.
- decrease in the FAA budget controlled by the U.S. Congress, savings in several areas and the allocation of expenses based on the reorganisation of FAA lines of business.

The stringent cost-containment measures implemented by the European ANSPs following the COVID-19 pandemic resulted in a steep reduction of support costs between 2019 and 2021 (-4.0%) primarily achieved through savings in support staff costs. Similarly, the support costs for the FAA-ATO also reduced (-2.1%) over the same period.

Figure 4-10 shows the trends in ATCOs in OPS and support staff as well as the breakdown of these two staff categories for 2021 in Full Time Equivalents (FTEs). It shows that in 2021 the FAA-ATO employed some -10% less ATCOs in OPS and some -21% less support staff than the SES States, while controlling more than double the traffic.

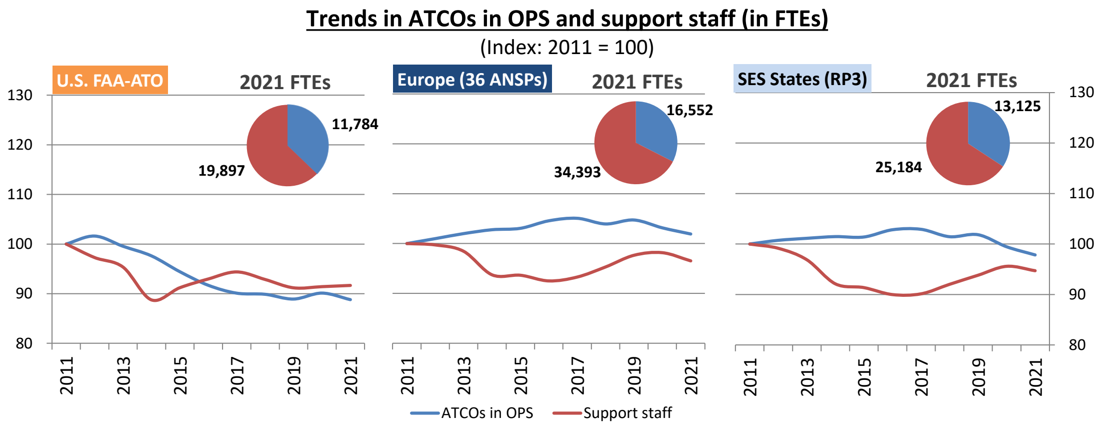


Figure 4-10: Trends in ATCOs in OPS and support staff (2011-2021)

Between 2011 and 2019 the number of support staff employed in the SES ANSPs remained relatively unchanged with two opposite trends observed during this period: a continuous reduction in support staff until 2016 and intake of additional support staff between 2016 and 2019, which coincides with the rapid traffic growth experienced by the SES States over this period.

The reduction of support staff for FAA-ATO between 2011 and 2014 is due mainly to the ATO reorganization, which is consistent with the decrease in support costs during the same time period. Between 2012 and 2019, FAA-ATO saw a reduction in the total number of ATCOs which is further discussed in section 4.3.3. While in training, developmental ATCOs in OPS control a portion of traffic; however, to allow for consistency in reporting and comparison, they are not counted as ATCOs in OPS, but rather as support staff until they become fully certified.

Unit support costs (defined as all ATM/CNS provision costs other than ATCO in OPS employment costs per IFR flight-hour controlled) followed a similar pattern as observed for unit ATM/CNS provision costs between 2011 and 2021 (see Figure 4-8).

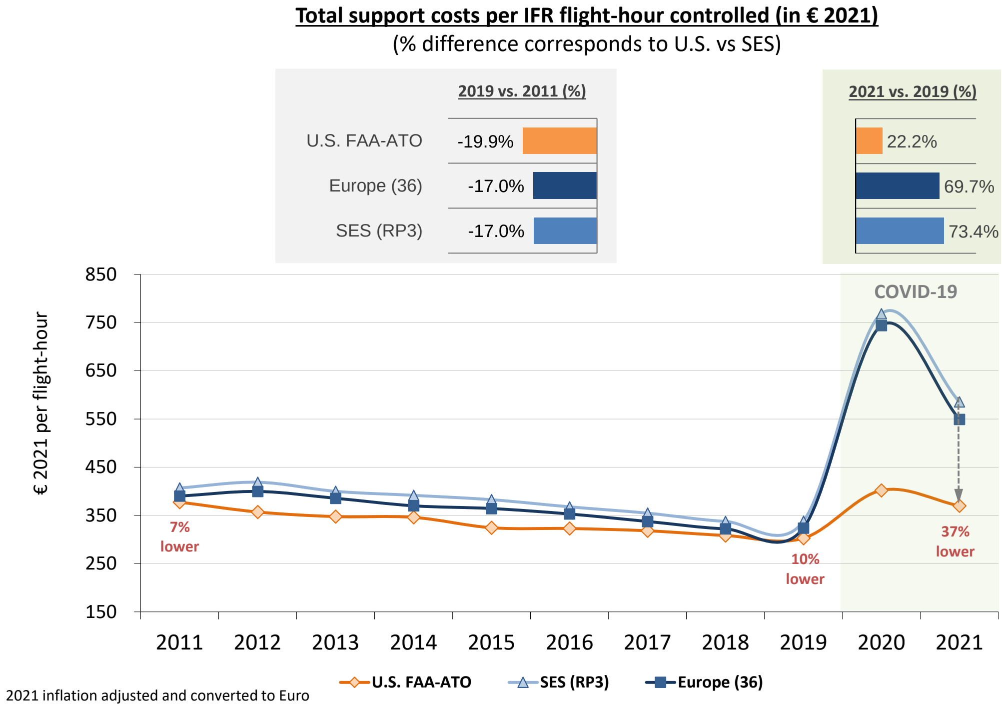


Figure 4-11: Trends in unit support costs (2011-2021)

Unit support costs decreased almost continuously between 2011 and 2019 for both the FAA-ATO and the SES States (-19.9% and -17.0% respectively over the period) with the gap remaining relatively stable. Following the COVID-19 pandemic, the unit support costs increased substantially on both sides of the Atlantic, with the unit support cost increase of +22.2% for the FAA-ATO between 2019 and 2021 and +73.4% for the SES States. As a result, the gap in unit support costs between the U.S. and the SES States increased more than seven-fold from 29.4 Euro per flight-hour in 2011 to 215.8 Euro in 2021.

4.4.3 ATCO-HOUR PRODUCTIVITY

Figure 4-12 shows the trends in ATCO-hour productivity, expressed as total IFR flight-hour controlled per total ATCO in OPS hours on duty. In the case of FAA-ATO, the total ATCO in OPS hours on duty is a product of the average annual hours on duty per ATCO and the total number of Continental ATCOs in OPS. There are notable differences in working arrangements between the U.S. and Europe (annual leave, etc.) impacting on the analysis. In 2021, the average annual hours on duty per ATCO in OPS in the U.S. (1,447 hours[33]) were some 18% higher than in SES States (1,221 hours).

