TRANSNAV
http://www.transnav.eu
the International Journal
on Marine Navigation
and Safety of Sea Transportation
Volume 19
Number 2
June 2025
DOI: 10.12716/1001.19.02.28

Air Traffic Management in Europe – History and Challenges Ahead

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ABSTRACT: The European Air Traffic Management network has shown remarkable growth over the past decade, driven by increased air traffic, population purchasing power, and sector advancements. However, the sector faces challenges, resulting in rising delays and capacity constraints, which have impacted its efficiency. The paper analyses the growth and actual status of air traffic management in Europe. The study draws on historical and forecasted data to assess actual status and future challenges, using information sourced from Operations reports, Aviation Outlook reports and economic forecasts. The aviation sector plays a vital role in driving economic growth, creating jobs, and supporting global trade, but is highly sensitive to geopolitical situations and trade tensions. In recent years, volumes have been on unprecedented levels. Looking ahead, the European ATM market is projected to continue growing, thus long–term investments and strategic planning will be essential to address potential inefficiency. The growth of European flights is heavily influenced by the maximum capacity available at airports. Forecasts indicate up to million flights may be unaccommodated in 2050 [2]. Despite the current slowdown, the aviation sector is still anticipated to experience significant growth, although it will face ongoing challenges related to capacity limitations, uncertainty, and evolving market conditions. Key factors contributing to ATFM delays within the scope of air traffic management are ATC staffing, ATC capacity and airport capacity. The only way to overcome capacity limitations is improved navigation infrastructure, which can increase the ability to accommodate a larger number of flights.

1 INTRODUCTION

The European ATM Network´s performance has reached unprecedented levels over the past decade, mainly due to the Russian invasion of Ukraine and the COVID-19 pandemic in recent years. The overall positive trend in air traffic growth (average daily traffic) ranged from 0.9% to 4.4%, not considering the pandemic period [1]. In 2010, the highest ATFM delay per flight recorded 2.9 minutes, with 2 minutes of this delay attributed to en-route delay. This delay represented an 82% increase compared to 2009 [1]. The overall average delay in 2010 was cumulatively more than 51% higher compared to 2005, highlighting a long-term negative trend in air traffic management efficiency [1]. This increase could be attributed to various factors, including higher air traffic volumes, capacity constraints on controlled routes, and technical or organizational issues in air transport.

Air transport has an undeniable impact on countries' economies. Two primary measures of the aviation sector´s impact are the number of jobs it creates and its contribution to the gross domestic product (GDP), generated by direct aviation (ANSPs, manufacturers, airlines, airports, on-site business), or additional activities as supply chain and tourism activities [5]. Aviation drives global trade and

investment, enhances labor and capital productivity, and accelerates innovation. By facilitating the movement of goods, the air transport industry contributes to better economic outcomes through catalytic collaboration and increased specialization. Aviation supports the creation of an efficient and dynamic supply chain while driving the expansion of e-commerce. During a crisis and unstable geopolitical situations, air cargo delivers humanitarian aid and emergency relief. Air networks are essential for unlocking economic growth potential, empowering industries nationwide to participate in dynamic business activities. The scope of international and domestic connectivity serves as both a catalyst and a driver for generating and distributing economic benefits.

The Air Traffic Management Market in Europe is projected to experience significant growth, driven by rising demand for air travel and an increase in aircraft acquisitions by airlines in the region. The introduction of new routes and airport expansion drives the demand for advanced air traffic management systems. Eurocontrol initiatives to develop and implement comprehensive air traffic management strategies. However, the market´s long-term trajectory may encounter challenges stemming from operational issues and unforeseen factors. For the air transport market, it is essential to consider long-term forecasts due to the necessary long-term investments (ATM systems, new aircraft types, infrastructure, etc.).

