PERSPECTIVES FOR AERONAUTICAL RESEARCH IN EUROPE

PARE

CHAPTER 2

Meeting Societal and Market Needs

Final Report

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 769220. This publication [communication] reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.

Table of Contents

Table of Contents 2

List of Figures 3

List of Tables 6

Chapter 2 – Meeting Societal and Market Needs 7

2.1. Air Traffic Capacity 7

2.1.1. Runway Capacity and Dynamic Separation 7

2.1.2. Terminal Area Airways Capacity 8

KEY TOPIC T2.1 – EVOLUTION OF THE AIR TRAFFIC CAPACITY 8

KEY TOPIC T2.2 – RELATION OF ATM WITH CAPACITY 31

2.2. Ground Infrastructure and Multimodal Transport 42

KEY TOPIC T2.3 – GROUND AND AIR OPERATIONS 42

2.3. Choice of Most Efficient Mobility Solutions 64

KEY TOPIC T2.4 – MULTIMODAL TRANSPORT 65

2.4. Overall Ground Plus Air Travel Time 89

KEY TOPIC T2.5 – AIR TRANSPORT AND OTHER MOBILITY CHOICES 89

KEY TOPIC T2.6 – OVERALL GROUND PLUS AIR TRAVEL TIME 101

KEY TOPIC T2.7 – FACTORS IN OVERALL AIR TRAVEL TIME 113

2.5. Air Traffic Management (ATM) and Weather 115

KEY TOPIC T2.8 – WEATHER EFFECTS ON AIR TRAFFIC 116

List of Figures

Figure 2.1. 90% of departures come from the largest 250 airports (2006 data). Source: Euro control Trends in Air Traffic Volume 3. A place to stand: Airports in the European network. 10
Figure 2.2. Comparison of en-route area control centers (2017). Source: 2017 Comparison of Air Traffic Management-Related Operacional Performance: U.S./Europe (FAA, EU, Eurocontrol). 13
Figure 2.3. Technological, operational and societal/human dimension of goal 1 Benchmarks 14
Figure 2.4. Traffic complexity score in 2010. Source: Performance review report 2010 Eurocontrol 16
Figure 2.5. Most congested ACC in Europe in 2010. Source: Performance review report 2010 (Eurocontrol) 16
Figure 2.6. Key data for 34 biggest European airports. Source: Comparison of ATM-related performance: U.S. – Europe, 2019 17
Figure 2.7. Actual airport throughput vs declared capacity (2017). Source: 2017 Comparison of ATM-related performance: U.S. – Europe, 2019. 17
Figure 2.8. and Figure 2.9. Weather conditions at the main 34 airports in the U.S. and Europe (2017). Source: 2017 Comparison of ATM-related performance: U.S. – Europe 18
Figure 2.10. Four air traffic scenarios of Eurocontrol 20
Figure 2.11. - IFR movements forecast for 2050. Source: Task 7: European Air Traffic in 2050 (Eurocontrol) 20
Figure 2.12. Unaccommodated demand by local airports. Source: Challenges of Growth 2013 Summary Report (Eurocontrol) 21
Figure 2.13. One day average level of congestion. Source: The effect of air traffic network congestion in 2035 (Eurocontrol) 22
Figure 2.14. High-Speed rail network. Source: Challenges of growth 2008 (Eurocontrol) 22
Figure 2.15. Mitigation Summary. Source: Task 5: Mitigation of the Challenges, Eurocontrol 23
Figure 2.16. Unaccommodated demand 2030 24
Figure 2.17. Unaccommodated demand 2050 24
Figure 2.18. Comparison of observed runway arrival throughput in low headwind and in strong headwind. Source: time-based separation factsheet, Eurocontrol 25
Figure 2.19. RECAT-EU categories. Source: http://www.eurocontrol.int/articles/recat-eu 27
Figure 2.20. Factors affecting airport efficiency 28
Figure 2.21. Implementation of Airports CDM 29
Figure 2.22. European Airports that have implemented CDM 30
Figure 2.23. Increased adoption of a A-COM at european airports 31
Figure 2.24. ADS-B diagram. Source: ICAO. 32
Figure 2.25. ADS-B Implementation Status. Source: https://ads-b-europe.eu/ 33
Figure 2.26. En route ATFM delay (RP1-RP2) (min/flight) 36
Figure 2.27. Operational ANS Performance. Source: Framework for the analysis of Operational ANS Performance at airports, Eurocontrol 37
Figure 2.28. Summary of the 2020 Performance Targets. Source: European Air Traffic Management Master Plan, Eurocontrol 39
Figure 2.29. Evolution of European IFR flights (1990-2023). Source: Eurocontrol Annual Report 2016, Eurocontrol 40

Figure 2.30. Advanced Surface Movement Guidance and Control System implementation progress. Source: ATM Master Plan monitoring, Eurocontrol 40

Figure 2.31. Free Route Airspace implementation progress. Source: ATM Master Plan monitoring, Eurocontrol 41

Figure 2.32. Comparison between investments and benefits. Source: European ATM Master Plan, Eurocontrol 41

Figure 2.33. The map of airports in Europe 44

Figure 2.34. EU-28 growth in total passenger air transport by Member State, 2017-2018 (Eurostat) 45

Figure 2.35. Overview of EU-28 air passenger transport in 2018 (Eurostat) 45

Figure 2.36. Typical six segment net flightpaths. Source: Own elaboration based on EASA, 2017 47

Figure 2.37. NOx emission by source groups (Fleuti, 2014). 48

Figure 2.38. Characterization of GSE (Fleuti, 2014) 48

Figure 2.39. Typical turn-around activities (Norin, 2008) 50

Figure 2.40. High-speed rail network mostly develops in Western Europe (Eurocontrol, 2013) 52

Figure 2.41. Airport Capacity Constraints 53

Figure 2.42. Conventional Fuel Consumption from International Aviation, 2005 to 2050, Including Potential Use of Sustainable Aviation Fuels. Source: https://www.icao.int/environmental-protection/Pages/ClimateChange_Trends.aspx 57

Figure 2.43. Net CO2 Emissions from International Aviation, 2005 to 2050, Including Sustainable Aviation Fuels Life Cycle CO2 Emissions Reductions. Source: https://www.icao.int/environmental-protection/Pages/ClimateChange_Trends.aspx 58

Figure 2.44. Full Flight NOx Emissions from International Aviation, 2010 to 2050. Source: https://www.icao.int/environmental-protection/Pages/ClimateChange_Trends.aspx 58

Figure 2.45. The European Green Deal. Source: Communication from the EC – COM (2019) 640 final - The European Green Deal. 60

Figure 2.46. Increasing number of airports with summer delay (in minutes/flight). 63

Figure 2.47. Main Delay Causes at the Top 10 Affected Departure Airports (Eurocontrol, 2017) 64

Figure 2.48. Main Delay Causes at the Top 10 Affected Arrival Airports (Eurocontrol, 2017) 64

Figure 2.49. Great-circle distance flown by departures from the biggest 528 airports in Europe. Source: Eurocontrol Trends in Air Traffic Volume 3. A place to stand: Airports in the European network 67

Figure 2.50. Departures grouped by airport size. Source: Eurocontrol Trends in Air Traffic Volume 3. A place to stand: Airports in the European network 67

Figure 2.51. Technological, operational, societal/human and network dimension of goal 2 Benchmarks 68

Figure 2.52. Evolution of airport departure delays in 2010. Source: Eurocontrol CODA Digest: Delays at Ari Transports in Europe December 2010 71

Figure 2.53. Average delay per movement (all causes) for Arrivals. Source: Eurocontrol CODA Digest: Delays at Ari Transports in Europe December 2010 71

Figure 2.54. Primary and reactionary all-cause delay, by IATA code (%). Source: Eurocontrol CODA Digest: Delays at Ari Transports in Europe December 2010 72

Figure 2.55. Drivers of departure delays (2007-2010). Source: Eurocontrol PRR 2010 73

Figure 2.56. EUROPE map of existing & planned rail connections to airports (ACI June 2012) 78

Figure 2.57. The airport network. Air Transport System 2050 Vision to Planning for Research and Innovation. EREA 84

Figure 2.58. Mitigation Measures for Traffic Capacity 85

Figure 2.59. Aurora's VTOL aircraft use eight lifting propellers for vertical take-off, and a cruise propeller and wing to transition to high-speed forward cruise ... 85

Figure 2.60. Top of an eight-story downtown parking garage converted to vertiport capable of supporting 12 VTOLs (UBER Elevate) ... 86

Figure 2.61. Joby S2 ... 86

Figure 2.62. Airbus A3 Vahana ... 86

Figure 2.63. Boeing VTOL during first flight ... 87

Figure 2.64. Possible timeline regarding VTOLs development ... 89

Figure 2.65. "Vahana" VTOL concept by Airbus ... 91

Figure 2.66. NASA's concept for a possible UTM system ... 91

Figure 2.67. Applications of small UAS (NASA UTM) ... 92

Figure 2.68. Complete UTM architecture (NASA UTM) ... 92

Figure 2.69. Madrid-Barajas Airport in 1998 and in 2008, respectively ... 93

Figure 2.70. Drivers of departure delays (2007-2010) (Eurocontrol PRR 2010) ... 94

Figure 2.71. Self-bag drop at Hong Kong Airport. Source: Introducing advanced technologies and new facilities in the airport experience, Hong Kong Airport ... 95

Figure 2.72. Different processes in Aruba Happy Flow ... 96

Figure 2.73. ECAC Standards timeline. Source: Assessing the impact of ECAC3 on baggage handling systems, BEUMER Group ... 97

Figure 2.74. Comparison of ECAC Standard 2 system with a proposed ECAC Standard 3 system. Comparison of ECAC Standard 2 system with a proposed ECAC Standard 3 system ... 97

Figure 2.75. Passengers using APC kiosks at Miami Airport ... 98

Figure 2.76. A-CDM common objectives. Source: Airport CDM Implementation Manual. Eurocontrol, ACI, IATA ... 100

Figure 2.77. A-CDM implementation progress. Source: ATM Master Plan monitoring, Eurocontrol ... 100

Figure 2.78. All European airports location (Brusow et al., 2007) ... 103

Figure 2.79. Distribution of the European airport pairs distances (Brusow et al.,2007) ... 105

Figure 2.80. Cumulative distribution function of the city distance to the nearest airport (Brusow et al., 2007) ... 105

Figure 2.81. Cumulative distribution function of the population within catchment's areas of airports and landing facilities (Brusow et al., 2007) ... 110

Figure 2.82. Budapest 60, 90, 120, and 180 minutes' drive time ... 110

Figure 2.83. Primary departure delay causes 2008 vs 2007 (Eurocontrol) ... 111

Figure 2.84. Primary Delay Causes 2015 vs. 2016 (Eurocontrol) ... 112

Figure 2.85. Breakdown of the Average Delay per Delay Q3 2016 vs. Q3 2017 (Eurocontrol) ... 113

Figure 2.86. US Weather's Share of National Aviation System (NAS) Delays in the period November, 2016 – November, 2017 (Left) and December, 2017 – September, 2018 (Right). Source: U.S. DOT Bureau of Transportation Statistics. Airline On-Time Statistics and Delay Causes. ... 117

Figure 2.87. Impact of weather conditions on flight operations in the US and Europe. Source: Comparison of ATM-related performance: U.S. – Europe, 2015 ... 118

Figure 2.88. Impact of visibility conditions on runway throughput. Source: Comparison of ATM-related performance: U.S. – Europe, 2015 ... 119

Figure 2.89. Causes of weather-related airport ATFM delays in the period 2008-2015. Source: Comparison of ATM-related performance: U.S. – Europe, 2015 ... 119

List of Tables

Table 2.1. Scope of the Goal 1 ... 9
Table 2.2. Average number of daily IFR movements at the main European airports. Source: Eurocontrol Statistics and forecasts (STATFOR) ... 11
Table 2.3. Average daily movements in the En route European Airspace. Source: Eurocontrol ANS performance monitoring (RP2, 2019) ... 12
Table 2.4. Key data for 34 biggest European airports. Source: 2010 Comparison of ATM-related performance: U.S. – Europe. ... 15
Table 2.5. Summary Estimated benefit pool actionable by ATM. Source: 2017 Comparison of ATM-related performance: U.S. – Europe ... 19
Table 2.6. ICAO wake turbulence categories and separation minima. Source: European Wake Turbulence Categorisation and Separation Minima on Approach and Departure, Eurocontrol ... 26
Table 2.7. RECAT-EU WT distance-based separation minima on approach and departure. Source: European Wake Turbulence Categorisation and Separation Minima on Approach and Departure, Eurocontrol ... 27
Table 2.8. Key performance indicators (KPI) and performance indicators (PI) as established by EU Regulation No. 390/2013 ... 34
Table 2.9. Union-wide targets for performance monitoring during reference period 2 (RP2) ... 35
Table 2.10. Top airports in the EU-28 in terms of total passengers carried in 2018 (Eurostat). ... 46
Table 2.11. European Aviation Environmental Report (EAER) Dashboard 2019 summarizing the most relevant parameters affecting environmental impact of aviation. ... 56
Table 2.12. Forecast airport congestion (SAMPLE AIRPORTS) ... 70
Table 2.13. Intra-EU traffic at country level: top-10 country pairs represent almost 40 % of 2018 intra-EU traffic (Eurostat) ... 102
Table 2.14. Summary of flight forecast for Europe (ECAC). Total traffic. (Eurocontrol) ... 102
Table 2.15. Summary of flight forecast for Europe (ECAC). Growth. (Eurocontrol) ... 102
Table 2.16. Top airports in the EU-28 in terms of total passengers carried in 2018 ... 104
Table 2.17. Airports and airfields of the 10 busiest European cities (Eurocontrol) ... 106
Table 2.18. Surface access modes to UK airports (DATASET2050) ... 106
Table 2.19. French airport surface access modes (DATASET2050) ... 107
Table 2.20. Surface access mode share for 22 German airports (DATASET2050) ... 107
Table 2.21. Driving and public transport speeds (km/h) by airport (DATASET2050) ... 108
Table 2.22. Airport accessibility by rail for the 30 largest airports in the European Economic Area + Switzerland (DLR, 2010) ... 109
Table 2.23. Ceiling and visibility criteria. Source: Comparison of ATM-related performance: U.S. – Europe, 2015 ... 117

Chapter 2 – Meeting Societal and Market Needs

This set of 5 goals concerns air traffic capacity (2.1.1), ground infrastructure (2.1.2), mobility (2.1.3), speed (2.1.4) and punctuality (2.1.5).