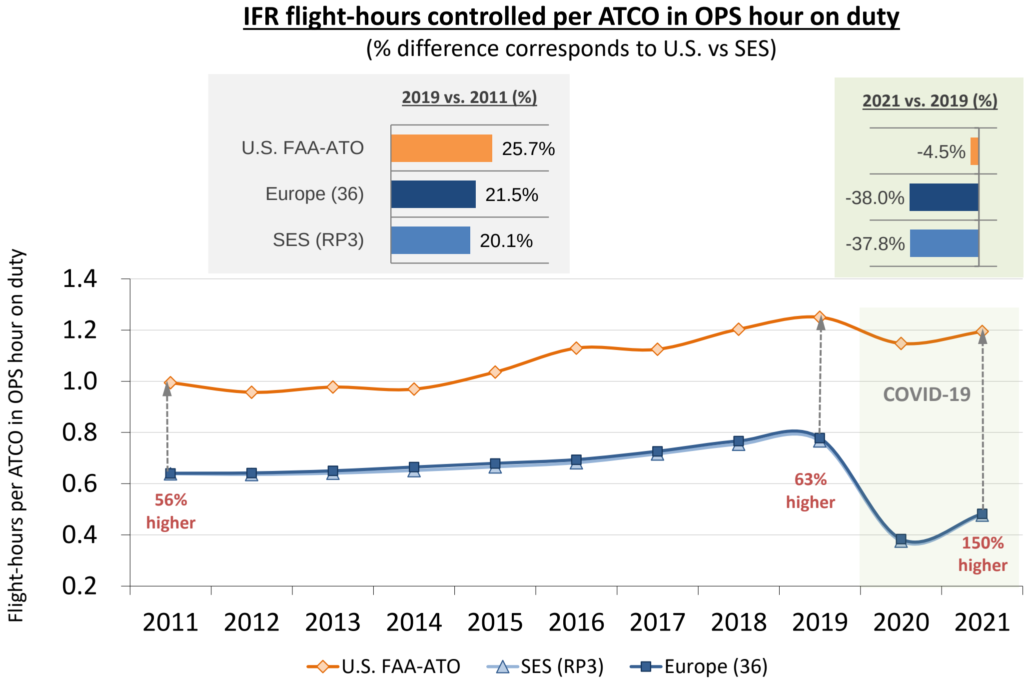


Figure 4-12: Trends in ATCO-hour productivity (2011-2021)

From 2011 to 2021, the output per ATCO-hour has been significantly higher in the U.S., and, while the productivity gap between the U.S. and the SES States was gradually closing until 2015, the significant productivity gains for FAA-ATO between 2015 and 2019 reversed this trend and resulted in an increase of the gap from 56% at the beginning of the period to 63% in 2019.

For FAA-ATO, this significant improvement in ATCO-hour productivity results from the decline in the number of ATCOs, as discussed in Section 4.4.2 (see also Figure 4-10). Meanwhile, the average annual ATCO in OPS hours on duty (not shown as its own data component) remained consistent between 2011 and 2019.

In Europe, the level of overall productivity may also be influenced by the level of fragmentation with, on average, smaller and more numerous en-route facilities which require more handovers and interactions, as explained in Section 1.2.

As a result of the COVID-19 pandemic, the ATCO productivity indicator in the SES States dropped much more than in the U.S., partly because of the much greater traffic reduction in Europe. As a result, in 2021 the FAA-ATO ATCOs controlled almost 2.5 times more flight-hours per working hour than their counterparts in SES States (1.19 vs. 0.48 flight-hours per ATCO-hour on duty).

Figure 4-13 provides a breakdown of the various components affecting the ATCO-hour productivity indicator. It shows the evolution of flight-hours controlled, ATCOs in OPS and total ATCOs in OPS hours on duty between 2011 and 2021.

[33] Average annual working hours reported by the FAA-ATO represent actual hours worked including time worked outside of the scheduled shift, minus leave, as collected through Labour Distribution Reporting. This number also does not include the hours on duty worked by the "developmental" controllers or controllers working in Contract Towers. It is also understood that this number includes some time spent on activities outside of the OPS room. This differs from the definition used in Europe, which only considers hours spent on active duty (incl. mandatory breaks).

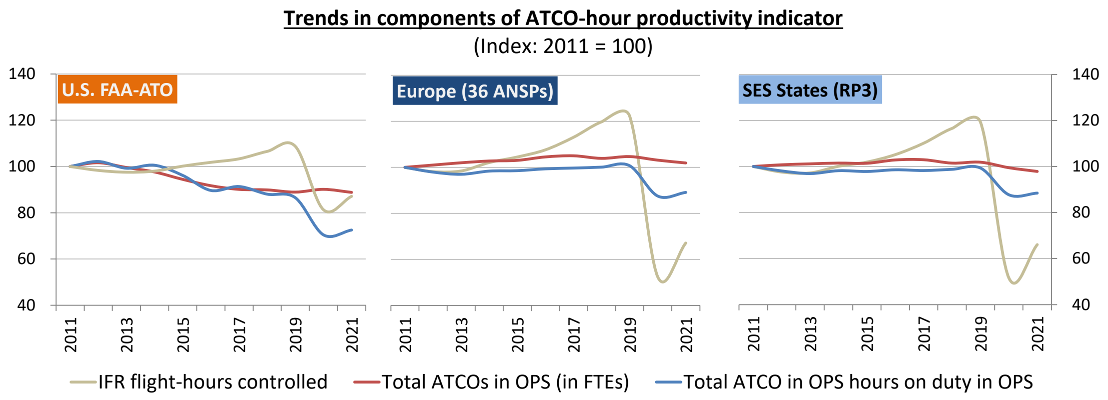


Figure 4-13: Trends in components of ATCO-hour productivity (2011-2021)

Figure 4-13 shows that for the SES States, the continuous ATCO-hour productivity gains over 2011-2019 period were achieved by maintaining the total ATCO-hours on duty mostly stable in the context of significant traffic increase. At the same time, the number of ATCOs in OPS also remained comparatively stable.

The sudden drop in traffic levels in 2020 as well as implementation of exceptional COVID-19-related measures affecting the operations of many of the European ANSPs were also reflected in the working arrangements for the European ATCOs in OPS. The re-allocation of ATCOs to non-OPS duties, reductions in overtime (in ANSPs which recorded overtime) as well as changes in sectorisation and rostering to adapt to considerably lower traffic resulted in a -11.7% reduction in total ATCO-hours on duty for SES States.

For the FAA-ATO, the number of total ATCOs in OPS hours on duty declined almost continuously between 2012 and 2019. The decrease between 2015 and 2018 for the FAA-ATO is driven by ATCO in OPS hiring challenges between 2013 and 2015. With an approximately two-year training time to certify as an ATCO, this impacted the hiring and training pipeline through 2018.

During 2020 and 2021, to enhance the health and safety of its workforce and maintain the resiliency of the ATC system, the FAA-ATO temporarily adjusted the operating hours of approximately 100 air traffic control towers nationwide and created segregated teams of controllers to curtail the possibility of cross-exposure to COVID-19 caused by normal shift rotations. The slight reduction of the ATCO in OPS in 2021 is a result of attrition, delay in certification of ATCOs, and a reduction of hiring due to COVID-19.

4.4.4 ATCO IN OPS EMPLOYMENT COSTS

As already indicated in section 4.2.3, it is important to account for the differences in purchasing power between the comparators when directly comparing employment costs in international comparisons. The top part of the figures is expressed in 2021 real terms and in Euros while the bottom part shows the same metric expressed in PPS.

Figure 4-14 shows the evolution of the ATCO employment costs[34] per ATCO in OPS between 2011 and 2021. After the slight reduction recorded in 2012 and 2013 (-2.1% and -0.5% respectively), the ATCO employment costs per ATCO in the SES States grew continuously between 2013 and 2019 (+1.5% p.a.) primarily owing to upward pressure on salaries experienced by several Central and Eastern European countries following their accession to the EU. The immediate pressures on the costs of European

34 The employment costs include gross wages and salaries (including payments for overtime), social security scheme contributions, pension contributions and other benefits.

ANSPs following COVID-19 pandemic reversed the trend and resulted in a sharp reduction in unit ATCO costs (-9.1% between 2019 and 2021).

For the FAA-ATO, the ATCO employment costs per ATCO in OPS grew constantly between 2011 and 2016 (+2.0% p.a.), with most notable increases observed in 2015 and 2016 which reflect an increase in premium pay (e.g. overtime, cash awards, etc.). The unit ATCO employment costs remained mostly flat throughout the rest of the period until 2021. The number of ATCOs in OPS in the FAA-ATO decreased by -11.2% between 2011 and 2021.