Considering the goal of achieving sustainable aviation, the Eurocontrol Aviation Outlook [2] has considered factors such as the deployment of electric and hydrogen-powered aircraft or the increasing use of sustainable aviation fuels. Economic benefits of using green fuels are undeniable, as well as improved environmental performance and related increased efficiency, not only in the aviation sector. Economic model and potential benefits are described in the work [6]. Suitable development of transport is one of the EU's goals for sustainable development on a global scale. A key approach to reducing environmental impact in terms of sustainable transport development is cargo consolidation [8].

While the capacity of some European airports is considerably limited, sustainability is becoming a significant factor influencing future predictions. Similarly, it takes into account the impact of COVID-19, even though there has been a return to pre-pandemic levels. The Russian invasion of Ukraine emphasizes the importance of considering energy price inflation and economic cycles.

2 IFR MOVEMENTS FORECAST

Flights in the ECAC region doubled from 5 to 10 million a year, averaging 4% growth per year in the 20-year period from 1988 to 2007, thanks to the development of low-cost carriers, a single market, and trade expansion [2]. The following years were marked by worldwide economic crises, such as the global financial crisis (United States, 2007 – 2008) and the Eurozone crisis (2009 – 2012), resulting in a debt crisis that continued until 2013. The years 2017 and 2018 saw a solid rate increase of around 4% [2]. The growth rate eroded in 2019 when the largest European economies faced trade tensions, the slowdown in emerging markets, stagnation in manufacturing areas, uncertainty related to Brexit, and geopolitical tensions. Other events, such as the bankruptcies of some airlines or Boeing 737 MAX groundings, had a direct impact on the aviation market. The last growth rate before the pandemic represented +0,9% (2019) [1]. The COVID-19 pandemic had a profound effect on aviation and air traffic in 2020. By early March, the disruption reached unprecedented levels, compounded by ongoing travel restrictions [2].

Numerous European countries implemented stringent travel bans, border closures, and lockdowns, resulting in a 41.1% decline in flight volumes compared to 2019 [1]. The rollout of a vaccination campaign in Europe, along with the introduction of the green travel certificate, accelerated the region's recovery. The recovery from the pandemic continued throughout 2022, with 9.3 million flights, accounting for 83% of the 2019 flight volume [2]. The Russian invasion of Ukraine and its impact on airspace led to significant deviations from standard flight routes. European aviation recovery continued throughout 2023, with a reported growth of 9.9% compared to 2022. However, the Russian invasion of Ukraine continued to pose significant challenges [1] [2].

Historical annual growth rates averaged 4% between 1960 and 2009 but slowed to approximately 3% when accounting for the impact of the global financial crisis over the extended period from 1960 to 2019 [2]. As stated, the contribution to GDP (Gross Domestic Product) is one of the factors that indicates transport´s impact on the economy. Economic growth is the most important factor influencing the growth of air transport. Based on historical data, we can see the correlation between GDP growth and IFR growth, demand for air travel followed a decline, and the growth of economic cycles. Eurocontrol Aviation Outlook 2050 provides 3 scenarios for future growth. The base and the most likely scenario predict 15.4 million flights in 2050, with an average growth of 1.6% yearly, representing an increase of 52% (compared to 2023) [2].

Table 1. ECAC – IFR movements forecast [2]

ECAC	IFR Movements						
	2023		2050			2050/2019	
	Total (million)	Avg. Daily (thousands)	Total (million)	Avg. daily (thousands)	Extra flights/day (thousands)	Total growth	AAGR
High scenario	10.1	27.8	18.0	49.4	5.9	+78%	+2.2%
Base scenario			15.4	42.1	0.9	+52%	+1.6%
Low scenario			12.2	35.5	0.9	+20%	+0.7%

One of the most important factors that has a significant impact on flight growth is the maximum capacity available at several airports. Due to the COVID-19 pandemic and related uncertainty, several airports have revised their previous forecasts, focusing on short-term rather than long-term forecasts. Flight growth in Europe is projected to lag 14 years behind the long-term forecast published before the COVID-19 pandemic. Despite the current slowdown, significant growth is still anticipated, though challenges remain [2].