2.1. Air Traffic Capacity

*Flightpath 2050 goal 1: "An air traffic management system in place that provides a range of services to handle at least 25 million flights a year of all types of air vehicles, including unmanned and autonomous systems integrated into and interoperable with the overall air transport system with 24-hour operation of airports. European airspace is used flexibly to facilitate reduced environmental impact from aircraft operation".

The present chapter addresses the main issue of air traffic capacity (25 million flights per year) and flexibility of operation. The integration of unmanned and autonomous aircraft is addressed in goal 16 (section 5.3). The 24-hour operation of airports and environmental impacts are addressed in goals 9 and 10 (Chapter 4). The main issue of air transport capacity (section 2.1) concerns runway (2.1.1) and airways terminal capacity (2.1.2). Airport ground infrastructure and air traffic management are considered in goals 2 and 5 (sections 2.2 and 2.5).

2.1.1. Runway Capacity and Dynamic Separation

Most often the main limit on airport capacity is the availability of runways. The simultaneous operation of runways is permitted if they are parallel (no crossing flights) and spaced more than 400 meters (the vortex wakes of aircraft operating from one runway do not affect operations from other runways). A standard separation of 90 seconds between flights would allow 40 movements (take-off or landings) per hour from a single runway. Careful planning can increase this figure up to 60 movements per hour per runway, depending on the safe separation between aircraft, which is the critical safety factor.

The safe separation (SS) is such that the vortex wake of the leading aircraft has decayed sufficiently so that its effects are within the control power of the following aircraft. The ICAO separation table divides aircraft into "light", "medium" and "heavy" and sets SS for all 9 possible pairs: the largest separation for a light aircraft behind a heavy, and vice-versa for the shortest separation. The ICAO separation rules are empirical and have proved safe, though there are exceptions: (a) the Federal Aviation Administration (FAA) introduced a 'special' category for the Boeing 757 after some incidents showed that it did not fit into its weight category; (b) the world's largest airliner, the Airbus A380 is subject to 'super heavy' separation larger than the "heavy". During recent years, knowledge about wake vortex behaviour in the operational environment has increased due to recorded data and improved understanding of wake turbulence behaviour. As a result, EUROCONTROL has developed a re-categorisation of ICAO wake turbulence scheme and associated longitudinal separation minima on approach and departure, called "RECAT-EU". RECAT-EU is further explained on page 25.

The SS actually depends on many more factors than just aircraft weight: (i) the characteristics of the leading aircraft that determine its vortex wake; (ii) the atmospheric conditions that affect the decay of the wake until it encounters the following aircraft; (iii) the control capability of the following aircraft in overcoming the effects of the wake encounter. The maximization of runway capacity would be achieved by "dynamic separation" that sets the separation distance or time appropriate to the characteristics of each pair of aircraft and the prevailing atmospheric conditions. The use of extended separation tables with more than 3 aircraft categories is a smaller step than the full use of dynamic separation.

2.1.2. Terminal Area Airways Capacity

Besides runway capacity, the other important factor is to manage take-offs and landings with the minimum safe separation without (a) having aircraft circling above in holding patterns; (b) queuing on the ground to reach a take-off position. The landing and take-off delays are a major contributor to emissions near airports, burning fuel that also affects airline economics. The maximum use of available runway capacity requires four-dimensional space-time navigation so that successive aircraft land and take-off at precise times with the minimum safe separation. This requires not only efficient management of ground movements (goal 2 and section 2.2) but mainly efficient air traffic management (goal 5 and section 2.5) in the terminal area around airports that is the most congested. The issues to be resolved include: (i) the organization of incoming flights into a landing sequence with optimal separations; (ii) the management of the take-off sequence without waiting or idle times on the ground; (iii) the merging of the take-off (ii) and landing (i) sequences without holding patterns in the air; (iv) the compatibility of terminal area traffic (take-offs and landings) with other airways traffic. These items (i) to (iv) are among the most important aspects of Air Traffic Management (ATM) often with the greatest impact on capacity. The current airline traffic of 10 million flights per year is expected to rise to 14 million in 2025, and the goal of 25 million by 2050 is consistent with a growth rate of air transport of 2.8 % per year in Europe. Traffic forecasts vary with the region of the world and have a degree of uncertainty, and there is no doubt on the need for increased capacity to cope with traffic growth.

The evolution of the air traffic capacity is closely related to air traffic management (ATM) that is thus a Key Topic.

KEY TOPIC T2.1 – EVOLUTION OF THE AIR TRAFFIC CAPACITY

Scope of the goal

Air traffic capacity

Goal 1: An air traffic management system in place that provides a range of services to handle at least 25 million flights a year of all types of air vehicles, including unmanned and autonomous systems integrated into and interoperable with the overall air transport system with 24-hour operation of airports. European airspace is used flexibly to facilitate reduced environmental impact from aircraft operation.

Comparison with 2017 SRIA document	Why	Lacks
The description of the goal is not exactly aligned with the action lines proposed in the 2017 version of the SRIA document.	Although the measures included in the report in order to increase air traffic capacity are coherent (simultaneous operations, lower safe separation), they are not contemplated in the SRIA document.	• Performance-based operations would allow aircraft to fly the most efficient route and profile, assuring improvements in capacity. • The automation introduction and advanced navigation technologies will allow improving accuracy, quality of the service and the system capacity.

Components missing	The main issue of air transport capacity concerns runway system capacity, Terminal Area (TMA) capacity and En route Capacity.	ATM (Air Traffic Management) accounts for increases in capacity in both EN route and TMA. Although ATM is addressed in goal 5 it is necessary to address the challenges of En route capacity here at the same level than the challenges on Terminal Area
Components missing	The goal claims for a "range of services" that might be required by "all types of air vehicles". Although unmanned and autonomous are addressed in goal 16 (section 2.4.3), this section does not cover other types of vehicles that will be part of the future population of airspace-users such as VTOL.	Companies like Uber are envisaging a concept of "On-demand aviation" supported by a network of small, electric aircraft that take off and land vertically (called VTOL aircraft for Vertical Take-off and Landing), will enable rapid, reliable transportation between suburbs and cities. Dozens of start-ups and companies, with as many different design approaches, are working to make urban VTOLs a reality.
	Additionally, all this new type of vehicles and applications for UAS will demand a new set of services provided by a new and revolutionary Traffic Management System (a safety system may be needed to help ensure this newest entrant into the skies does not collide with buildings, larger aircraft, or one another).	Known as UTM, this system is today only conceptual project but should become an important assess of the future Air transport system, that should also be studied as part of in goal 16 in section 2.4.3. NASA is researching prototype technologies such as airspace design, dynamic geofencing, congestion management and terrain avoidance for a UAS Traffic Management (UTM) system that could develop airspace integration requirements for enabling safe, efficient low-altitude operations.

Table 2.1. Scope of the Goal 1

Benchmarks

The main issue of air transport capacity (section 2.1) concerns runway (2.1.1) and airways terminal capacity (2.1.2), as well as en route capacity (2.5).

The expected demand of 25 Million of flights will challenge three main elements in the transport system: a) the capacity of the runway system, b) the capacity of the TMA (Terminal Manoeuvring), c) the en route capacity. The accommodation of such a growth in flights will be determined by the most restrictive of these 3 capacity limits.

The European air traffic network contains some 170,000 links between airports. Over a network of more than 2100 airports, 528 airports accounted for just 25% of airports, but 98% of the departures; and just 25 out of Europe's 2100 airports generate 44% of all flights. For all airports in Europe, the Figure 2.1 shows the number of departures by the rank of the airport (inset). The figure also zooms in on the largest airports (main part) to illustrate that 44% of all departures come from the 25 largest airports in Europe, two-thirds of departures from the top 75 and 90% of all traffic comes from the largest 250 airports. There is a geographical concentration of airports in the region London-Amsterdam-Munich- Milan. This creates dense air traffic, with large numbers of climbing and descending aircraft: a significant challenge for Terminal Area and en route capacity.

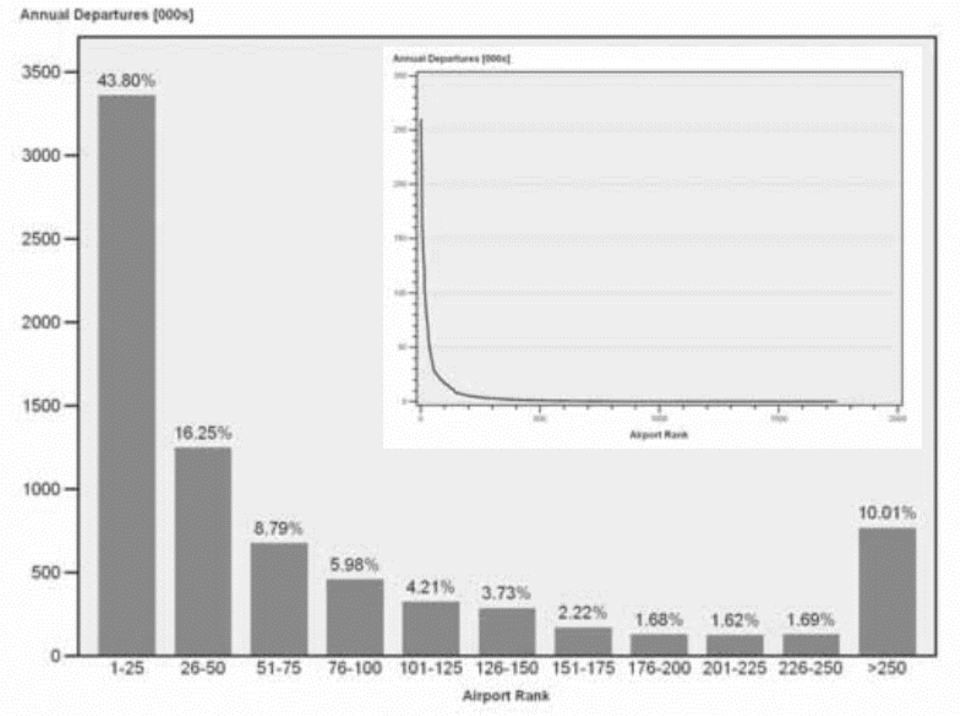


Figure 2.1. 90% of departures come from the largest 250 airports (2006 data). Source: Euro control Trends in Air Traffic Volume 3. A place to stand: Airports in the European network.

The Table 2.2 shows the average number of daily IFR movements at the main European airports (2019). As can be observed, the number of average daily IFR departures at the biggest airport in Europe (Frankfurt) is of 1407 operations per day.

ICAO CODE	AIRPORT	COUNTRY	AVERAGE DAILY MOVEMENTS 2019
EDDF	FRANKFURT MAIN	GERMANY	1.407,80
EDDM	MUENCHEN 2	GERMANY	1.134,90
EGKK	LONDON/GATWICK	UNITED KINGDOM	780,6
EGLL	LONDON/HEATHROW	UNITED KINGDOM	1.309,80
EHAM	SCHIPHOL AMSTERDAM	NETHERLANDS	1.395,00
LEBL	BARCELONA	SPAIN	943,9
LEMD	MADRID BARAJAS	SPAIN	1.167,60
LFPG	PARIS CH DE GAULLE	FRANCE	1.383,20
LIRF	ROME FIUMICINO	ITALY	848,7
LTBA	ISTANBUL-ATATURK	TURKEY	363,40

Table 2.2. Average number of daily IFR movements at the main European airports. Source: Eurocontrol Statistics and forecasts (STATFOR)

Airport operations depend upon several factors as well as on interactions between them which all affect runway capacity to some degree. In addition to physical constraints, such as airport layout, there are "strategic" factors such as airport scheduling and "tactical" factors which include, inter alia, the sequencing of aircraft and the sustainability of throughput during specific weather conditions. The runway throughput is directly related to the time needed to accommodate each flight safely. The separation requirements in segregated mode depend on the most constraining of any one of the three parameters: (1) wake vortex separation, (2) radar separation, or (3) runway occupancy time. From the **technological and operational perspectives of the runway operation,** the challenge to achieve a maximum throughput is to optimize final approach spacing in line with wake vortex, prevailing atmospheric conditions and radar separation requirements so that the spacing is close to minimum runway occupancy time. The maximization of runway capacity would be achieved by "dynamic separation" and state of the art in wake vortex, radar separation and runway occupancy time technology and procedures.