When expressed in Euros, ATCO employment costs per ATCO in the U.S. consistently exceeded those in the SES States from 2011 to 2021, with the gap widening from around 4% in 2011 to 14% in 2021. However, when expressed in PPS, the gap between the SES States and the U.S. shows an inverse trend, indicating that, when factoring in the cost of living, unit ATCO costs are generally comparable.

For SES States, pre-COVID-19 period saw continuous growth in ATCO employment costs per ATCO in OPS hour on duty reflecting growth in ATCO employment costs in the context of relatively stable hours on duty.

Considering differences in average working hours per ATCO indicated in section 4.4.3, the U.S. has notably lower ATCO employment costs per ATCO-hour than the SES States.

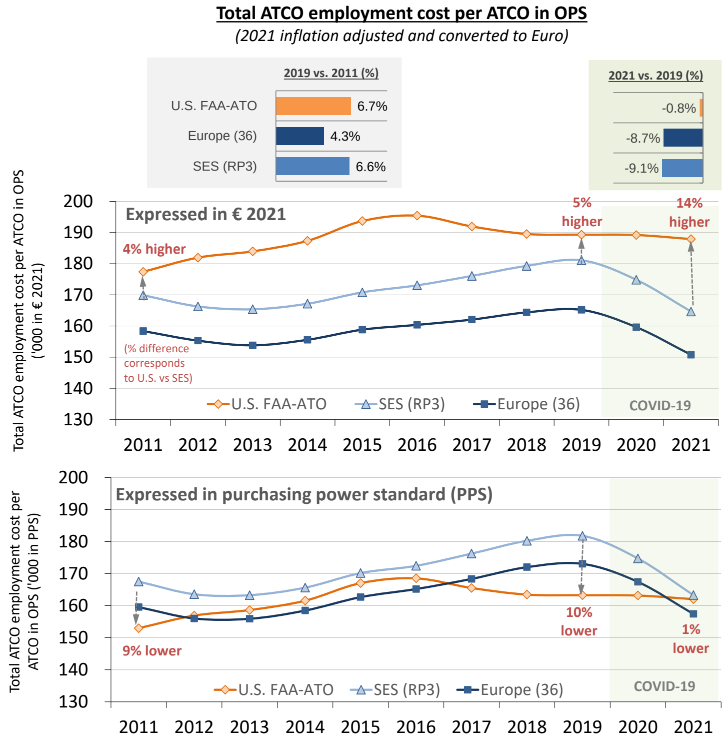


Figure 4-14: Total ATCO employment costs per ATCO in OPS, in '000 €2021 and in PPS (2011-2021)

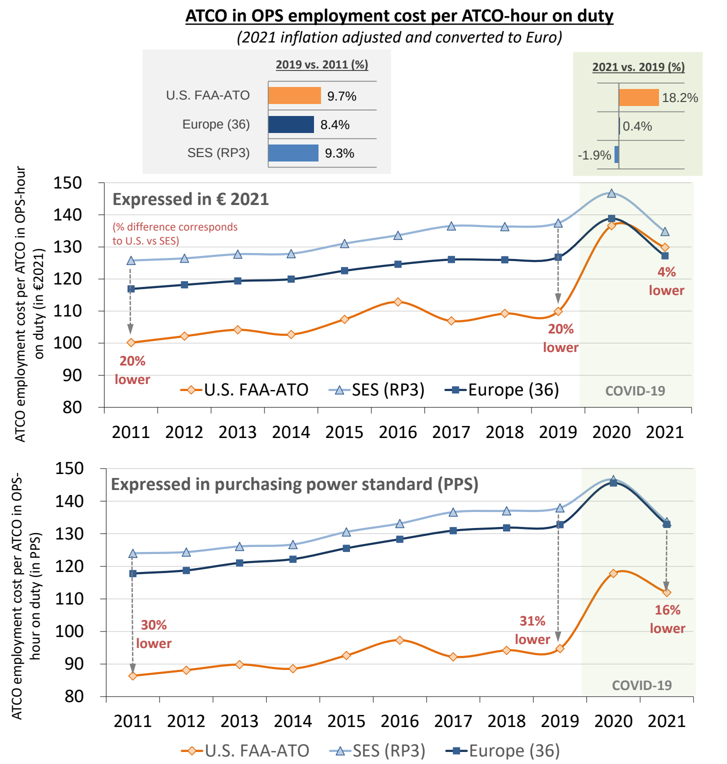


Figure 4-15: ATCO in OPS employment costs per ATCO-hour on duty, in €2021 and in PPS (2011-2021)

However, when accounting for purchasing power, this gap widens even further, increasing from 4% in Euros to 16% in PPS in 2021.

When combining the ATCO employment costs and the output in terms of controlled flight-hours (see analytical framework in Figure 4-3), the resulting ATCO in OPS employment costs per flight-hour were 49% and 51% lower in the U.S. than in the SES States in 2011 and 2019 respectively when expressed in Euros (Figure 4-16).

This reflects the significantly higher productivity in the U.S. (see Figure 4-12), whereby each U.S. ATCO handles almost double the flight-hours than their average European counterparts, while the employment costs per ATCO in OPS are only about +14% higher than in the SES States (Figure 4-14).

This gap becomes even wider when also considering the differences in the cost of living (from 62% in Euro to 67% in PPS in 2021).

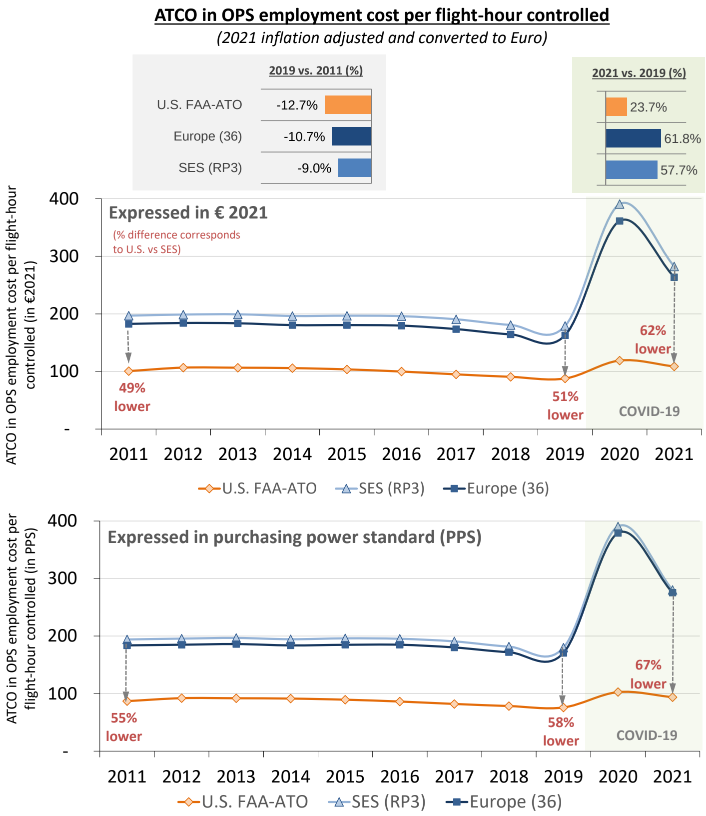


Figure 4-16: ATCO employment costs per flight-hour, in €2021 and in PPS (2011-2021)

4.5 CONCLUSIONS - ANS COST-EFFICIENCY COMPARISON

The U.S. is a realistic comparator for the European ANS system when considering the airspace characteristics and corresponding traffic volumes. Despite many similarities, it is worth highlighting that there are different regulatory, economic, social, and operational environments which may affect performance.