Now, predictions in the base scenario expect exceeded capacity by 1.1 million non-accommodated flights in 2050, representing 7% of total demand. In the high scenario, unaccommodated flights climbed to 3 million flights, which represents 14% of the total demand that would not be fulfilled [2]. The most likely impacted airports would be those in Norway, Portugal, Sweden, and the UK, representing a gap of less than 50,000 flights unaccommodated; the Netherlands with less than 200,000 flights; and Spain and Turkey with more than 200,000 unaccommodated flights. The base scenario counts capacity gaps in nine countries, while the high scenario predicts sixteen countries [2].

3 ECONOMIC FORECAST

The European Union forecasts a 1,5% GDP growth, driven by rising consumption and a rebound in investment following the 2024 contraction. In 2026, economic activity is expected to grow by 1,8%, driven by sustained demand expansion. The euro area is projected to follow a similar trend, with growth reaching 1,3% (2025) and 1,6% (2026) [3]. The European Union has been particularly impacted by the Russian invasion of Ukraine, which drove up energy prices. While the escalating conflict in the Middle East has had a limited effect so far, risks of global oil and gas supply disruptions are rising again. Meanwhile, sluggish innovation and weak business dynamism, combined with aggressive financial tightening, resulted in stagnation in the period 2022 – 2023 [3].

The labour market generated jobs for 750K workers and continued to recover; monetary policy ensured a decline in inflation. However, economic forecast remains uncertain, Russia´s protracted war and the Middle East conflict continue vulnerability to energy security. As measured by the European Commission´s consumer survey, high inflation continues to influence consumer behavior. Although inflation has decreased significantly from October 2022, when it peaked at 11,5%, the cost of living remains elevated, especially affecting low–income consumers [3].

The global trade policy environment and interconnectedness of economies have been deteriorating in the last fifteen years, including the Global Financial Crisis, geopolitical tensions, China´s integration into the global manufacturing system, protectionist trade policies, the double shock of the energy crisis, and the pandemic. Despite these facts, the global export of services and goods kept its share of GDP at levels comparable to the pre-Global Financial Crisis peak. With the arrival of the new US government, the US administration imposed 25% tariffs on EU imports of industrial steel and aluminium and their derivative products. In response, the EU Commission has launched countermeasures on US imports. Total bilateral trade in 2023 represented 851€ billion - 503€ billion of goods exported to the US and 347€ billion imported, meaning a surplus of 157€ billion for the EU [3] [4].

However, bilateral trade in services was worth 746€ billion; the EU imported 427€ billion of services while exporting 319€ billion to the US, resulting in a deficit of 109€ billion for the EU. The EU Commission responded in two steps, allowing the suspension of the existing 2018 and 2020 countermeasures against the US to expire on April 1st, which targets a range of products (representing 8€ billion), and a new package of countermeasures on exports worth 18€ billion[3] [4]. In total, countermeasures could target US goods exports valued at up to €26 billion, aligning with the economic impact of the US tariffs [4]. Unstable geopolitical situation, trade tensions, and war situation from last years showed how much global economies rely on the condition of transport. Not only US taxes, but also sanctions adopted by the European Union towards Russia and related limited gas and oil supplies, closure of Ukrainian airspace, showed the need for protection of critical infrastructure, and backup supply chain directions. The approach to the analysis of transport´s critical elements is reviewed in the work [7].

As we stated, the airports most impacted according to the most probable base scenario would be airports in Turkey and the Netherlands. The measurement of transport´s impact on the economy can be performed using various methods. Key indicators for measurements are the contribution to the gross domestic product and the number of jobs generated. The economic impact of air transport in Turkey represents USD 14.3 billion of economic output (247,300 people directly employed in aviation), which is equal to 1.3% of GDP. Total contribution to GDP is USD 82.4 billion (7.4% of GDP), including wider supply chain, tourism activities, and employee spending [5].