Once the maximum runway throughput has been achieved, the only way to increase capacity at congested airports will be airport expansion through additional new runways and infrastructures. This affects basically to the **social/human dimension** of the target as the growth of airports is severally constrained by social restrictions. Besides the plans for airport expansions, by 2030 no fewer than 19 European airports will be operating at full capacity eight hours a day, every day of the year. This will mean 50 % of all flights affected by delays; a system more vulnerable to disruption due to airport congestion and less able to recover from crises, and delays that will persist in the system for longer and will propagate more rapidly and widely.

Exhausted the potential growth of the biggest airports demand will need to be necessarily absorbed by closest airports, which refers to **the network dimension of air the transport**. The cities closest to Europe's busiest airports have between 4 and 46 airfields within 100 Km from the city centre, for 8 of the 10 cities close to Europe's biggest airports, a single airport handles 80% or more of all the departures within 100km.

A more conservative upper target for runway system, TMA and en route capacity can be derived from the "Challenge of growth" study. As part of this study, the first EUROCONTROL forecast of IFR flight movements in Europe up to 2050 focuses on understanding the factors that will form the future air traffic and the challenges that lie ahead. It uses four scenarios to explore European air traffic in 2050: A – Global Growth; C – Regulated Growth; C': Happy Localism; and D – Fragmenting World. Besides, the totally unexpected coronavirus crisis may be equivalent, at least temporarily, to the scenario D – Fragmenting World, which was hitherto considered a less likely case farther into the future. The scenarios produce different levels and flows of traffic and follow different paths of growth. The most 'visionary' scenario, Scenario A (Global Growth), is characterised by strong economic growth in an increasingly globalised world, with the technology used successfully to mitigate the effects of sustainability challenges, such as the environment or resource availability. It reflects the highest growth with 26.1 million IFR movements forecast in Europe for 2050 – 2.7 times more than in 2012, although there will be significant unaccommodated demand (36% by 2050). This prognosis considers a region-wide trend for the growth of airport capacity with incremental improvements in capacity at an annual rate of 0.8% per annum from 2035 capacities, across the network. The traffic growth will be faster in the early years, stronger in Eastern Europe and for arrivals/departures to/from outside Europe than for intra-European flights. When the capacity limits are reached, congestion at airports will increase quite rapidly which will lead to extra pressure on the network, and more delays. Even with airport capacity restrictions, airports will grow. In 2035, there will be 20 airports handling more than 150,000 departures a year in the most-likely scenario; a level of traffic currently achieved at 8 airports only. Some faster-growing airports in Southern and Eastern Europe will join the top 25 within the 20-year horizon (though the list depends on the scenario). Therefore, it is expected, unless breakthrough takes place, that airport capacity will severely limit the traffic growth; and it will be necessary for policymakers and business planners to decide if, and how, to invest in order to reduce unaccommodated demand.

The terminal area airspace (TMA) is the managed airspace environment created to assist in achieving safety and efficiency where a number of larger, more complex airports and smaller, local airports operate in close proximity. It is characterised by high numbers of aircraft conducting climbing and descending manoeuvres in a relatively small volume of airspace. Operations within TMA airspace are dynamic and heavily influenced by demand, regularly resulting in the need to delay aircraft in established vertical holding stacks and causing other delays in the air and on the ground. Biggest TMAs in Europe are today complex and saturated scenarios where the traffic of the busiest airports in Europe is integrated with the traffic of other airports in their neighbourhood. Example of high-density TMA in Europe are Paris, London and Frankfurt.

The Paris TMA includes two major airports, i.e. Paris Charles De Gaulle or Roissy (LFPG) and Paris Orly (LFPO), some secondary airports, e.g. Le Bourget (LFPB), Pontoise (LFPT), Beauvais (LFOB) and many other general aviation aerodromes like Toussus-Le-Noble (LFPN) and Lognes (LFPL). Within the TMA, major and segregated arrival and departure flows converge and leave from the two main Paris airports, i.e. Paris CDG and Paris Orly. The two airports are close to each other (slightly less than 20 NM). Further, the vicinity of Le Bourget induces additional traffic complexity within Paris CDG approach. Considering the average daily movements at both airports (roughly 1300 at LFPG and 650 at LFPO) this TMA has to attend more than 2000 movement daily on average. The London TMA includes two major airports, i.e. Heathrow (EGLL) with 1300 movements per day and Gatwick (EGKK) with 800 movements per day, which are close to each other (slightly more than 20 NM). There are also some secondary airports (i.e. Stansted with 245 movements per day, Luton with 180 movements per day, London City), which are in expansion as low-cost airlines operate from these secondary airports. In all the TMA has to manage more than 2500 movement per day.

Regarding the airspace capacity, the highest concentration of en route traffic takes places In Europe in the "core area" comprising of the Benelux States, Northeast France, Germany, and Switzerland is the densest and most complex airspace. At this zone, the density of fights is higher than 5 aircraft per hour and square kilometre.

The Table 2.3 summarises the average number of daily movements in the European Airspace, and the daily movements in the big block of Airspace. It can be observed how the core or central area of Europe (FABEC) has to accommodate almost 3/5 of the European daily traffic.

FAB (based on FIR)	Average daily Movements 2018	Average daily Movements 2019
SES Area (RP2)	27.987	28.313
Baltic FAB	2.675	2.809
BLUE MED FAB	7.294	7.570
DANUBE FAB	2.864	2.905
DK-SE FAB	2.986	2.946
FAB CE (SES RP2)	6.315	6.538
FABEC	17.090	17.254
NEFAB	2.945	2.956
SW FAB	5.941	6.085
UK-Ireland FAB	7.113	7.174

Table 2.3. Average daily movements in the En route European Airspace. Source: Eurocontrol ANS performance monitoring (RP2, 2019)

The Figure 2.2 shows the average daily IFR flights in the top 20 European and American en route area control centres (2017) where the busiest centres move more than 5000 movements per day.

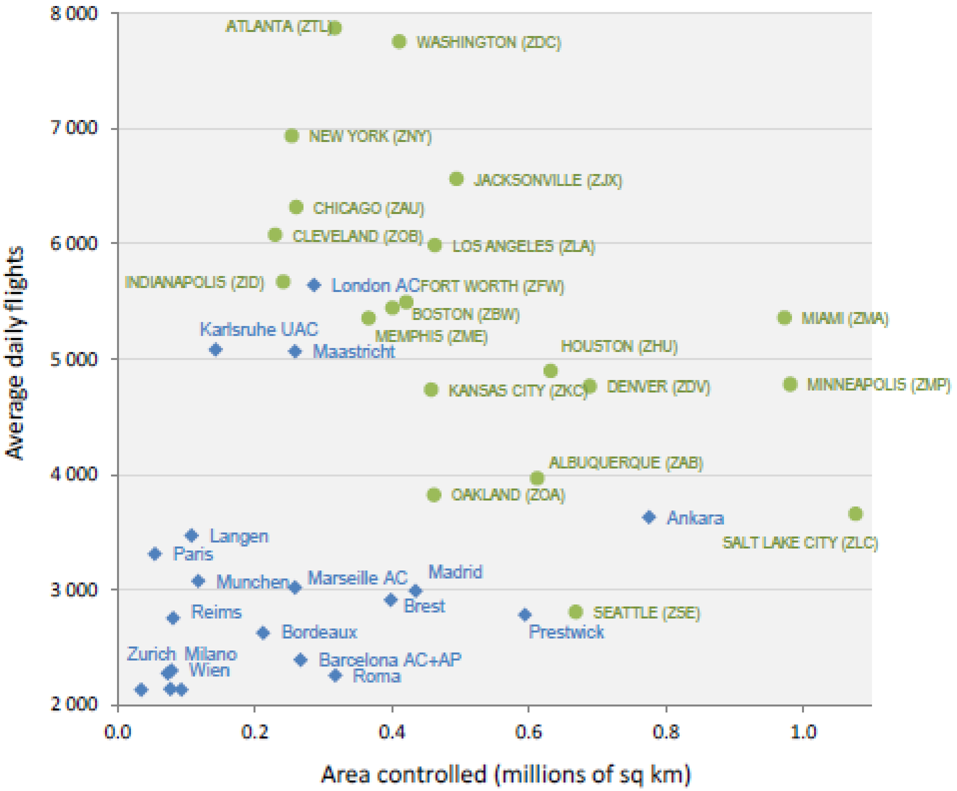


Figure 2.2. Comparison of en-route area control centres (2017). Source: 2017 Comparison of Air Traffic Management-Related Operacional Performance: U.S./Europe (FAA, EU, Eurocontrol).

The achievements of the benchmark for the TMA and En route movement will highly rely on the technological and operational performance of the future Air Traffic Management Systems and its social and human dimensions as discussed in section 2.5

Providing that current IFR traffic in Europe is around 10 Million IFR flights per year, an increase by a factor of 2,5 is expected by 2050. Considering a homogeneous not restricted traffic grow, high-density airports, surrounded TMAs and congested en route control centres will have to accommodate figures of **about 3500 (1400*2,5), 7500 (2500*3) and 12500 (5000*2,) daily movements, respectively.**

Benchmarks to be achieved in en route and terminal area will require technological, operational and also social/human improvements currently under design for the future ATM system. Key to the Future ATM concept is the business trajectory principle in which the users of the airspace and controllers define together, through a collaborative process, the optimal flight path. Taking full advantage of both existing and newly developed technologies — such as Galileo — Future ATM target concept relies on a number of new key features at 3 different dimensions:

Technological and operational dimension:

- Trajectory management, reducing the constraints of airspace organization to a minimum;
- New aircraft separation modes, allowing increased safety, capacity and efficiency;
- System-wide information management, securely connecting all the ATM stakeholders which will share the same data;

Social/human dimension:

- Humans as the central decision-makers: controllers and pilots will be assisted by new automated functions to ease their workload and handle complex decision-making processes.

Network operation dimension:

- The network operation plan, a dynamic rolling plan for continuous operations that ensures a common view of the network situation;
- Full integration of airport operations as part of ATM and the planning process;

Figure 2.3 illustrates the benchmarks discussed for goal 1.

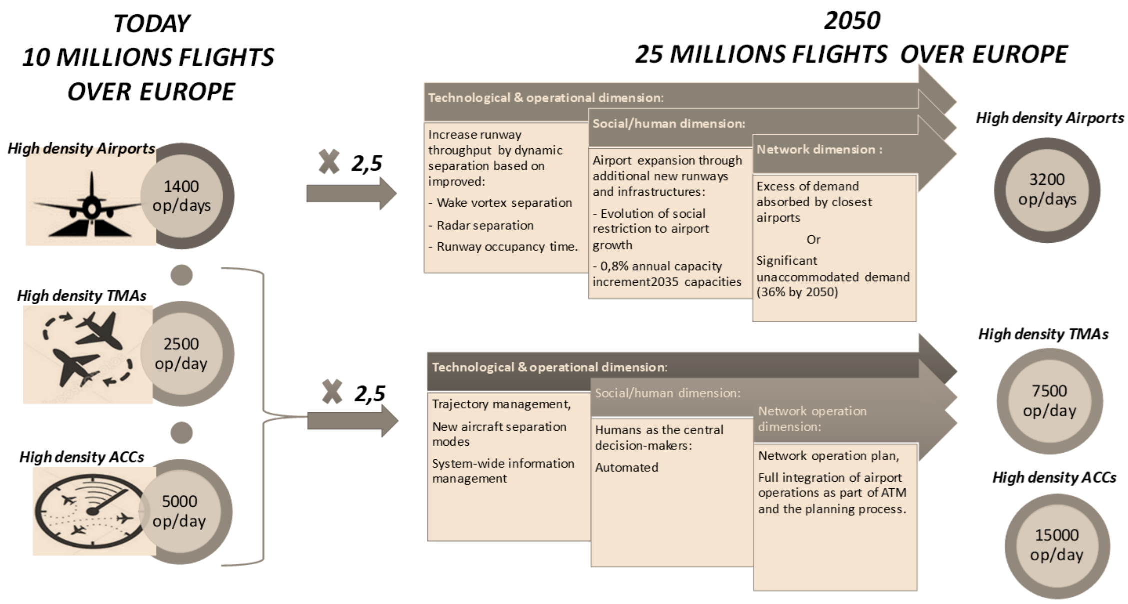


Figure 2.3. Technological, operational and societal/human dimension of goal 1 Benchmarks

Reference State in 2010

As stated in previous sections, Goal 1 of 25 million flight by 2050 needs to be accommodated by each of the Air Transport systems components: Airport runway system, Terminal Management Area airspace and en route Airspace. This section states the capacity limit of each of the previous components as in 2010.

Airport runway system

As already explained the runway throughput and the number of runways becomes the principal limitation of capacity at an airport. Hereafter some data are provided to characterize these elements in 2010. The Table 2.4 provides high-level indicators for the main 34 airports in Europe, including an average number of runways and the number of movements, as well as average daily IFR departures in order to provide an order of magnitude of the operations of the airports.

Main 34 airports in 2010	Europe 2010	Europe Vs. 2008
Average number of annual movements per airport ('000)	237	-9%
Average number of annual passengers per airport (million)	24	-3%
Passengers per movement	102	+6%
Average number of runways per airport	2.5	0%
Annual movements per runway ('000)	95	-9%
Annual passengers per runway (million)	9.7	-3%

Table 2.4. Key data for 34 biggest European airports. Source: 2010 Comparison of ATM-related performance: U.S. – Europe.