To ensure comparability and consistency over time, the analyses of the cost-efficiency trends are based on key metrics from the well-established performance framework developed in Europe as part of the ACE benchmarking project[35].

Considering the significant disruption caused by the COVID-19 pandemic in aviation on both sides of the Atlantic from 2020 onward, conducting a long-term analysis of cost-efficiency trends spanning the entire period from 2011 to 2021 offers limited value. Instead, to more accurately capture the distinct cycles observed in the SES States and the FAA-ATO and to gain a deeper understanding of the pandemic's impact on the two systems, the analysis was divided into two separate periods: (1) 2011-2019 and (2) 2019-2021.

[35] More information on the ACE project is available online: https://ansperformance.eu/economics/ace-overview/

The year 2012 marks the start of the Single European Sky (SES) performance scheme in Europe while in the U.S. the FAA Modernization and Reform Act of 2012 was signed into law. Both initiatives are expected to have a bearing on cost-efficiency performance in the first analysis period (2011-19).

The impact of the COVID-19 crisis on both systems is then analysed by comparing 2021 to the pre-crisis results in 2019.

Evolution of cost-efficiency drivers

Figure 4-17 shows the trends in the main components of the cost-efficiency KPI for the U.S. FAA-ATO (orange) and the European States subject to the third reference period of the SES performance scheme (blue). Furthermore, the main drivers affecting the changes in the unit ATM/CNS provision costs between 2011 and 2019 are shown as complementary information.

Between 2011 and 2019, the main cost-efficiency KPI - ATM/CNS provision costs per IFR flight-hour controlled- reduced significantly in both the SES States (-14.4%) and the U.S. (-18.4%).

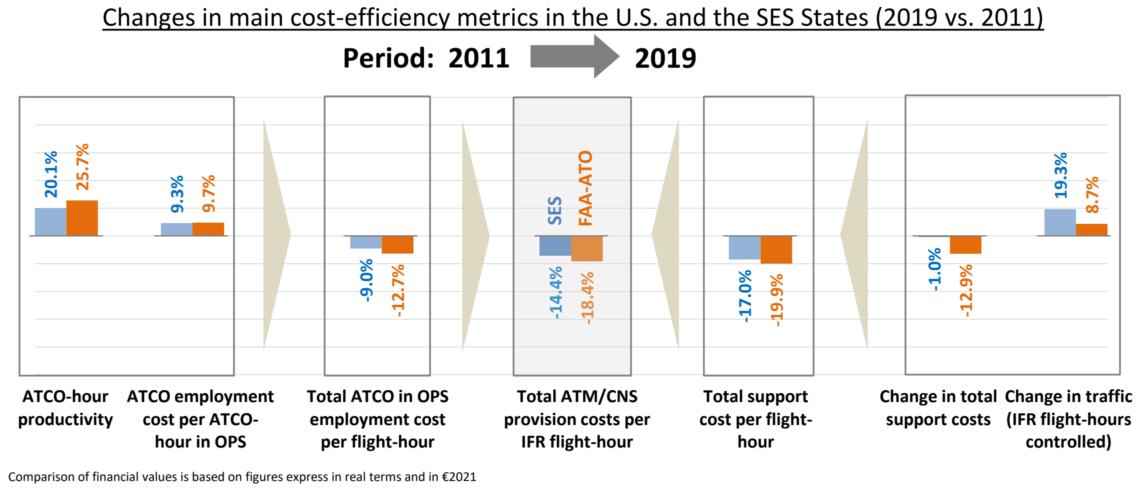


Figure 4-17: Changes in main cost-efficiency metrics in the U.S. and the SES States (2011-2019)

The notable enhancement in cost-efficiency within the U.S. primarily stemmed from a substantial decrease in support costs (-12.9% compared to 2011). This reduction, combined with robust traffic growth (+8.7% compared to 2011), led to a significant decrease in support costs per flight-hour (-19.9% compared to 2011).

The increase in ATCO employment costs per ATCO-hour (+9.7% vs. 2011) was more than compensated by the increase in ATCO hour productivity (+25.7% vs. 2011), leading to a significant reduction of ATCO employment cost per IFR flight-hour (-12.7% vs. 2011).

In Europe, the overall performance trends over 2011-19 period were similar to those observed in the U.S. However, the reduction in unit ATM/CNS provision costs by 14.4% between 2011 and 2019 was much more driven by the substantial growth in IFR flight-hours (+19.3% vs. 2011) and only to a much lesser extent by a reduction in total support costs (-1% vs. 2011).

It is worth highlighting that the substantial growth in ATCO-hour productivity (+25.7%) between 2011 and 2019 in the U.S. could be achieved with notably less ATCOs in OPS (-11.1% vs. 2011) and less ATCO-hours on duty (-13.5% vs. 2011). In SES States, ATCO hour productivity also increased substantially between 2011 and 2019 (+20.1% vs 2011) but as a result of continuously increasing traffic levels which were served by a relatively stable number of ATCOs in OPS (+1.8% vs. 2011) and hours on duty (-0.7% vs. 2011).

To better capture the impact of COVID-19 pandemic on the two systems, Figure 4-18 shows the breakdown of cost-efficiency changes between 2019 and 2021.

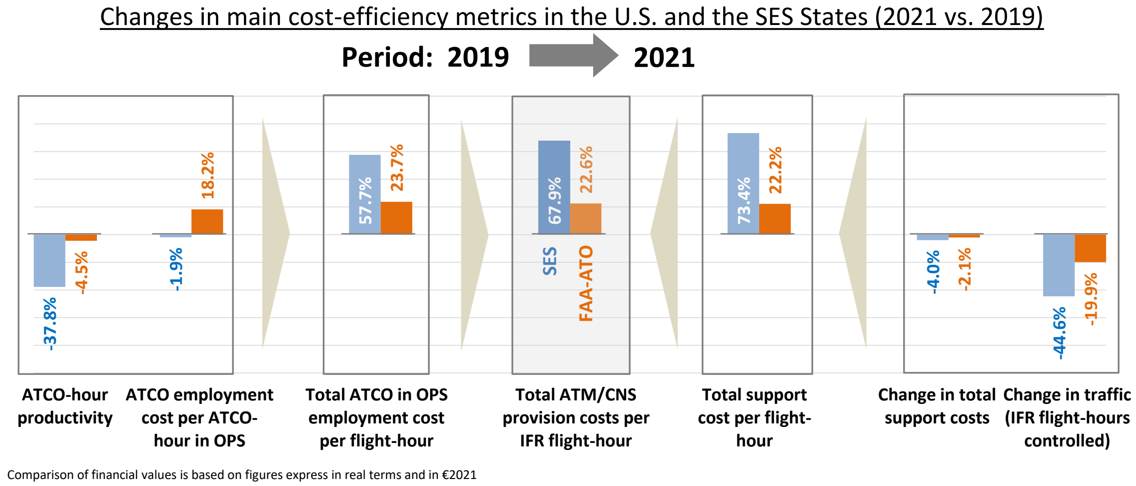


Figure 4-18: Changes in main cost-efficiency metrics in the U.S. and the SES States (2019-2021)

Following the collapse of traffic levels between 2019 and 2021, the SES States reacted by implementing a range of cost-saving measures which resulted in a -7.0% reduction in total ATM/CNS provision costs. These substantial savings, however, were not sufficient to compensate for the dramatic reduction in IFR flight-hours (-44.6%) which led to a substantial increase in ATM/CNS provision costs per IFR flight-hour (+67.9%) in 2021.

The sudden drop in traffic levels also had a considerable effect on ATCO-hour productivity in Europe which, despite a significant reduction in total ATCO in OPS hours on duty (-11.0%), decreased substantially (-37.8%), further widening the observed gap in productivity between Europe and the U.S.