Aviation plays a crucial role in supply chain activities and e-commerce growth - in 2023 there were transported 1.7 million tonnes of air cargo. In the Netherlands, aviation directly employs 111,000 people, contributing USD 10.5 billion to GDP, equaling 0.9% of total GDP. The total contribution represents USD 39.9 billion of economic output (3.6% of GDP). Air cargo transported 1.4 million tonnes in 2023, supporting import and export volumes. For both countries, Europe is the largest international market for passenger flows. The cumulative growth of O-D international passenger departures over the last decades represents +31.0% from the Netherlands and 67.9% from Turkey [5].

3.1 *ATFM delay evolution overview*

Based on historical data, the largest ATFM delay per flight was recorded in 2010 (2,9 min). This overall delay represents an increase of 82% compared to 2009 and a cumulative deviation of more than 51% compared to 2005. Another significant increase occurred in 2018 (2.33 min) with a 97% increase of en-route delay (1.73 min) [1]. A paradox is that the traffic volume was 13% lower than in the previous year. 1.3 million flights were delayed, with a third of them having a delay of more than 15 minutes. The main causes of delays on the route were ATC capacity, weather, and ATC human resources. Despite a slight improvement in 2019, the level of overall delay remained high [1].

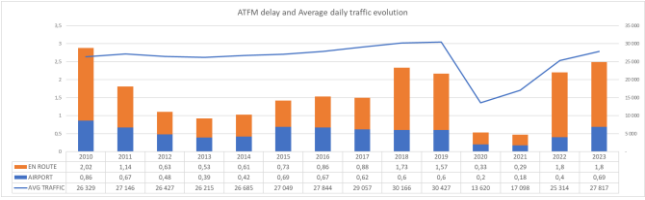

Figure 1. ATFM delay and average daily traffic evolution (work of authors)

The biggest contributors to route delays between 2010 and 2014 were en-route ATC capacity and airport weather in the case of airport/TMA ATFM delays. Between 2015 and 2023, the biggest contributors remained en-route ATC capacity, en-route weather, airport weather, en-route ATC staffing, and airport capacity, as shown in the distribution below. Based on the presented analyses, we can say that the main contributors to ATFM delays, which we can influence within air traffic, are ATC capacity, ATC human resources, and airport infrastructure.

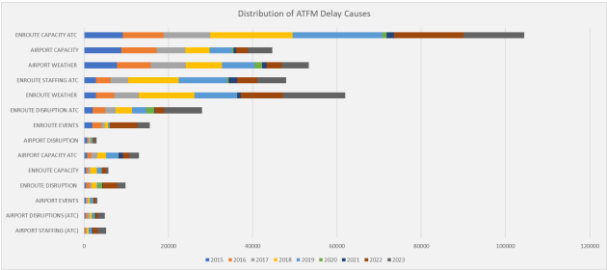

Figure 2. Distribution of ATFM delay causes (work of authors)

3.2 *Average daily airport delay evolution*

Analysing the top 5 ranking for average delay traffic among the airports over the past years, we can observe 4 airports that regularly appear, with only their ranking positions changing. Airports with the main average daily traffic are Istanbul (LTFJ), Amsterdam Schiphol (EHAM), London Heathrow (EGLL), Frankfurt (EDDF), and Paris Charles de Gaulle (LFPG). The top rankings for the highest daily average airport delays are assigned to Amsterdam Schiphol (EHAM). Based on historical data, Amsterdam Schiphol (EHAM) appears in total of 6 times over the period 2013 – 2023 in the top position with the highest average delay traffic, as shown in the rating [1].

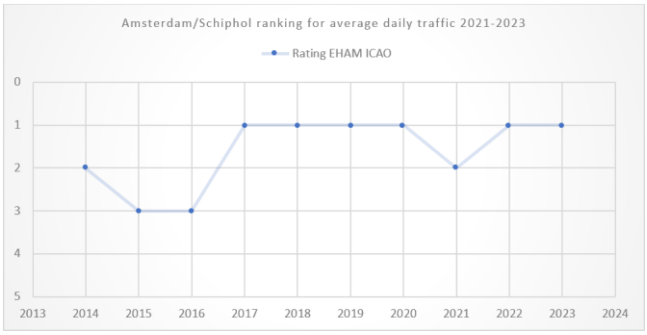

Figure 3. Amsterdam/Schipol ranking for average daily traffic 2021-2023 (work of authors)

The next highest positions were taken by airports in regions of Turkey, followed by Lisbon, Portugal, and the UK airports, Gatwick and Heathrow.