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

En route airspace

In Europe, there were, in 2010, 38 en route service providers of various geographical areas each operating their own system. This makes it more difficult to implement arrival management across national boundaries (e.g. sequencing traffic into major airports of other States) and may affect the level of coordination in ATFM and ATC capacity. Ground ATFM delays principally originate from en route capacity shortfalls in Europe, which is not the case in the US.

The next Figure 2.4 shows the traffic complexity score in 2010. At European level, the aggregate complexity score is relatively stable. In 2010, it is close to 6 minutes of interactions per flight hour. At the local level, the aggregate complexity scores differ quite significantly.[1]

[1] The complexity indicator is a composite measure calculated for the entire year which combines adjusted density (concentration of traffic in space and time) and structural complexity (structure of traffic flows10). A complexity score of 10 means that for each flight hour within the respective airspace, there were on average 10 minutes of potential interactions with other aircraft.

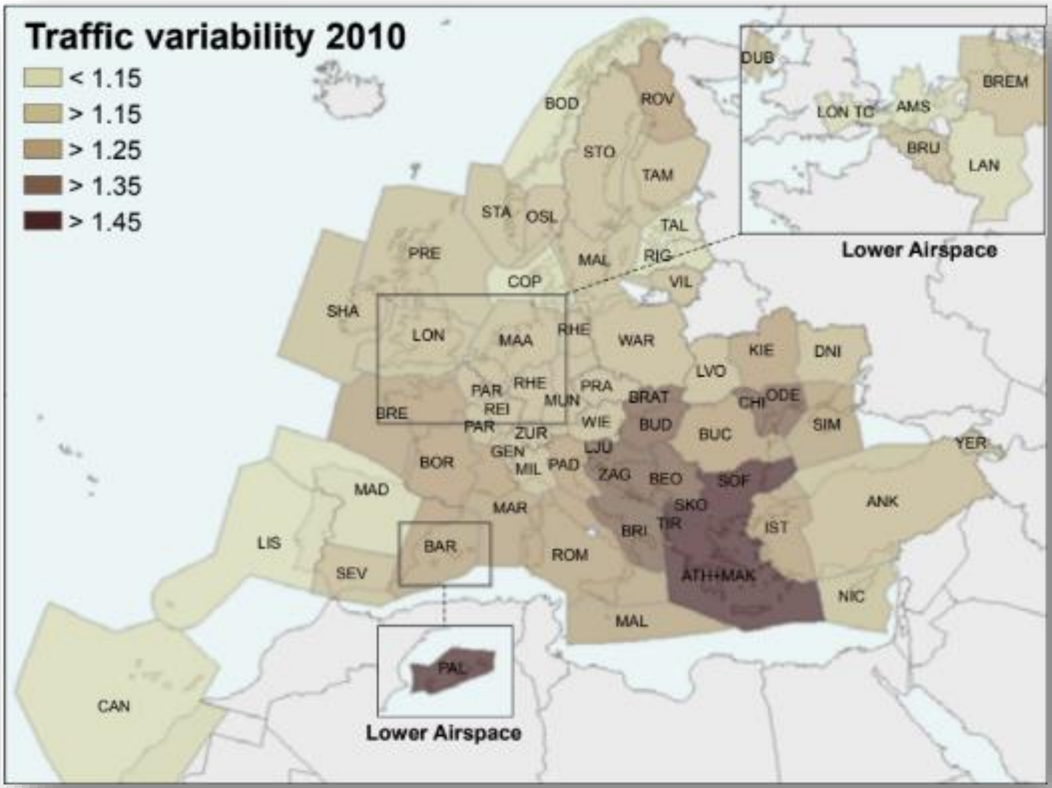
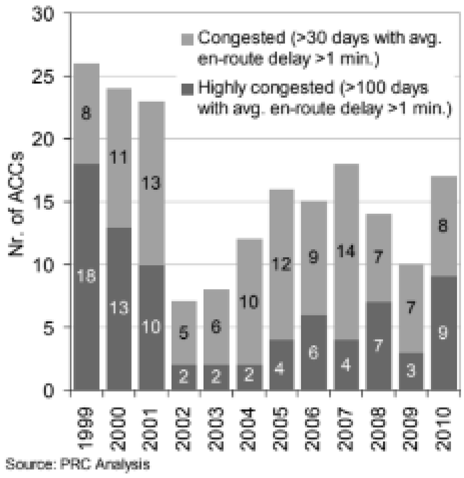


Figure 2.4. Traffic complexity score in 2010. Source: Performance review report 2010 Eurocontrol

The next Figure 2.5 presents the more congested ACC in Europe in 2010.



Most congested ACCs in 2010	Days en-route ATFM >1 min.	En-route delay /flight (min.)	% of flights delayed >15 min.	En-route delay ('000)	% of total en-route delay	% flight hours	Traffic growth (%)
Nicosia	262	3.56	9.1%	1 008	5.2%	0.4%	6.5%
Barcelona AC+AP	167	1.84	4.8%	1 380	7.1%	1.1%	1.0%
Rhein	167	1.38	3.9%	1 883	9.7%	1.5%	-0.1%
Madrid	163	1.42	3.8%	1 377	7.1%	1.4%	1.5%
Warszawa	158	1.13	3.4%	659	3.4%	1.0%	6.0%
Wien	148	1.53	4.3%	1 101	5.7%	0.7%	-0.4%
Langen	143	1.07	3.0%	1 319	6.8%	1.0%	0.5%
Brest	141	2.28	5.5%	1 855	9.6%	1.4%	-0.9%
Marseille AC	129	2.96	6.4%	2 950	15.2%	1.3%	1.4%
Zagreb	89	1.10	3.2%	471	2.4%	0.6%	10.7%
Canarias	79	1.18	2.6%	325	1.7%	0.6%	3.1%
Bordeaux	64	1.09	2.1%	839	4.3%	1.4%	-0.4%
Zurich	61	0.51	1.5%	381	2.0%	0.5%	0.9%
Sevilla	52	0.52	1.4%	185	1.0%	0.5%	2.2%
Paris	52	0.82	2.0%	938	4.8%	1.0%	-4.4%
Athinai+Macedonia	44	1.03	2.3%	652	3.4%	1.5%	2.9%
Bremen	33	0.31	0.9%	189	1.0%	0.6%	2.4%

Figure 2.5. Most congested ACC in Europe in 2010. Source: Performance review report 2010 (Eurocontrol)

Progress up to now

Airport runway system

The Figure 2.6 provides high-level indicators for the main 34 airports in both Europe and the U.S., including an average number of runways and the number of movements, as well as average daily IFR departures in order to provide an order of magnitude of the operations of the airports.

Main 34 airports	U.S.		Europe		U.S. vs. Europe (2017)
	2017	vs. 2015	2017	vs. 2015	
Avg. number of annual IFR movements per airport ('000)	390	2.4%	248	5.2%	+57%
Avg. number of annual passengers per airport (million)	38.7	6.8%	31.1	11.4%	+24%
Passengers per IFR movement	99	4.3%	125	5.8%	-21%
Average number of active runways per airport	3.4	0.0%	1.9	-1.5%	+76%
Annual IFR movements per runway ('000)	114	2.4%	128	6.8%	-11%
Annual passengers per runway (million)	11.3	6.8%	16.0	13.1%	-29%

Figure 2.6. Key data for 34 biggest European airports. Source: Comparison of ATM-related performance: U.S. – Europe, 2019

In Europe, the declared airport capacity is a limit typically set as early as six months before the day of operations through a coordination process involving the airport managing body, the airlines, and local ATC. The peak arrival throughput is an approximation of the operational airport capacity in ideal conditions. It is the 95th percentile of the number of aircraft in the "rolling" hours sorted from the least busy to the busiest hour. The indicator has, however, limitations when the peak throughput is lower than the peak declared capacity, in which case it is necessary to determine whether a variation in peak arrival throughput is driven by a change in demand or by a change in operational airport capacity.

The Figure 2.7 provides a comparison of the actual airport throughput vs declared capacity for the biggest airports in Europe and the U.S. in 2017. Although they are developed and used for different purposes, the values may provide some insights into the role of capacity on operational performance.

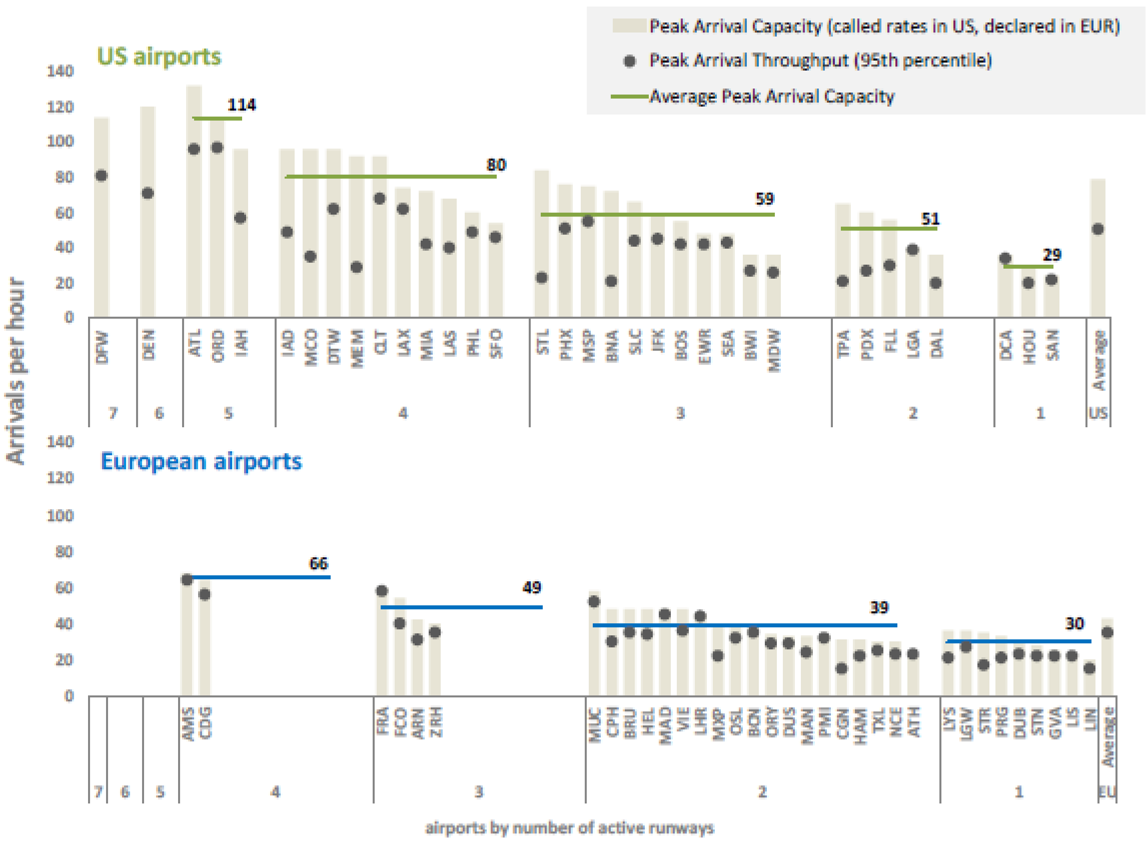


Figure 2.7. Actual airport throughput vs declared capacity (2017). Source: 2017 Comparison of ATM-related performance: U.S. – Europe, 2019.

In 2017, the main 34 European airports spent on average 76.7% of the time in VMC, 14.3% in marginal, and 9.0% in instrument. At the system level, weather conditions in Europe slightly declined in 2017 compared to 2015 with a 1.1% reduction in VMC and a 1.0% increase in instrument conditions. At the airport level, the share of time spent in VMC, MMC, and IMC vary based on differing susceptibility to weather events which is largely based on geographic location (Figures 2.8-2.9). The European airports located in the subtropical Mediterranean region including Nice (NCE), Palma (PMI), Madrid (MAD), Rome (FCO), Athens (ATH), and Barcelona (BCN) are the airports with the highest percentage of the VMC.