It is worth highlighting that the combination of cost-saving measures also affecting ATCO in OPS employment costs and the reduction of ATCO in OPS hours on duty resulted in a -1.9% decrease in ATCO employment costs per hour in SES States.

In the U.S., the ATM/CNS provision costs per IFR flight-hour in 2021 increased by +22.6% compared to 2019. Although this is a high increase compared to 2019, it was much lower than the increase in Europe (+67.9%). The better cost-efficiency performance in the U.S. the result of a -1.8% reduction in total ATM/CNS provision costs supported by a notably lower traffic reduction compared to Europe following the COVID-19 outbreak in 2020.

Additionally, the U.S. notably reduced the total ATCO in OPS hours on duty in 2021 (-16.1% vs. 2019) which helped to keep relatively high ATCO-hour productivity levels (-4.5% vs. 2019) despite traffic levels still lower than before the pandemic. The reduction in ATCO in OPS hours on duty combined with relatively stable ATCO in OPS employment costs (-0.9% vs. 2019) nonetheless resulted in a significant overall increase in ATCO employment costs per hour on duty in the U.S. in 2021 (+18.2%).

Results of main cost-efficiency metrics in 2021

Figure 4-19 provides a direct comparison of key cost-efficiency performance indicators between the SES States and the U.S. in 2021. As indicated before, the indicators for 2021 are heavily influenced by the effects of COVID-19 crisis.

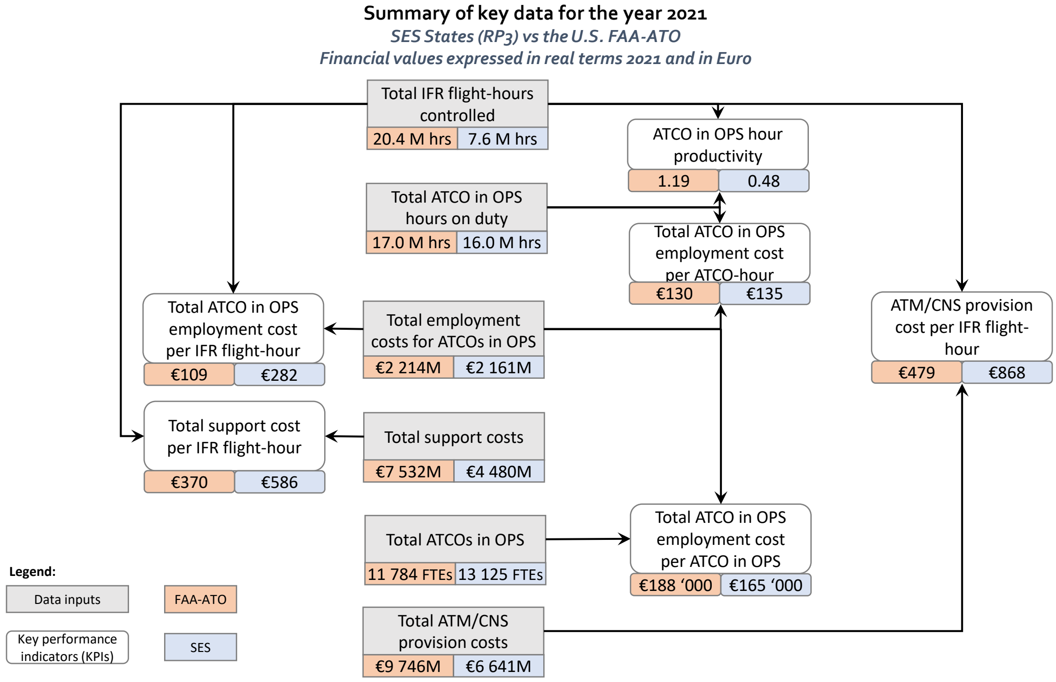


Figure 4-19: Summary of main cost-efficiency results for 2021

Previous comparisons of Air Navigation Service (ANS) cost-efficiency between the SES States and the U.S. had already highlighted that ATM/CNS provision costs per flight-hour were significantly lower in the United States, with provision costs per flight-hour being approximately 81% higher in the SES States in 2021.

Even though the overall ATM/CNS provision costs in the SES States were approximately 32% lower than those in the U.S., the notable difference in unit costs between the two regions was primarily driven by the fact that the SES States managed roughly 62% less traffic in 2021.

In the SES States, the significant factors contributing to the observed gap in cost-efficiency performance compared to the U.S. include notably lower ATCO-hour productivity (-60% compared to the U.S.), along with considerably higher ATCO employment costs per flight-hour controlled (+160% compared to the U.S.) and higher unit support costs (+58% compared to the U.S.).

While historically the employment costs per ATCO in OPS have been lower in the SES States (-12% vs. U.S. in 2021), when taking into consideration the differences in cost of living between Europe and the U.S., the ATCO unit employment costs become comparable (+1% vs. U.S. in 2021).

Conversely, as a result of measures implemented by the SES ANSPs and the FAA-ATO in response to the COVID-19 pandemic, there has been a significant reduction in the disparity of the total time spent by ATCOs directly involved in ATC activity (referred to as total ATCO in OPS hours on duty) between Europe and the U.S. This gap has diminished considerably, decreasing from 23% lower total ATCO-hours on duty in the SES as compared to the U.S. in 2011 to 6% lower in 2021.

As documented in the relevant sections of this report, areas for improvements in terms of data reporting have been identified during the preparation of this document. The proper identification and capturing of certain elements could help to improve the cost-efficiency comparison of the U.S. and European ANS systems going forward.

5 Emerging themes for future research

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.

Building on commonly agreed metrics in line with the ICAO Global Air Navigation Plan (GANP) indicators, the main operational and cost-efficiency trends and differences between the two systems have been identified and documented in several comparison reports between the U.S. and Europe.

In Europe, many operational and cost-efficiency questions revolve around the fragmentation of air navigation service provision and its impact on system-wide flow management and ATM performance and ANS provision cost. The airspace architecture in Europe, the ATM operational concept, as well as the processes and technology have not changed much and are still largely in line with national boundaries instead of operational needs and traffic flows. Although local improvements are visible at State level in Europe, there is a need to move further towards a true network-oriented approach to leverage synergies and to realise additional performance benefits (airspace interfaces, capacity provision, duplication of services, data and information flows, etc.). With very limited or no en-route support function in Europe, the air traffic flow management focuses on strategic planning (airport scheduling) and the application of departure slots to solve capacity/ demand imbalances en-route or at airports.

In the U.S., the Air Traffic Organization (ATO) is the operational arm of the FAA and responsible for providing safe and efficient air navigation services. Although there is only one service provider in the U.S., the financing and accounting is different from Europe and exact cost and staff allocation can be challenging to enable a perfect like with like comparison of cost-efficiency metrics. Operationally, there is more emphasis in the U.S. on tactical traffic management in the gate-to-gate phase to maximise throughput under prevailing conditions on the day of operations. Compared to Europe, airport demand levels are self-controlled by airlines which most likely encourages higher throughput, but which makes operations more susceptible to disruptions which potentially result in major delays and cancellations.

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

ANS operational performance

Quantify the Magnitude and Effect of Traffic Flow Initiatives: In an environment with limited capacities, any deviation from the flight plan or schedule potentially results in time penalties (i.e. delay) or an underutilization of available resources if provisions for capacity and demand variations are made in advance. When an imbalance between capacity and demand occurs, 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 utilization of scarce capacity, and the environment. More work is needed to determine how to minimize the impact of flow measures on airspace users and the environment in each flight phase while maximizing the use of scarce airport and en-route capacity. For instance, the degree to which the U.S. system currently offers more flexibility in mitigating demand/capacity imbalances using traffic flow initiatives that are coordinated across multiple en-route centres. More research is needed to understand required flexibility levels of system users and what level of "delay" in which flight phase would be necessary to maximize the use of capacity.