Amsterdam Schiphol Airport ranked in 1st position for average daily delay for almost 7 consecutive years. The main contributors to the en route average delay per flight in the summer period in recent years were ATC capacity, followed by weather and special events.

Table 2. Average daily delay rating – Airports 2014 – 2023 (work of authors)

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Amsterdam Schiphol (EHAM)	2	3	3	1	1	1	1	2	1	1
Athens International / Eleftherios Venizelos (LGAV)						5		1	5	5
Barcelona (LEBL)					2					
Berlin International (EDDB)								5		
Franfurt/Main (EDDF)	5									
Iraklion Nikos Kazantzakis (LGIR)								3		
Istanbul Sabiha Gökcen (LTFJ)			1	2						
Istanbul/Ataturk (LTBA)	3	2	2	3	5					
Istanbul/Sabiha Gökcen (LTFJ)		1								
Lisbon (LPPT)					3	2	3		2	2
London Gatwick (EGKK)			5	5		4			3	3
London/Heathrow (EGLL)	1	4	4	4	4	3	2			
Madrid (LEMD)							4			
Paris / Orly (LFPO)							5			
Paris Orly (LFPO)									4	4
Porto (LPPR)								4		
Zurich (LSZH)	4	5								

4 NEW TRENDS IN ATM

As stated, ATC capacity, ATC staff, and airport infrastructure are significant challenges for European air traffic management nowadays. Several measures have been implemented and are ongoing for increasing efficiency. Navigation infrastructure and emerging technologies are crucial for enhancing the already constrained airspace capacity. New approaches are described in the works [9] [11].

4.1 *A – CDM Airport collaborative decision making*

A – CDM was developed based on the American concept introduced in 1998 to decrease capacity reductions. In experimental phases, delays were reduced by 15%. European A–CDM trials were conducted in 2000 at several airports to develop the concept for Europe. Partners can thus optimize their decisions in coordination with other partners to improve traffic predictability and situational awareness, taking into account constraints, preferences, current and forecasted conditions. Process is supported by the exchange of timely information along with tailored procedures, tools, and mechanisms. The core element of the concept is Information sharing between CDM partners, which is the foundation for other elements, such as turn - round process, tracking the flight from planning to take off, variable taxi time calculation, management of flight updates, pre-departure sequence [12] [13].

In 2024, in total of 33 airports were connected to the Network Manager Operations Centre (NMOC), via departure planning information (DPI). For smaller airports, which do not suffer from remarkable delays, and there is no justification for full CDM integration, is the possibility for Advanced ATC TWR, which shares a set of CDM information. Both of them, Advanced ATC TWR and A-CDM, account for 49.2 % of departure information (DPI) received by NMOC [12] [13].

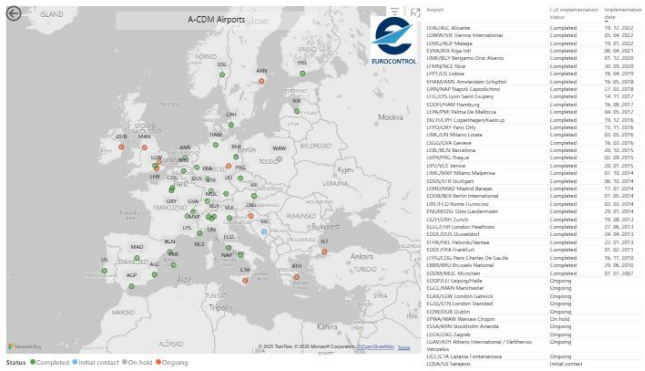

Figure 4 A-CDM implementation (Power BI, Eurocontrol) [12]

To increase regional airport coverage and connectivity, the Regional Airport Connectivity concept was developed to enhance regional airport coverage and connectivity, aiming to expand the coverage of departing flights within the ECAC area to more than 90%. Using the set of A-CDM measures in combination with ADS-B infrastructure is the concept supporting tactical planning and situational awareness.