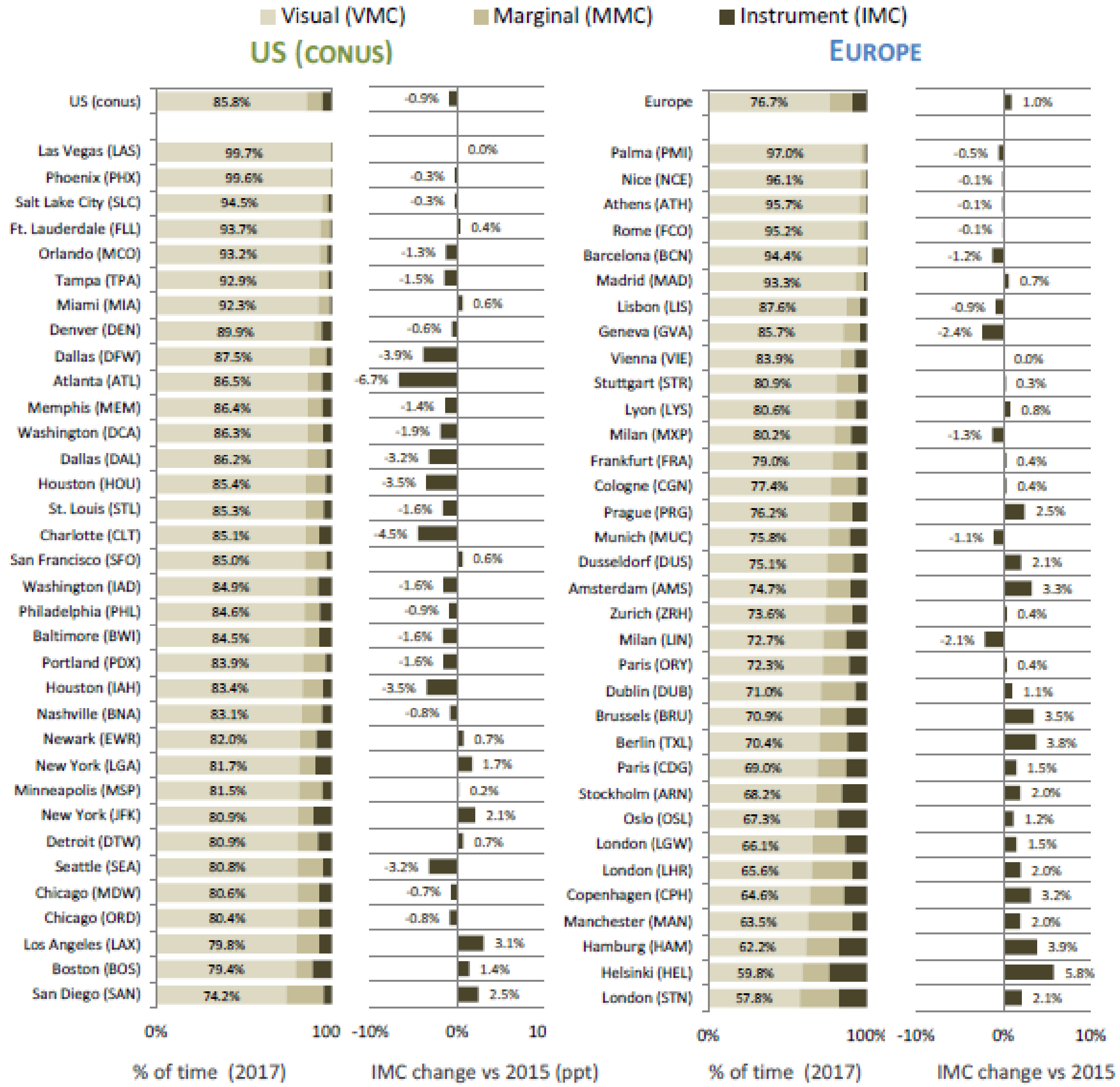


Figure 2.8. and Figure 2.9. Weather conditions at the main 34 airports in the U.S. and Europe (2017). Source: 2017 Comparison of ATM-related performance: U.S. – Europe

The following Table 2.5 presents an estimate of the "improvement pool" actionable by ATM comparing 2015 and 2017. The improvement was mainly driven by a reduction of en route ATFM delay at the departure gates and improvements in the level of horizontal flight efficiency.

Theoretical maximum "benefit pool" actionable by ATM for a typical flight (A320)		Estimated average additional time (min.)						Fuel burn	Estimated excess fuel burn (kg)[49]			
		EUR			U.S.			engines	EUR		U.S.	
(flights to or from the main 34 airports)		2015	2017		2015	2017			2015	2017	2015	2017
Holding at gate per departure (only delays >15min. included)	En-route-related (% of flights)	0.6 (2.0%)	0.9 (3.2%)	↑	0.2 (0.7%)	0.4 (1.0%)	↑	OFF	≈0	≈0	≈0	≈0
	airport-related (% of flights)	0.7 (2.3%)	0.8 (2.7%)	↑	1.1 (1.8%)	1.7 (2.4%)	↑	OFF	≈0	≈0	≈0	≈0
Taxi-out phase (min. per departure)		4.0	4.2	↑	6.0	6.8	↑	ON	60	63	89	102
Horizontal en-route flight efficiency		1.8	1.8	→	1.7	1.8	↑	ON	85	81	80	83
Terminal areas (min. per arrival)		2.8	2.8	→	2.5	2.5	→	ON	117	115	101	105
Total theoretical "benefit pool"		10.0	10.5	↑	11.5	13.2	↑		261	259	271	289

Table 2.5. Summary Estimated benefit pool actionable by ATM. Source: 2017 Comparison of ATM-related performance: U.S. – Europe

Predictions up-to-2025 and evolutionary progress up to 2050

During the past years, it has been identified as a growing gap between capacity and demand at a number of busy EU hubs. Congestion at these airports will remain a concern. Traffic will continue to grow in the future, as it has done over the past 50 years despite periods of economic downturn and other disruptions. Although air traffic in Europe will grow more slowly than in emerging economies, it will nevertheless nearly double by 2030 and more than double in 2050.

However, Europe will not be in a position to meet a large part of this demand due to a shortage of airport capacity. A percentage of this demand will not be accommodated because of capacity shortfalls. In concrete terms, by 2030 no fewer than 19 European airports will be operating at full capacity eight hours a day, every day of the year. This will have a major impact on the entire aviation network since by 2030 congestion at these airports will mean 50% of all flights affected by delays upon departure or arrival, or both.

In the following sections, there are proposed projects and measures that could improve air traffic capacity:

1. Eurocontrol measures to mitigate the capacity challenges
2. The SESAR project PJ02 (EARTH): Increased Runway and Airport Throughput
3. The Airport CDM concept

Although this goal focuses on increasing air traffic capacity, it is much related to the second goal: ground infrastructure and multimodal transport. Therefore, some of the measures that will be mentioned in this goal could be also applied for the second goal.

Eurocontrol measures to mitigate the capacity challenges

During the past years, there has been a stable growth trend in air traffic movements. At the horizon of 2050, the flight demand in Europe is predicted to be 25 million movements per year according to the ACARE goal, which is 2.5 times more than in 2010 with 10 million flights. This scenario is very similar to the scenario A (Global Growth) of Eurocontrol, which is characterised by strong economic growth in an increasingly globalised world, with 26.1 million IFR movements forecast in Europe for 2050, 2.7 times more than in 2012. However, it is expected that there will be significant unaccommodated demand (36% by 2050).

Eurocontrol contemplates four scenarios (Figure 2.10), each one with the following features:

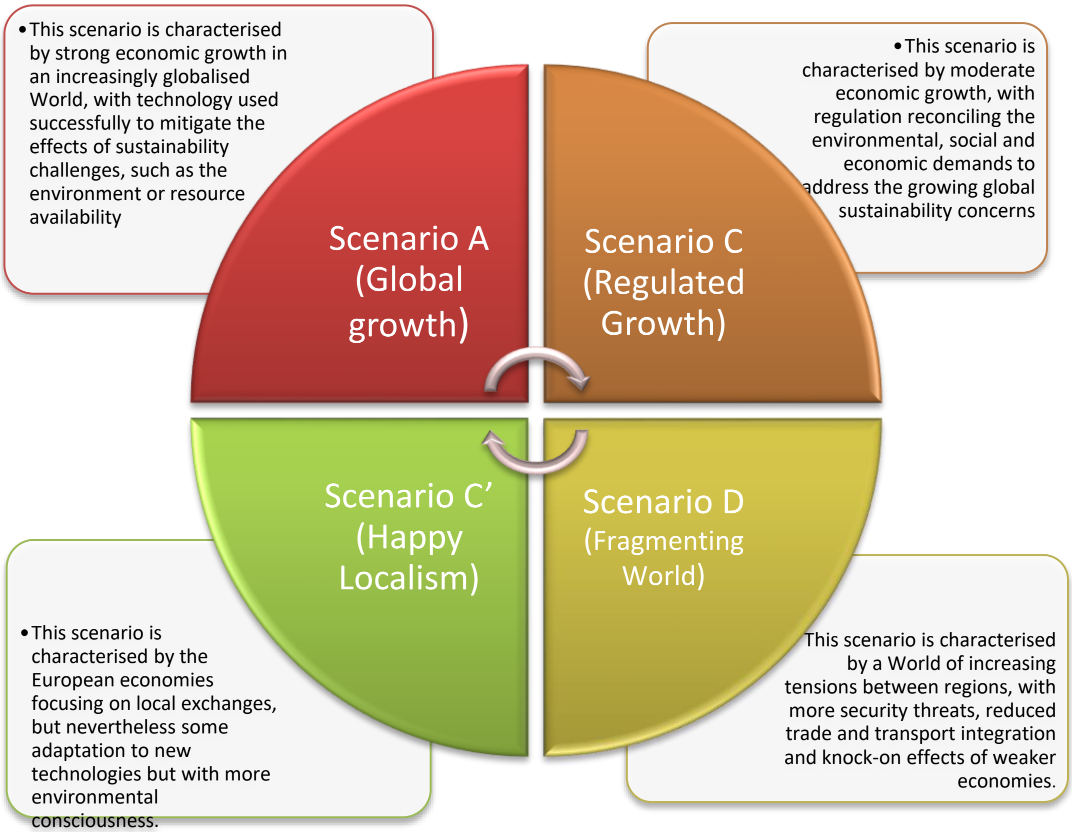


Figure 2.10. Four air traffic scenarios of Eurocontrol

The IFR movements expected for each Eurocontrol scenario can be seen in the next Figure 2.11:

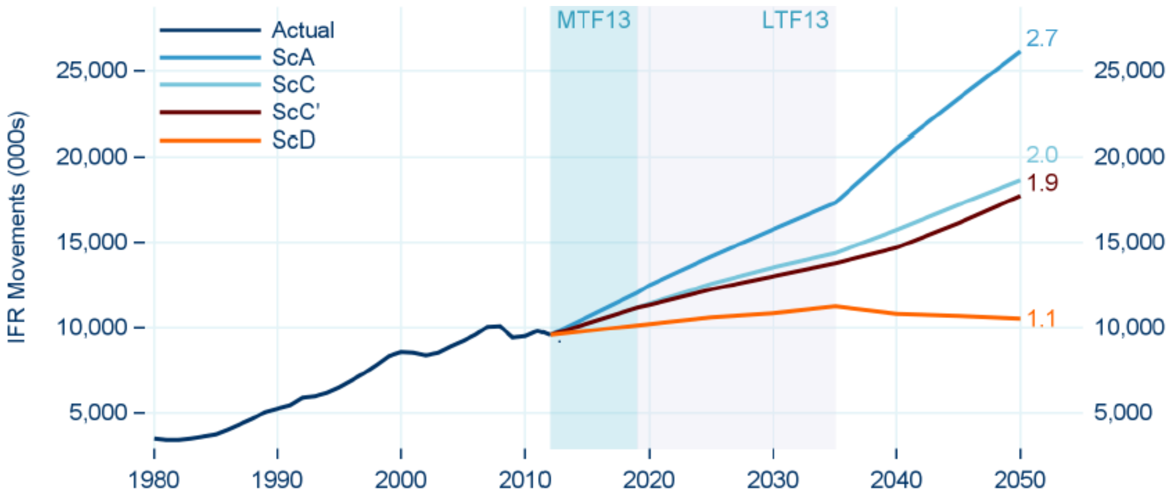


Figure 2.11. - IFR movements forecast for 2050. Source: Task 7: European Air Traffic in 2050 (Eurocontrol)

The 25 million flights movements expected for 2050 will result in great traffic growth in Europe. In view of the potential demand growth, it is expected that 36% of flight demand will not be accommodated at European airports.

In addition, it is estimated that by 2035, more than 20 airports will be operating at 80% or more of capacity daily, resulting in delays of up to 5-6 minutes. On the other hand, the mismatch between capacity and demand will not be the same across Europe. There will be regions where the shortfall is likely to be bigger: Turkey will be the most penalised facing almost 30% excess of demand for arrivals and departures at their airports in the most likely scenario C by 2035. The other States located mostly in Eastern Europe, like Bulgaria, Hungary, Romania will have around 17%-22% (each) excess of demand not accommodated by 2035 in scenario C (Figure 2.12). In terms of flights, rather than percentages, it is Turkey and the UK that will be most affected.