Quantify capacity utilization: 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. In a previous comparison report, a first view of airport arrival capacities and how they relate to peak throughput was done. In the U.S. the capacities were based on actual recorded ("called") rates whereas in Europe strategic peak arrival capacities from the airport scheduling process were used.

Although not done in this report, quantifying capacity utilization and assessing this trade-off would be a worthwhile subject for further study. The U.S. quantifies capacity utilization formally through its Terminal Arrival Efficiency Rating (TAER) measure. However, benchmarking the two systems would require a common understanding of how capacity is declared for comparable airports.

A better understanding of tactical capacities at airports but also in en-route centers would strengthen the comparison and enable a more complete assessment of flow management together with capacity utilization. This includes for instance also the impact of environmental constraints on ATM performance and runway throughput.

Factors affecting en-route flight efficiency: En-route flight efficiency is affected by a considerable number of factors involving different stakeholders. Not all factors are under the direct control of ANS (adverse weather conditions, special use airspace, etc.) but ANS has a role to play in reducing constraints to a necessary minimum while maximizing the use of airspace. In Europe, there is a high density of special use airspace in the core area of Europe which reduces flexibility in managing traffic flows. Future reports could provide some initial evaluations of those factors impacting en-route flight efficiency in each region (trade-offs, special use airspace, TMA entry points, weather impact, etc.).

Vertical flight efficiency: Vertical flight efficiency is not explicitly addressed in this comparison but is a frequent topic for discussion in various working groups. In previous reports there was an initial high-level assessment based on distance flown level in descent. More work is required to improve the assessment of vertical flight efficiency that can be attributed to ATM in the comparison report, and to develop commonly agreed indicators for the measurement of those inefficiencies.

ANS cost-efficiency

Improve Controller and Staffing Comparisons: This 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" and Certified Professional Controllers In-Training (CPC-ITs), 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). Moreover, a better understanding of working arrangements in each region (rostering practices, contractual working hours, overtime, leave, training) would be beneficial in future comparison reports. Similar investigation is also necessary to better assess the impact of contracted towers on the overall staffing level and ATCO output in the U.S. since these are not currently reflected in the analysis.

Support cost analysis and breakdown of costs: Support costs are all ATM/CNS provision costs minus ATCO in OPS employment costs. Support costs can be further broken down into support staff costs, depreciation costs, and other operating costs. Overall, support costs account for 77% of the total ATM/CNS provision costs in the U.S. and for some 68% in Europe. In view of the large share in the total ATM/CNS costs, it would be useful to better understand the main support cost drivers in the U.S. and in Europe, including a better understanding of the treatment of facilities and equipment as part of the total operating costs in each region.

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ANNEX 1 – Operational data sources

Various data sources have been used for the analyses in this report. These data sources include, inter alia, trajectory position data, ATFM imposed delay, key event times and scheduled data from airlines.

DATA FROM AIR TRAFFIC MANAGEMENT SYSTEMS

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

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

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

The data sets also provide flight trajectories which are used for the calculation of flight efficiency in terms of planned routes and actual flown routing. The data sets which include data in the en-route transitional phase and in the terminal areas allow for performance comparison throughout various phases of flight.

DATA FROM AIRLINES

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

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

In the U.S., most performance indicators are derived from the Aviation System Performance Metrics (ASPM) database which fuses detailed airline data with data from the Traffic Flow Management System (TFMS). Air carriers are required to report performance data if they have at least 1% of total scheduled-service domestic passenger revenues monthly. However, as of 2018, airlines with at least 0.5% of the total scheduled-service domestic passenger revenues are required to report performance data monthly. In addition, there are other carriers that report voluntarily. ASPM coverage is around 95% of the IFR traffic at the main 34 airports (within region) with 86% of the total IFR traffic reported as scheduled operations. Airline-reported performance data, which includes airline reported delay cause, for traffic at the main 34 airports represent around 65% of all IFR flights at these airports. This percentage (as well as the specific carriers that report) does not stay constant from reporting period to reporting period and this has some effect on the performance indicators based on OOOI data (On-Time percentage, Taxi-out, Taxi-in). However, for the study period, OOOI data was available for nearly all commercial carriers with flights to and from the U.S. through OAG.

In Europe, the Central Office for Delay Analysis (CODA) collects data from airlines each month. The data collection started in 2002 and the reporting was voluntary until the end of 2010. As of January

2011, airlines which operate more than 35 000 flights per year[36] within the European Union (EU) airspace are required to submit the data monthly according to EU Regulations [Ref. [14]].

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

ATM/TMI DELAY DATA

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

Individual flight level data is available for flights delayed due to the following Traffic Management Initiatives (TMIs): Ground Delay Programs (GDP), Ground Stops (GS), Airspace Flow Program (AFP), and Collaborative Trajectory Options Program (CTOP). These delays are reported using automation through the Air Traffic Control System Command Center (ATCSCC).

Flights delayed due to other TMIs, which include Severe Weather Avoidance Plan (SWAP), Miles-In-Trail (MIT), Departure Stop, Metering, and Departure/En-Route/Arrival Spacing Programs (DSP/ESP/ASP), are manually reported by facilities from where the aircraft departs (departure airport) [Ref. [15]]. A portion of these other TMI delays do not have a destination airport because they are recorded manually by the departure facility as a group of delayed flights. Because the destination airport is required to determine if a flight falls within the scope of this study, the U.S. CONUS area, the delays without a recorded destination airport are distributed proportionally to the share of international vs. U.S. CONUS operations at the departure airport.

ANS PERFORMANCE DATA

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

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

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

ADDITIONAL DATA ON CONDITIONS

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

36 Calculated as the average over the previous three years.

ANNEX 2 – Operations at the main 34 airports

OPERATIONS AT THE MAIN 34 AIRPORTS IN THE U.S.

USA	ICAO	IATA	COUNTRY	Avg. daily IFR departures in 2022	2022 vs. 2019
Atlanta (ATL)	KATL	ATL	United States	982	-20.3%
Chicago (ORD)	KORD	ORD	United States	963	-23.1%
Dallas (DFW)	KDFW	DFW	United States	892	-9.2%
Denver (DEN)	KDEN	DEN	United States	834	-4.0%
Los Angeles (LAX)	KLAX	LAX	United States	756	-19.7%
Charlotte (CLT)	KCLT	CLT	United States	673	-14.2%
Las Vegas (LAS)	KLAS	LAS	United States	638	3.5%
Miami (MIA)	KMIA	MIA	United States	617	9.4%
New York (JFK)	KJFK	JFK	United States	598	-2.5%
Phoenix (PHX)	KPHX	PHX	United States	555	-5.1%
Seattle (SEA)	KSEA	SEA	United States	545	-11.1%
Houston (IAH)	KIAH	IAH	United States	542	-16.9%
Newark (EWR)	KEWR	EWR	United States	542	-10.1%
Boston (BOS)	KBOS	BOS	United States	512	-11.8%
Orlando (MCO)	KMCO	MCO	United States	494	-0.5%
New York (LGA)	KLGA	LGA	United States	481	-4.9%
San Francisco (SFO)	KSFO	SFO	United States	475	-22.9%
Minneapolis (MSP)	KMSP	MSP	United States	421	-23.9%
Salt Lake City (SLC)	KSLC	SLC	United States	403	-4.9%
Washington (DCA)	KDCA	DCA	United States	401	-0.3%
Detroit (DTW)	KDTW	DTW	United States	387	-28.6%
Philadelphia (PHL)	KPHL	PHL	United States	383	-27.6%
Ft. Lauderdale (FLL)	KFLL	FLL	United States	370	-15.0%
Washington (IAD)	KIAD	IAD	United States	368	-12.1%
Nashville (BNA)	KBNA	BNA	United States	326	7.5%
Dallas Love (DAL)	KDAL	DAL	United States	306	-0.3%
Baltimore (BWI)	KBWI	BWI	United States	296	-16.7%
Memphis (MEM)	KMEM	MEM	United States	287	-7.4%
San Diego (SAN)	KSAN	SAN	United States	281	-9.8%
Chicago (MDW)	KMDW	MDW	United States	281	-9.1%
Tampa (TPA)	KTPA	TPA	United States	277	-2.3%
Houston (HOU)	KHOU	HOU	United States	240	-6.5%
Portland (PDX)	KPDX	PDX	United States	231	-26.9%
St. Louis (STL)	KSTL	STL	United States	212	-18.7%
Average (M34)				487	-12.0%