4.2 *GBAS - Ground Based Augmentation System*

To provide an alternative to the Instrument Landing System ILS, the GBAS system was introduced. Reference antennas of the system receive signals from GPS satellites, which secure more accurate position information. The ground facility also monitors general GPS satellite performance. The operational and economic benefits of the Ground-Based Augmentation System (GBAS) were empirically proven in 2014 during a noise mitigation study conducted at Frankfurt Airport. The configuration increased the glide slope angle of 3.0°. A further technological advancement was realized in 2022 through the SESAR DREAMS project. The GBAS installation at Frankfurt was upgraded to support CAT II operational capability, expanding the system's flexibility to accommodate up to 48 distinct approach path configurations. The upgrade also allowed for an increase in glide slope angles up to 3.2°, further enhancing noise abatement and operational efficiency. The GBAS system brings more flexible flight paths, greater precision guidance, and the elimination of flight cancellations due to unsuitable weather conditions, which are, as shown previously, among the top three reasons for ATFM delays. The accuracy of the systems is the subject of several studies, including [10] [14].

5 DISCUSSION

The main drivers of Air Traffic Flow Management delays addressable within the air traffic management system are ATC staffing, ATC capacity, and airport infrastructure. Enhancing navigation infrastructure and integrating emerging technologies are essential for alleviating the already strained airspace capacity. Technologies as Airport Collaborative Decision Making and ADS–B support enhanced tactical planning and situational awareness. Major technological advances in digitalization, communication, and satellite-based systems have paved the way for transformative innovations in ATM. These developments include the centralization of specific services, the implementation of remote and virtual towers, and the concept of sector-less ATM goals. As the future moves towards 4D trajectory management, seamless airspace will become crucial. To achieve this goal, there is also a need for a change in the monopoly position of air navigation service providers and a focus on their liberalization and commercialization. Regulation (EU) No 391/20103 states the option of terminal services being subject to market conditions. For the en route services, there is no legislative framework allowing for commercial provision, due to the problematic transfer of infrastructure and concerns related to national security.

6 CONCLUSIONS

The European ATM Network has experienced remarkable performance over the past decade, significantly impacted by the Russian invasion of Ukraine and the COVID-19 pandemic. Air transport plays a vital role in driving economic growth and contributing to gross domestic product through direct and indirect activities. It enhances global trade, boosts productivity, and fosters innovation, ultimately leading to better economic outcomes. Even the European air traffic faced significant disruptions; future forecasts predict 15.4 million flights in 2050, with an average growth of 1.6%, meaning an increase of 52%, according to the base scenario. While the air traffic is poised for growth, driven by rising air travel demand and aircraft acquisitions, challenges like operational issues, capacity constraints, geopolitical tensions, trade uncertainties, and unforeseen events can impact its long-term trajectory. Predictions for 2050 reflect a potential shortfall of 1.1 million non-accommodated flights, meaning 7% of total demand.

While challenges like capacity gaps persist, especially in several European countries, the aviation sector is still anticipated to experience substantial growth. However, global economic, geopolitical tensions and protectionist policies have affected the global trade environment, which may impact the aviation sector. In conclusion, the primary contributors to ATFM delays, which can be addressed within the air traffic management system, include ATC human resources, ATC capacity, and airport infrastructure. The most impacted, according to the base scenario, are projected to be airports in the Netherlands and Turkey, which also corresponds with the average daily delay rating in the period 2014 – 2023. Particularly, the airport

Amsterdam Schiphol is expected to be the most impacted by capacity issues according to the base scenario. Amsterdam has consistently ranked among the top airports with the highest average daily delays. To address these issues, several measures, including the implementation of A-CDM, have been introduced to enhance efficiency.

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