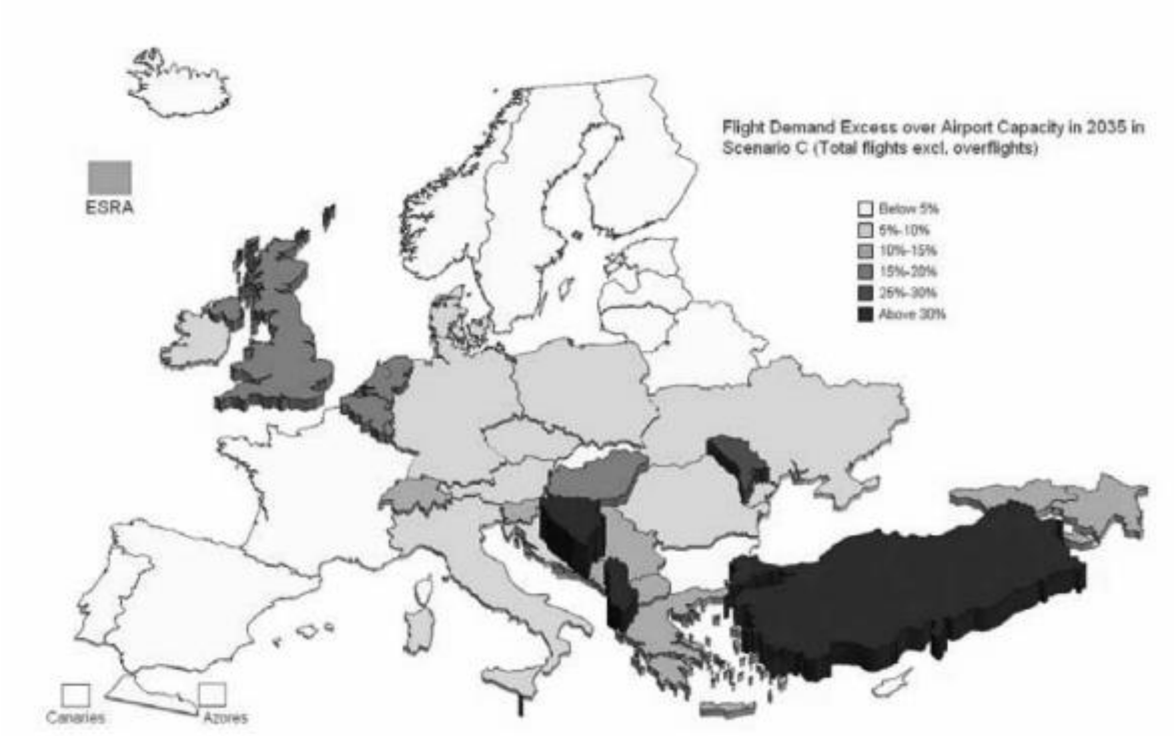


Figure 2.12. Unaccommodated demand by local airports. Source: Challenges of Growth 2013 Summary Report (Eurocontrol)

Therefore, due to the necessity of airport capacity to accommodate the future demand, Eurocontrol proposes a number of measures to mitigate the capacity challenges to reduce the levels of unaccommodated demand and increase capacity at airports:

- Alternative airports:

Shifting to alternative airports is considered as a real option for some airline and airport operators provided that potential issues of environmental acceptance and terminal airspace congestion can both be overcome. The measure is efficient in that it would reduce unaccommodated demand by around 30%, provided passengers and carriers are willing to relocate to such airports, which in turn is linked to the quality of the ground transportation links. This mitigation measure is also much related with the goal 2, since it will be necessary efficient mobility between airports.

- SESAR improvements

The SESAR programme to increase system capacity by developing and implementing new technologies, approaches, and procedures is perceived as the strongest enabler for sustaining future long-term demand. SESAR plus investments to bring airports to the performance level of the best-in-class has the potential to increase airport capacity by a significant margin, reducing unaccommodated demand by 40%.

- Schedule smoothing

This approach involves moving unaccommodated flights to times of the day when more airport capacity is available. However, Schedule smoothing is not considered as an answer to the airport capacity challenge, mainly because there is often little scope for moving flights to a nearby period and because it might not be the first choice of the passenger. As a result, this measure would reduce unaccommodated demand only by around 5%.

The next Figure 2.13 provides a one-day average level of congestion for a 24-hour time period.

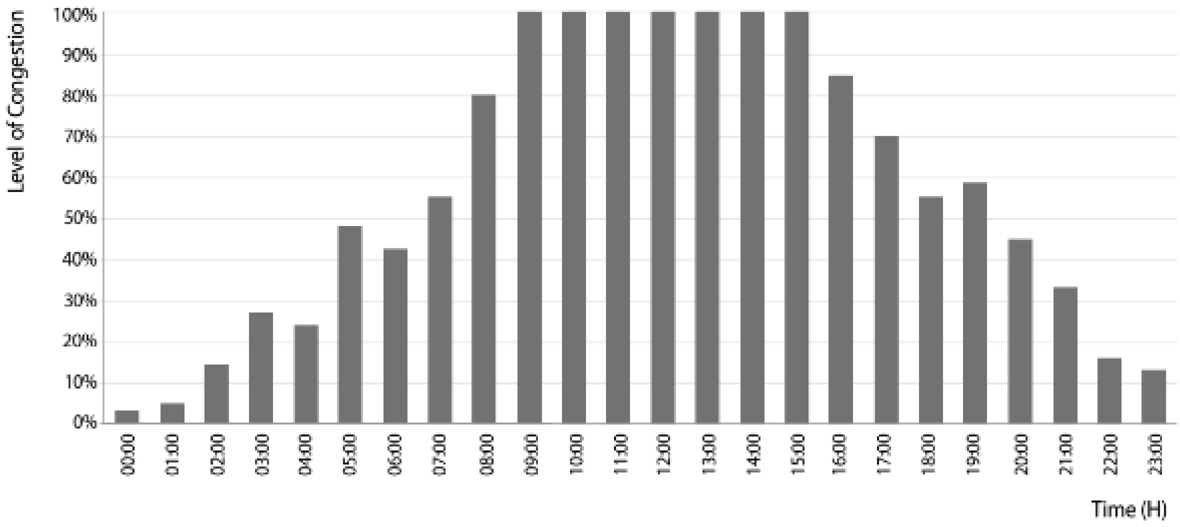


Figure 2.13. One day average level of congestion. Source: The effect of air traffic network congestion in 2035 (Eurocontrol)

➢ <u>High-Speed train investment</u>

This mitigation measure considers the impact of shifting flights to high-speed train (HST). Shifting short-haul flights to high-speed train is of limited benefit since there are only a small number of routes where the high-speed train could theoretically replace air services (Figure 2.14). As a result, this measure would reduce unaccommodated demand only by around 5%.

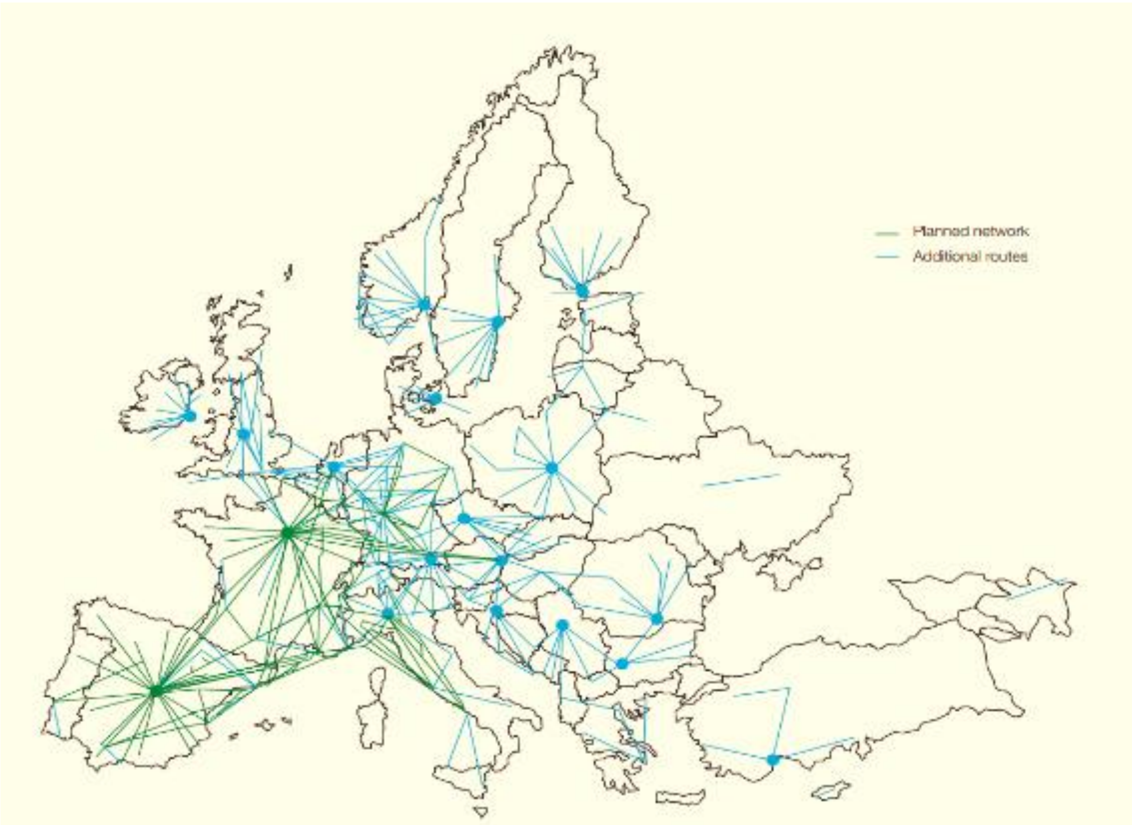


Figure 2.14. High-Speed rail network. Source: Challenges of growth 2008 (Eurocontrol)

➢ <u>Shifting to Larger Aircraft</u>

Shifting to larger aircraft can be a real option to accommodate more demand in the presence of a limitation on the allowable daily frequency between congested airports. In case of a frequency limitation of 15 daily flights in congested airports, the method has the potential to reduce the impact of the cap by more than a third.

Some previous measures, such as alternative airports or high-speed trains, would allow not only to increase capacity but also to improve mobility between airports, which is the objective of goal 2.

The following Figure 2.15 summarises the demand percentage that would be accommodated for each of the measures described above.

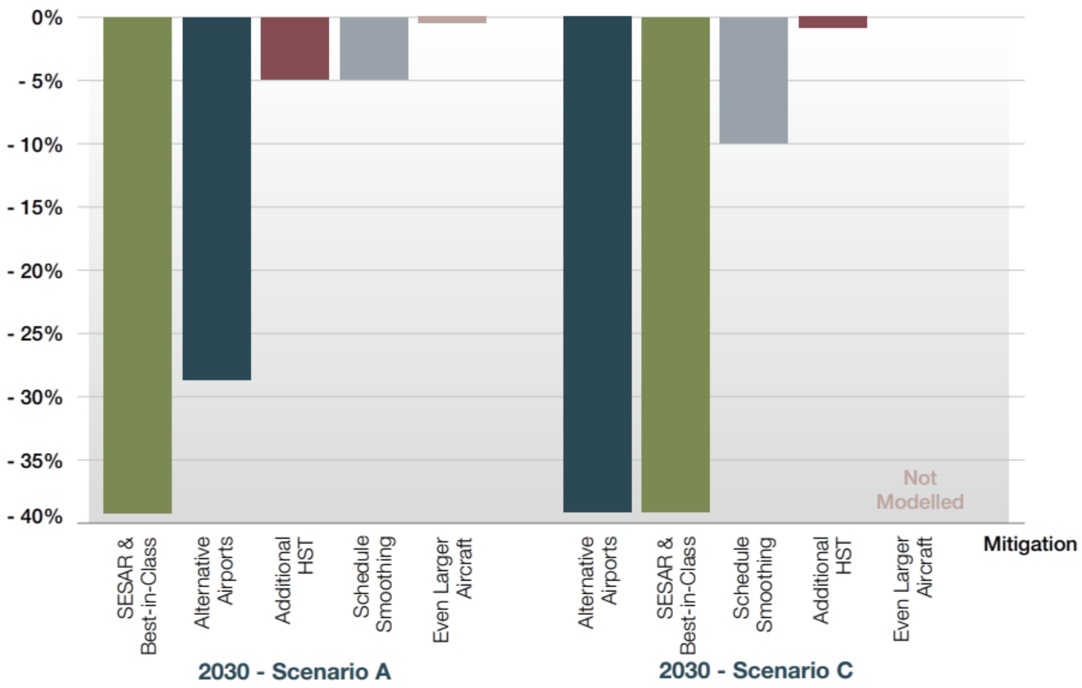


Figure 2.15. Mitigation Summary. Source: Task 5: Mitigation of the Challenges, Eurocontrol

As can be seen, alternative airports and SESAR improvements appear to be the most effective measures of reducing future unaccommodated demand. SESAR improvements and investment at airports has the potential to increase airport capacity by a significant margin, thus reducing unaccommodated demand by up to 40%. However, these capacity gains require an investment which is not yet reflected in airports' plans. Shifting to alternative airports reduces unaccommodated demand by 25%-40%. However, there will be environmental costs if additional ground transport is needed to reach more remote airports.

Schedule smoothing, Investment in High-Speed Train and larger aircraft are initiatives less efficient for reducing unaccommodated demand. High-Speed Train investments is a limited benefit, taking into account that building HST lines have a high cost and the demand accommodated is small. Schedule smoothing is also a limited benefit for accommodating more demand because there is often little scope for moving flights to a nearby period.