OPERATIONS AT THE MAIN 34 AIRPORTS IN EUROPE[37]

EUROPE	ICAO	IATA	COUNTRY	Avg. daily IFR departures in 2022	2022 vs. 2019
Istanbul (IST)	LTFM	IST	Türkye	578	1.3%
Amsterdam (AMS)	EHAM	AMS	Netherlands	570	-18.3%
Paris (CDG)	LFPG	CDG	France	561	-18.9%
Frankfurt (FRA)	EDDF	FRA	Germany	523	-25.6%
London (LHR)	EGLL	LHR	United Kingdom	521	-20.4%
Madrid (MAD)	LEMD	MAD	Spain Continental	482	-17.5%
Barcelona (BCN)	LEBL	BCN	Spain Continental	388	-17.7%
Munich (MUC)	EDDM	MUC	Germany	386	-31.9%
Palma (PMI)	LEPA	PMI	Spain Continental	302	1.4%
London (LGW)	EGKK	LGW	United Kingdom	298	-23.6%
Rome (FCO)	LIRF	FCO	Italy	291	-31.4%
Dublin (DUB)	EIDW	DUB	Ireland	290	-11.2%
Zurich (ZRH)	LSZH	ZRH	Switzerland	289	-21.6%
Athens (ATH)	LGAV	ATH	Greece	284	-6.0%
Oslo (OSL)	ENGM	OSL	Norway	282	-18.4%
Vienna (VIE)	LOWW	VIE	Austria	280	-27.5%
Lisbon (LIS)	LPPT	LIS	Portugal	278	-8.3%
Copenhagen (CPH)	EKCH	CPH	Denmark	277	-23.2%
Paris (ORY)	LFPO	ORY	France	272	-10.3%
Milan (MXP)	LIMC	MXP	Italy	256	-20.2%
London (STN)	EGSS	STN	United Kingdom	241	-11.4%
Brussels (BRU)	EBBR	BRU	Belgium	239	-24.0%
Stockholm (ARN)	ESSA	ARN	Sweden	233	-26.9%
Berlin (BER)	EDDB	BER	Germany	222	-42.5%
Geneva (GVA)	LSGG	GVA	Switzerland	213	-13.1%
Warsaw (WAW)	EPWA	WAW	Poland	198	-25.4%
Dusseldorf (DUS)	EDDL	DUS	Germany	192	-37.8%
Malaga (AGP)	LEMG	AGP	Spain Continental	191	-1.0%
Nice (NCE)	LFMN	NCE	France	185	-7.3%
Helsinki (HEL)	EFHK	HEL	Finland	182	-31.8%
Cologne (CGN)	EDDK	CGN	Germany	162	-15.7%
London (LTN)	EGGW	LTN	United Kingdom	161	-16.4%
Hamburg (HAM)	EDDH	HAM	Germany	141	-31.1%
Bucharest (OTP)	LROP	OTP	Romania	139	-17.2%
Average (M34)				297	-19.8%

[37] Although they are within the main 34 airports in terms of traffic in Europe, Istanbul (SAW), Antalya (AYT) and Manchester (MAN) airports were not included in the analysis due to data availability issues.

ANNEX 3 – European ANSPs included in the comparison

	ANSP	Country
1	Albcontrol	Albania
2	ANS CR	Czech Republic
3	ARMATS	Armenia
4	Austro Control	Austria
5	Avinor	Norway
6	BULATSA	Bulgaria
7	Croatia Control	Croatia
8	DCAC Cyprus	Cyprus
9	DFS	Germany
10	DHMİ	Türkiye
11	DSNA	France
12	EANS	Estonia
13	ENAIRE	Spain
14	ENAV	Italy
15	Fintraffic ANS	Finland
16	HASP	Greece
17	HungaroControl	Hungary
18	IAA	Ireland
19	LFV	Sweden
20	LGS	Latvia
21	LPS	Slovak Republic
22	LVNL	Netherlands
23	MATS	Malta
24	M-NAV	North Macedonia
25	MOLDATSA	Moldova
26	MUAC	
27	NATS	United Kingdom
28	NAV Portugal	Portugal
29	NAVIAIR	Denmark
30	Oro Navigacija	Lithuania
31	PANSA	Poland
32	ROMATSA	Romania
33	skeyes	Belgium
34	Skyguide	Switzerland
35	Slovenia Control	Slovenia
36	SMATSA	Serbia Montenegro

(shaded)	States covered by the SES Regulations
	States not covered by the SES Regulations

ANNEX 4 – Methodology - economic comparison

6.1 DEFINITIONS OF KEY DATA

ATCO in OPS (i.e. ATCO on operational duty) refers to an ATCO who is participating in an activity that is either directly related to the control of traffic or is a necessary requirement for an ATCO 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.

Support staff refers to total staff other than ATCOs in OPS. These figures include ATCOs which are not working on operational duties in the OPS room (e.g. on special projects outside the OPS room). As detailed in section 4.2.1, for FAA-ATO support staff also includes some operational staff engaged in ATC activities (i.e. traffic management coordinators, controllers, inflight services, developmentals and CPC-IT, Oceanic ATCOs).

ATCOs in OPS employment costs comprise the gross wages and salaries, payments for overtime, employers' contributions to any social security scheme, taxes directly levied on employment, employers' pension contributions and the costs of other benefits.

Total ATCO in OPS hours on duty refer to the total actual number of hours spent by ATCOs in OPS on duty in OPS, including breaks and including overtime in OPS**.** Since the FAA-ATO reports average working hours per ATCO in its data submission, the total ATCO in OPS hours on duty are derived as a product of continental ATCOs in OPS and average working hours per ATCO.

More details on the definitions of key data are available in the EUROCONTROL Specification for Economic Information Disclosure v3.0 [13].

6.2 INFLATION, EXCHANGE RATES AND PPP DATA

The costs for FAA-ATO and European (including the SES States) ANSPs are expressed in real terms using the Consumer Price Index (CPI) deflator for each year of the analysis. Inflation figures for Europe are in line with those published by EUROSTAT, while, for ANSPs for which EUROSTAT data are not available, IMF figures are used. For FAA-ATO, the IMF inflation figures are used.

Since the ANSPs (incl. FAA-ATO) provide their data to the Performance Review Unit of EUROCONTROL in national currency, the exchange rates are used to express the financial data in common currency (Euro) for the purposes of this analysis. For the European ANSPs, the exchange rates of the year of the analysis (i.e. 2021) are used to express the figures in €2021 and are in line with those used for charging purposes. ANSP level exchange rate data can be found on Annex 4 of the ACE Benchmarking Report (May 2023 edition) [9].

Similar methodology is applied to convert the European ANSP figures in Purchasing Power Standard (PPS) using the purchasing power parity (PPP). The PPP figures are sourced from EUROSTAT, while, for ANSPs for which EUROSTAT data are not available, IMF figures are used with the PPPs derived using a common conversion factor between these two data sources. More details on this methodology as well as the detailed PPP figures are available on Annex 4 of the ACE Benchmarking Report (May 2023 edition) [9].

The exchange rates, purchasing power parities and methodology used to convert the FAA-ATO figures to real €2021 are described in detail in section 4.2.3 of this report.

Further details on the treatment of financial data for European (incl. the SES States) ANSPs can be found in the ACE Benchmarking Report (May 2023 edition) [9] and ACE Benchmarking Handbook [8].

ANNEX 5 – Summary of key cost-efficiency data

U.S. FAA-ATO		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
Flight Hours		23.4 M	23.0 M	22.8 M	22.9 M	23.4 M	23.8 M	24.2 M	24.9 M	25.4 M	19.0 M	20.4 M	
ATCOs in OPS		13,270	13,482	13,209	12,953	12,530	12,168	11,957	11,927	11,800	11,959	11,784	
Other Staff		21,705	21,115	20,697	19,264	19,797	20,178	20,487	20,156	19,792	19,843	19,897	
Total staff		34,974	34,597	33,906	32,217	32,326	32,346	32,444	32,083	31,592	31,802	31,681	
Total ATM/CNS provision cost	nominal	11224 M$	10924 M$	10766 M$	10939 M$	10602 M$	10776 M$	10915 M$	11138 M$	11326 M$	11444 M$	11789 M$	
US Inflation rate (IMF)		3.1%	2.1%	1.5%	1.6%	0.1%	1.3%	2.1%	2.4%	1.8%	1.3%	4.7%	
Total ATM/CNS provision cost	$ 2021	13522 M$	12893 M$	12523 M$	12522 M$	12121 M$	12166 M$	12066 M$	12019 M$	12005 M$	11980 M$	11789 M$	Avg. 2011-2021
€/US$ exchange rates (EUROSTAT)		1.39	1.28	1.33	1.33	1.11	1.11	1.13	1.18	1.12	1.14	1.18	1.21
2021 prices using avg. €/US$ exchange rate of 1.21													
Total ATM/CNS provision cost	€ 2021	11179 M	10659 M	10353 M	10352 M	10021 M	10059 M	9976 M	9937 M	9925 M	9904 M	9746 M	
per flight hour		478	464	454	452	428	423	413	399	390	521	479	
Total support cost	€ 2021	8826 M	8206 M	7924 M	7926 M	7594 M	7681 M	7681 M	7676 M	7691 M	7642 M	7532 M	
per flight hour		378	357	348	346	324	323	318	308	303	402	370	
ATCO employment cost	€ 2021	2354 M	2453 M	2430 M	2427 M	2427 M	2378 M	2295 M	2261 M	2234 M	2263 M	2214 M	
per flight hour		101	107	107	106	104	100	95	91	88	119	109	Avg. 2011-2021
Purchasing Power Parities EU27=1 (EUROSTAT)		1.32	1.34	1.36	1.37	1.37	1.41	1.42	1.43	1.47	1.48	1.46	1.40
2021 prices using avg. PPP conversion rate of 1.40													
Total ATM/CNS provision cost	PPS	9641 M	9192 M	8928 M	8927 M	8642 M	8674 M	8603 M	8569 M	8559 M	8541 M	8405 M	
per flight hour		412	400	392	390	369	364	356	344	337	449	413	
Total support cost	PPS	7611 M	7077 M	6833 M	6835 M	6549 M	6623 M	6623 M	6620 M	6633 M	6590 M	6495 M	
per flight hour		326	308	300	298	280	278	274	266	261	347	319	
ATCO employment cost	PPS	2030 M	2115 M	2095 M	2093 M	2093 M	2051 M	1979 M	1949 M	1926 M	1951 M	1909 M	
per flight hour		87	92	92	91	89	86	82	78	76	103	94	

EUROPE (36 ANSPs)		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Flight Hours		14.1 M	13.8 M	13.9 M	14.4 M	14.7 M	15.2 M	15.9 M	16.9 M	17.2 M	7.4 M	9.5 M
ATCOs in OPS		16,243	16,403	16,566	16,691	16,738	16,982	17,063	16,879	17,008	16,753	16,552
Other Staff		35,628	35,529	35,075	33,397	33,369	32,964	33,239	33,959	34,792	34,976	34,393
Total staff		51,871	51,932	51,641	50,089	50,106	49,945	50,302	50,838	51,800	51,729	50,945
Total ATM/CNS provision cost	€ 2021	8069 M	8077 M	7897 M	7920 M	8024 M	8076 M	8143 M	8212 M	8391 M	8179 M	7693 M
per flight hour		572	584	569	550	545	532	511	486	486	1,105	813
Total support cost	€ 2021	5497 M	5529 M	5349 M	5323 M	5366 M	5353 M	5378 M	5437 M	5581 M	5504 M	5198 M
per flight hour		390	400	385	370	364	353	337	322	324	744	549
ATCO employment cost	€ 2021	2572 M	2547 M	2548 M	2597 M	2659 M	2723 M	2765 M	2775 M	2810 M	2674 M	2495 M
per flight hour		182	184	184	180	180	180	173	164	163	361	264
Total ATM/CNS provision cost	PPS	8275 M	8292 M	8108 M	8219 M	8357 M	8493 M	8598 M	8750 M	8978 M	8652 M	8210 M
per flight hour		587	599	584	571	567	560	539	518	520	1,169	867
Total support cost	PPS	5684 M	5733 M	5525 M	5574 M	5634 M	5688 M	5725 M	5847 M	6034 M	5847 M	5604 M
per flight hour		403	414	398	387	382	375	359	346	350	790	592
ATCO employment cost	PPS	2592 M	2559 M	2583 M	2645 M	2723 M	2805 M	2873 M	2904 M	2943 M	2805 M	2606 M
per flight hour		184	185	186	184	185	185	180	172	171	379	275

Single European Sky States (RP3)		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Flight Hours		11.6 M	11.3 M	11.3 M	11.6 M	11.8 M	12.2 M	12.8 M	13.5 M	13.8 M	6.0 M	7.6 M
ATCOs in OPS		13,415	13,512	13,566	13,611	13,600	13,792	13,804	13,608	13,661	13,342	13,125
Other Staff		26,591	26,367	25,762	24,491	24,294	23,925	23,964	24,466	24,947	25,417	25,184
Total staff		40,006	39,879	39,328	38,101	37,894	37,718	37,768	38,074	38,607	38,759	38,309
Total ATM/CNS provision cost	€ 2021	6991 M	6980 M	6746 M	6815 M	6839 M	6866 M	6955 M	6997 M	7139 M	6922 M	6641 M
per flight hour		604	618	599	588	579	564	545	518	517	1,159	868
Total support cost	€ 2021	4712 M	4733 M	4503 M	4540 M	4516 M	4479 M	4524 M	4557 M	4665 M	4589 M	4480 M
per flight hour		407	419	400	392	383	368	355	338	338	769	586
ATCO employment cost	€ 2021	2279 M	2247 M	2244 M	2275 M	2323 M	2387 M	2431 M	2440 M	2474 M	2333 M	2161 M
per flight hour		197	199	199	196	197	196	191	181	179	391	282
Total ATM/CNS provision cost	PPS	6893 M	6892 M	6653 M	6766 M	6786 M	6845 M	6934 M	7022 M	7162 M	6844 M	6556 M
per flight hour		595	610	591	584	575	562	544	520	519	1,146	857
Total support cost	PPS	4646 M	4682 M	4438 M	4512 M	4471 M	4467 M	4501 M	4569 M	4679 M	4513 M	4412 M
per flight hour		401	414	394	389	379	367	353	339	339	756	577
ATCO employment cost	PPS	2247 M	2210 M	2215 M	2254 M	2314 M	2378 M	2433 M	2453 M	2483 M	2331 M	2143 M
per flight hour		194	196	197	194	196	195	191	182	180	390	280

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