Taking into account the estimation (Figure 2.16) made of the unaccommodated demand for 2030, the estimation (Figure 2.17) for 2050 is as follows:

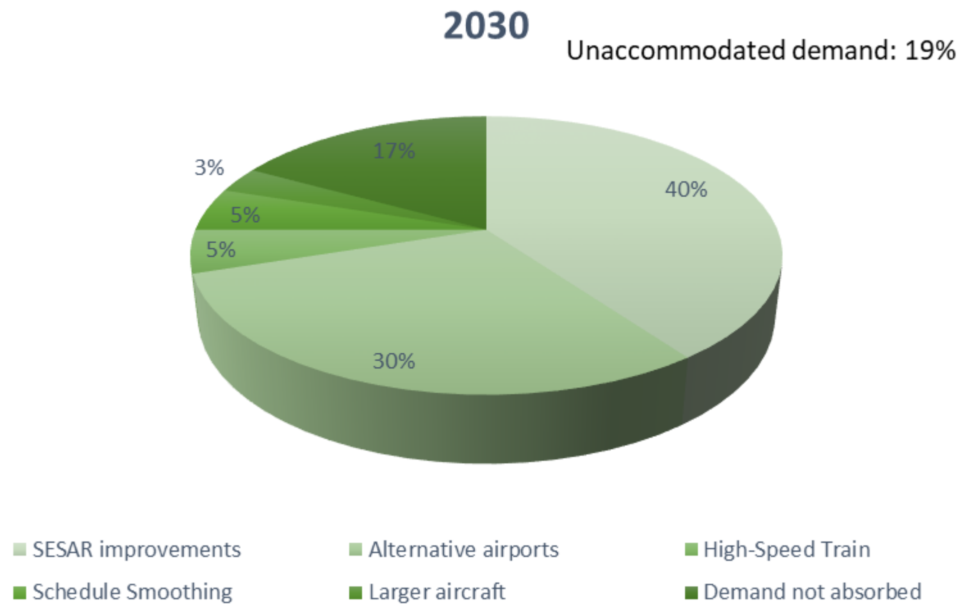


Figure 2.16. Unaccommodated demand 2030

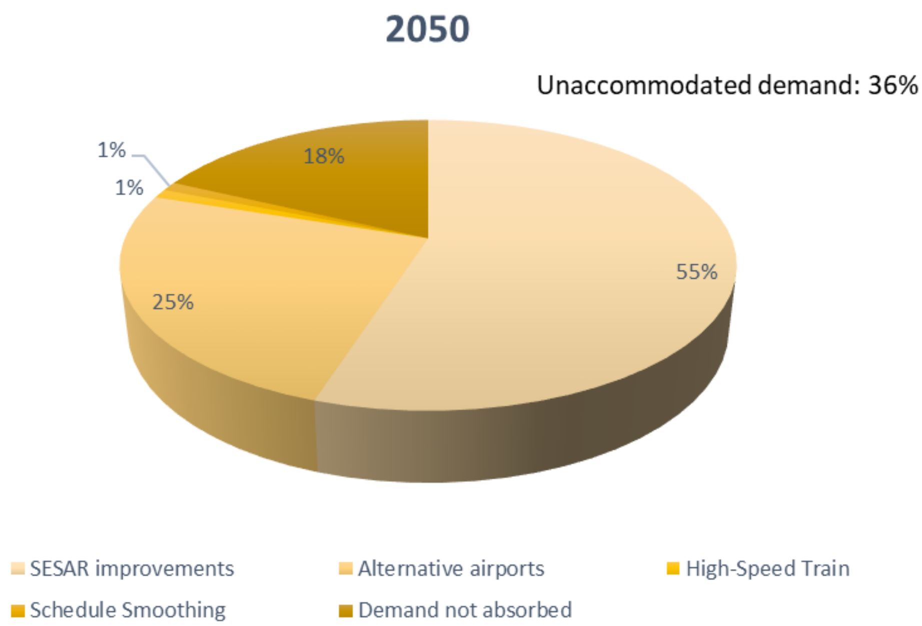


Figure 2.17. Unaccommodated demand 2050

A percentage of this demand will be absorbed by different mitigation measures proposed by Eurocontrol. It is important to highlight that, despite these mitigation measures, a demand percentage will not be accommodated.

Increased Runway and Airport Throughput - SESAR project PJ02 (EARTH)

One of the main elements that limit airport capacity is the maximum runway throughput, that is to say, the number of aircraft movements that can be safely operated. Due to the traffic growth expected in the future, there are several projects whose objective is to increase runway capacity to accommodate the foreseen growth in the number of aircraft movements. One of these projects is the SESAR project PJ02 (EARTH): increased runway and airport throughput.

This project focuses on developing, validating and delivering separation and procedures to improve runway and airport throughput considering wake vortex, weather, the environment and noise while taking account of different levels of traffic demand, future aircraft capabilities and airport configurations.

This project contemplates several measures which can be applied to increase runway capacity:

- Reducing runway occupancy time;
- Time-based separation;
- Re-categorization of wake turbulence categories.

➢ <u>Reducing runway occupancy time</u>

A key indicator for runway capacity is Runway Occupancy Time (ROT).

During the arrival of an aircraft, ROT is defined as the time interval between the aircraft crossing the threshold of the runway and the tail of the aircraft leaving the runway. Runway capacity is often limited by ROT because only one aircraft can use the runway at any given time. The leading aircraft must first vacate the runway before the trailing aircraft is allowed to cross the threshold.

ROT can be reduced through the use of high-speed exits. These exits are not perpendicular to the runway, but instead use a smaller angle allowing aircraft to vacate sooner and at higher speeds, reducing ROT.

In addition, The SESAR project will investigate the use of satellite navigation and augmentation capabilities, such as GBAS and satellite-based augmentation systems (SBAS), to enhance landing performance and to facilitate advanced arrival procedures (e.g. curved approaches, glide slope increase, displaced runway threshold). By doing so, noise is reduced while runway occupancy time (ROT) is optimised. The aim is to also reduce the need for separation for wake vortex avoidance.

➢ <u>Time-based separation</u>

When there are strong headwinds, aircraft ground speed is reduced on final approach. This results in a reduced landing rate, causing delays and even flight cancellations (Figure 2.18).

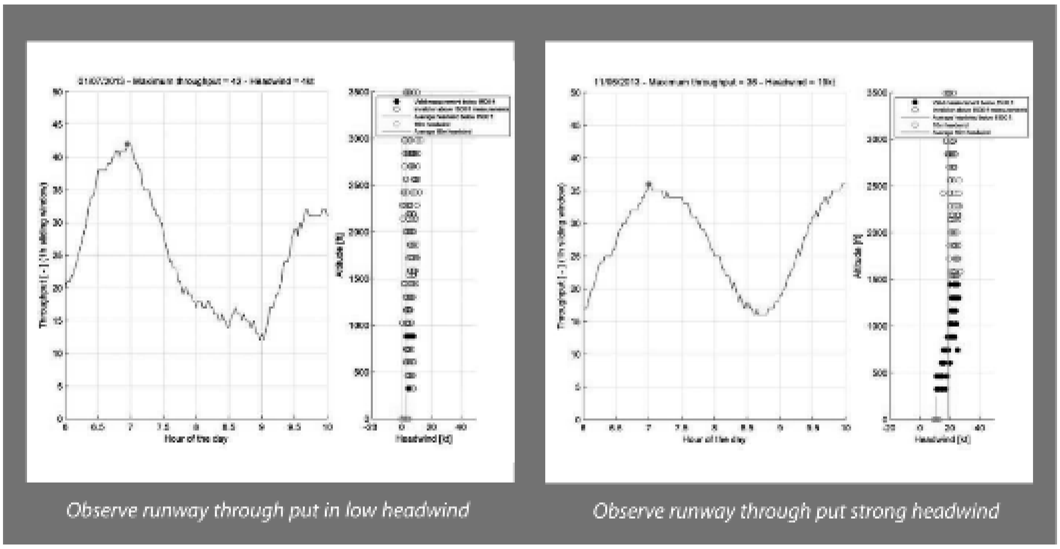


Figure 2.18. Comparison of observed runway arrival throughput in low headwind and strong headwind. Source: time-based separation factsheet, Eurocontrol

The concept of time spacing is based on the performance of an aircraft in strong headwinds conditions, where wake vortex is quickly dispersed, permitting then to reduce the distance between aircraft, while maintaining safety levels. Consequently, airports can operate with the same landing and capacity rates as in light wind conditions.

TBS aims at reducing the gap in landing rates in light and strong headwind conditions. It will help maintain airport capacity at the same level in all wind conditions.

TBS brings numerous benefits for airports, airlines and passengers, including:

- Increase of resilience of runway throughput and efficiency, due to space reduction between aircraft in strong headwind conditions while maintaining the same safety levels;
- a reduction in delays, cancellations and consequent operating costs
- shorter overall flight times
- advanced information for controllers, as TBS needs wind profile measurement in the final approach area and this information can be used by the controllers

➢ Re-categorization of wake turbulence categories:

Runway capacity and efficiency use are often directly linked with the minimum separation between aircraft. These minima are constrained by ATS surveillance capabilities and wake turbulence.

During recent years, knowledge about wake vortex behaviour in the operational environment has increased thanks to recorded data and improved understanding of physical processes. It is mainly for this reason that it was possible to revise wake turbulence categorisation and corresponding separation minima to enable optimisation of airport capacity and efficiency whilst maintaining acceptable levels of safety. A safe separation minimum implies to consider wake vortex generated by an aircraft but also the wake encounter impact and resistance of the following aircraft on departure or final approach. Existing ICAO wake vortex separation rules (Table 2.6) were implemented over 40 years ago and they have become outdated. These separations are based on certificated Maximum Take-off Mass (MTOM) and it includes three categories (HEAVY, MEDIUM or LIGHT) allocating all aircraft into one of them. Because the separations are defined based on the worst-case in each category, this leads to over separation in many instances.

Leader / Follower	A380-800	HEAVY	MEDIUM	LIGHT
A380-800		6 NM	7 NM	8 NM
HEAVY MTOM ≥ 136 tons		4 NM	5 NM	6 NM
MEDIUM 7 tons ≤ MTOM < 136 tons				5 NM
LIGHT MTOM < 7 tons				

Table 2.6. ICAO wake turbulence categories and separation minima. Source: European Wake Turbulence Categorisation and Separation Minima on Approach and Departure, Eurocontrol

This means that each category may cover a wide range of different sized aircraft that leads to over-conservative separations in many cases, and so a loss of runway throughput.

As a result, EUROCONTROL has developed a re-categorisation of ICAO wake turbulence scheme and associated longitudinal separation minima on approach and departure, called "RECAT-EU", to the benefits of Airports and ATM Network Performance enhancement.

European Wake Vortex Re-categorisation (RECAT-EU) is (Figure 2.19) a new, much more precise categorisation of aircraft than the traditional ICAO one. It aims at safely increasing airport capacity by redefining wake turbulence categories and their associated separation minima. It divides the current Heavy and Medium categories into two sub-categories and creates a new Super Heavy one for the Airbus A380.

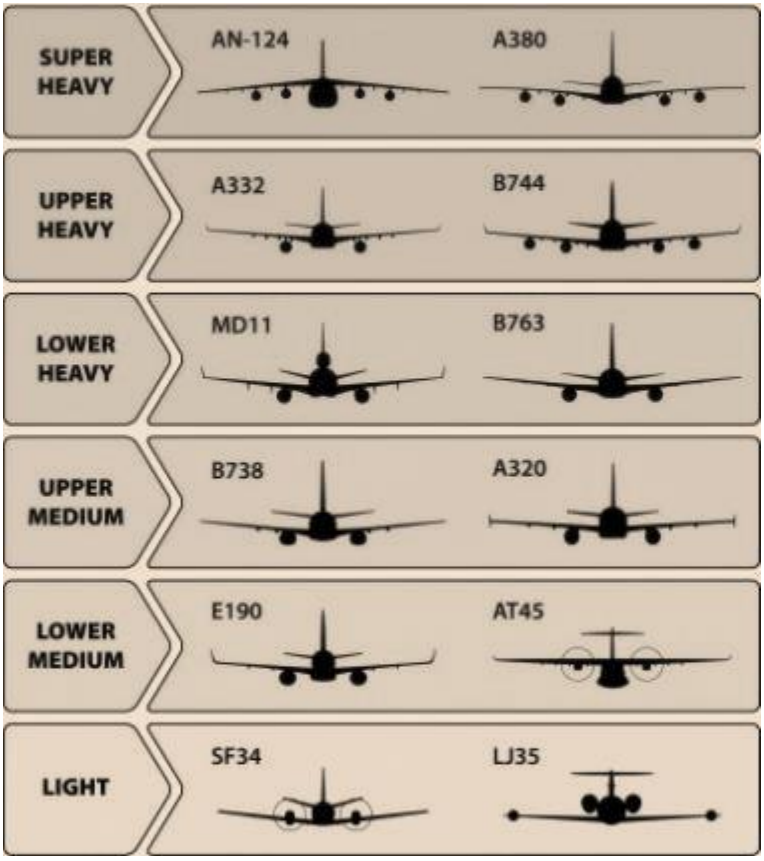


Figure 2.19. RECAT-EU categories. Source: http://www.eurocontrol.int/articles/recat-eu

The separations minima applicable between the RECAT-EU wake turbulence categories are provided in the following Table 2.7:

RECAT-EU scheme Leader / Follower		"SUPER HEAVY" "A"	"UPPER HEAVY" "B"	"LOWER HEAVY" "C"	"UPPER MEDIUM" "D"	"LOWER MEDIUM" "E"	"LIGHT" "F"
"SUPER HEAVY"	"A"	3 NM	4 NM	5 NM	5 NM	6 NM	8 NM
"UPPER HEAVY"	"B"		3 NM	4 NM	4 NM	5 NM	7 NM
"LOWER HEAVY"	"C"		(*)	3 NM	3 NM	4 NM	6 NM
"UPPER MEDIUM"	"D"						5 NM
"LOWER MEDIUM"	"E"						4 NM
"LIGHT"	"F"						3 NM

Table 2.7. RECAT-EU WT distance-based separation minima on approach and departure. Source: European Wake Turbulence Categorisation and Separation Minima on Approach and Departure, Eurocontrol

Thanks to this new categorisation, it is expected several benefits:

- The runway throughput benefits can reach 5% or more during peak periods depending on the individual airport traffic mix
- For an equivalent throughput, RECAT-EU also allows a reduction of the overall flight time for an arrival or departure sequence of traffic, and this is beneficial to the whole traffic sequence.

- RECAT-EU will also enable more rapid recovery from adverse conditions, helping to reduce the overall delay and will also enable improvements in ATFM slot compliance through the flexibility afforded by reduced departure separations.

➢ Projection

The SESAR project is found in the first levels of development since it is a new project that started in 2016. It is expected that this project finishes in 2019. However, this estimation is too positive because the project is in the concept phase (**TRL3**), so it may be fully implemented by 2025.

Airport CDM Concept

An airport is a complex system that involves many stakeholders and processes. Stakeholders actively and passively participate in this system and are affected by the outcome of these processes.

However, due to this complex system, airport stakeholders often operate independent systems in isolation, focusing on their own outcomes and without a shared situational awareness across the wider airport community. This limited perspective on the operation, as a whole, can result in widespread inefficiencies. The main factors that result in a decrease in the operational efficiency at airports are the following (Figure 2.20):

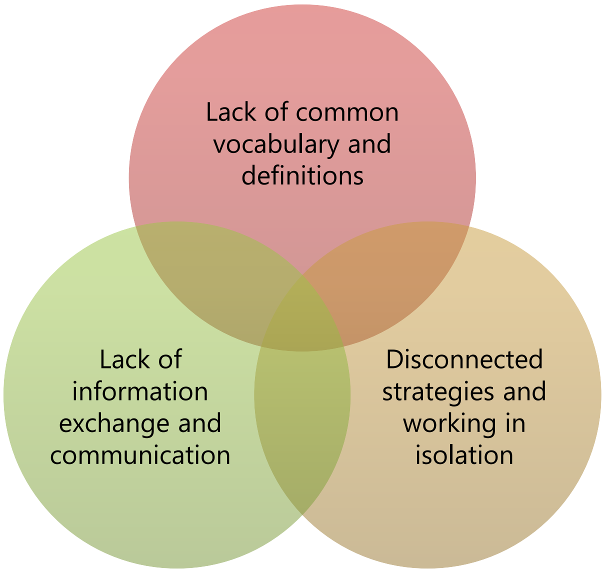


Figure 2.20. Factors affecting airport efficiency

Lack of Common Vocabulary and Definitions: Groups with limited interaction often develop their own semantic references; this includes airport stakeholders as they may use different terminologies to cover the same reality. This lack of common definition and understanding of terms and processes across the stakeholder community can exacerbate misunderstanding and contribute to the lack of common situational awareness.

Lack of Information Exchange and Communication: Another major factor that causes inefficiencies and misunderstanding among stakeholders is a lack of clear and concise communication and information exchange processes. There are many instances where departments and organisations work independently of each other and do not share information, data and concerns, which leads to decisions and actions being reactive rather than proactive and are based on incomplete or inaccurate information.

Disconnected Strategies and Working in Isolation: In an effort to improve their own performance, stakeholders may work independently to deliver increased efficiencies in their area without realising the impact on other stakeholders and thus, the overall operation, including their own. These disconnected or fragmented procedures, strategies, and systems often lead to decreased efficiency and performance across the entire operation.

Due to all these factors that contribute to an operational inefficiently at airports, the CDM concept arises.

The principle of CDM is to put in place agreed cross-collaborative processes including communication protocols, training, procedures, tools, regular meetings and information sharing, which moves ATM operations from stovepipe decision-making into a collaborative management process that improves overall system performance and benefits the individual stakeholders.

Airport-CDM is a process that applies to all airports irrespective of the size that supports landside, airside, and en route air traffic flow management (ATFM) operations, while enhancing forward planning and tactical decision-making. Implementing the concept of Airport CDM could improve the situation in congested airports.

Transparency and sharing of information are fundamental principles of A-CDM. As soon as the decision is made to implement A-CDM, agreed principles, processes, and data quality standards for multi-directional information exchange should be agreed. On the one hand, transparency allows stakeholders to make decisions based on a common situational awareness and take collaborative action that would be beyond the ability of anyone stakeholder with incomplete and fragmented information. On the other hand, sharing timely and accurate information that can improve the safety and efficiency of the aircraft flight between the concerned stakeholders would allow making more appropriate decisions.

➢ Airport CDM Collaboration Levels

Implementation of the Airport CDM concept involves various levels of collaboration and sharing information (Figure 2.21):

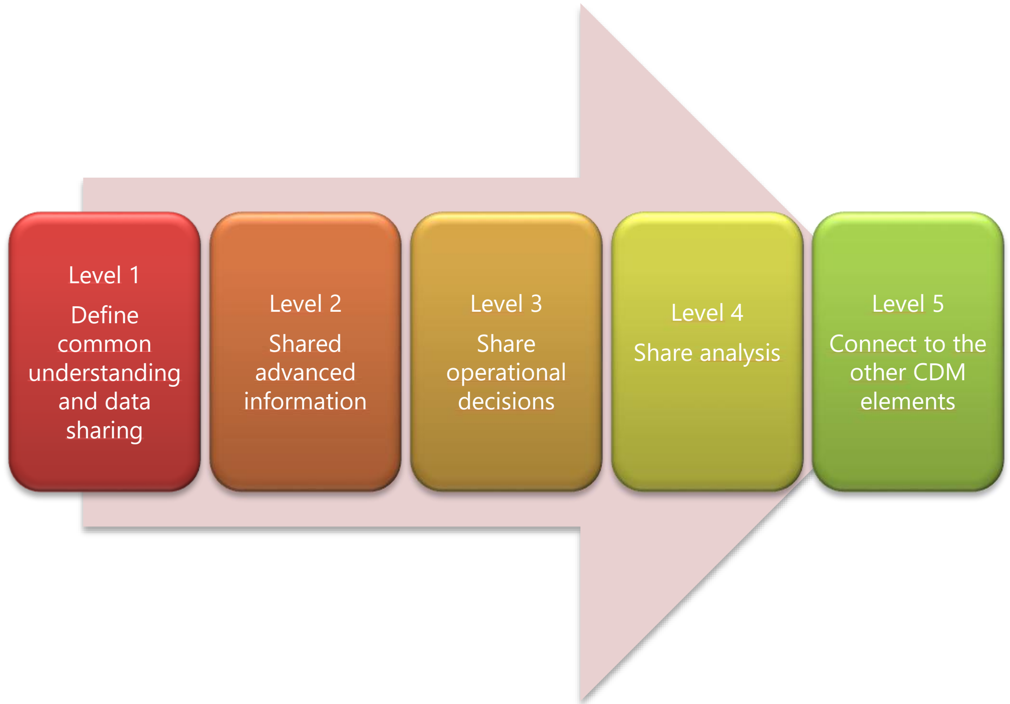


Figure 2.21. Implementation of Airports CDM

Level 1: Define a common understanding and data sharing. Agree on flight-related information elements (for example, scheduled and actual times) that will be shared and how that information will be distributed among the stakeholders.

Level 2: Share advanced information. Weather forecasts, the anticipated reduction in capacity (for example, construction on the runway), surveillance data, traffic load forecast, and resource allocations create a higher degree of situational awareness.

Level 3: Share operational decisions. The stakeholders agree to share their respective decisions or intended actions. For example, an ANSP shares its decision to increase the runway arrival capacity so that the other stakeholders, such as the ground handlers, can expect an increase in gate demand and allocate resources accordingly.

Level 4: Share analysis. Based on the analysis and respective decisions, the stakeholders agree to collaborative cross-organisational decisions. For example, the airport may adapt gate availability to meet the expected arrival demand by pushing departing aircraft into remote parking locations. This requires collaborative decision-making by the ANSP, the airlines and the ground-handling agents.

Level 5: Connect to the other elements of CDM. A-CDM can assist in optimising en route traffic flow management by sharing accurate departure take-off times. This information allows better prediction of en route demand versus available capacity and facilitates improved dynamic airspace and resource planning. By sharing information about passengers (such as check-in and security), baggage and crew, it also increases the efficiency and predictability of the landside turnaround process, which improves the overall system performance.

<u>Benefits</u>

A-CDM would help each stakeholder to reach, as often as possible, the maximum capacity under given conditions. The process of collaboration, communication, and coordination, along with common data and a robust shared decision-making process, would help to maximise capacity, identify weaknesses, focus on operationally essential matters, and to allocate resources appropriately while minimising the negative impact on each partner. Sharing information allows all stakeholders to appropriately plan and to minimise the disruptive effects of irregular operations or unusual situations, not only on their organisations but also on all airport partners by agreeing on a joint solution and defining an agreed recovery process that helps bring stability to the operation.

In addition, through its capacity optimisation, A-CDM would help in solving issues by bringing more predictability and efficiency.

It is important to highlight that the A-CDM concept could be useful not only for improving airport capacity (which is the purpose of the goal 1) but also for enhancing the airports' mobility which is the aim of the goal 2. Therefore, this concept could be applied to both goals.

- <u>Airport CDM implementation</u>

The first airport to be considered fully Airport CDM was the Munich airport in 2007. Since then, A-CDM is fully implemented in several airports across Europe nowadays, as can be seen in the next figure 2.22:

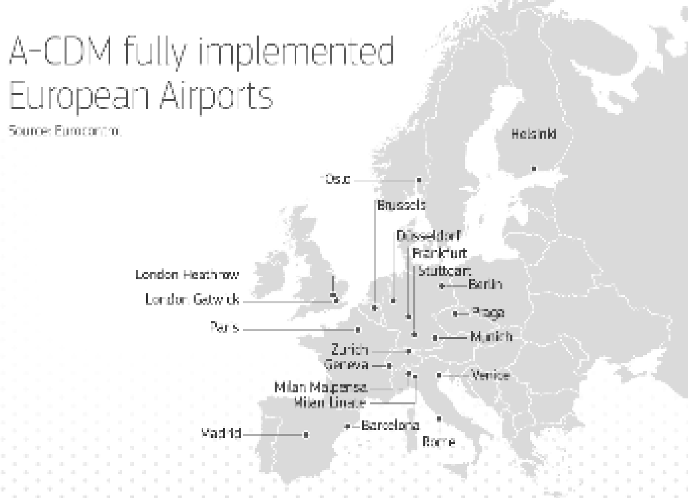


Figure 2.22. European Airports that have implemented CDM

Therefore, the A-CDM concept has been already developed, up to, the Technology Readiness Level 9. The next step is to evaluate the expansion level of the A-CDM concept to all European airports (Figure 2.23):

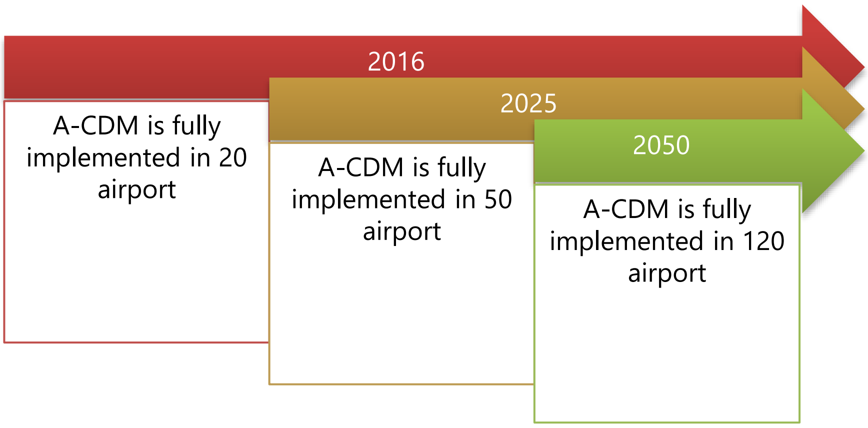


Figure 2.23. Increased adoption of a A-COM at European airports

KEY TOPIC T2.2 – RELATION OF ATM WITH CAPACITY

Progress up to now

ADS (Automatic Dependent Surveillance)

SSR (Secondary Surveillance Radar) has been the technological pillar of the surveillance system in aviation alongside PSR (Primary Surveillance Radar) since their use was standardized in the late 50s by ICAO. The network of both primary and secondary radars installed around the world has allowed to position aircraft in real-time on the ground and especially airborne since the 20th century.

Recent surveillance technologies are now possible due to the implementation of datalink as a new way of both air-ground and air-air communication.

Regarding ADS, it is a surveillance technique in which aircraft gathers data obtained from its avionics and transmits it to terrestrial systems and other aircraft's onboard systems. These data include aircraft callsign, position, altitude, speed or route.

There are two types of ADS in use in aviation:

- Automatic Dependent Surveillance – Contract, which includes the transfer of data from an aircraft to ANSPs (Air Navigation Service Provider). These contracts could be periodic, event contracts, demand contracts or emergency contracts. Periodic contracts are time-based and can be varied when necessary by ANSP needs; event contracts are set up by ANSP that predesignates aircraft's altitude, vertical speed or any other different parameter in which if aircraft deviates from these parameters, ANSP is notified; demand contracts are set by ANSP when it is necessary to know every aircraft position and emergency contracts are controlled and initiated by pilots during emergency circumstances[2].
- Automatic Dependent Surveillance-Broadcast, which includes the transfer of data from an aircraft to ground and other airplanes. It is the most used form of ADS in aviation. This allows the aircraft to display the positions of other nearby traffic through its CDTI (Cockpit Display Traffic Information).

[2] https://www.duncanaviation.aero/intelligence/2012/November/understanding-fans-ads-c-cpdlc

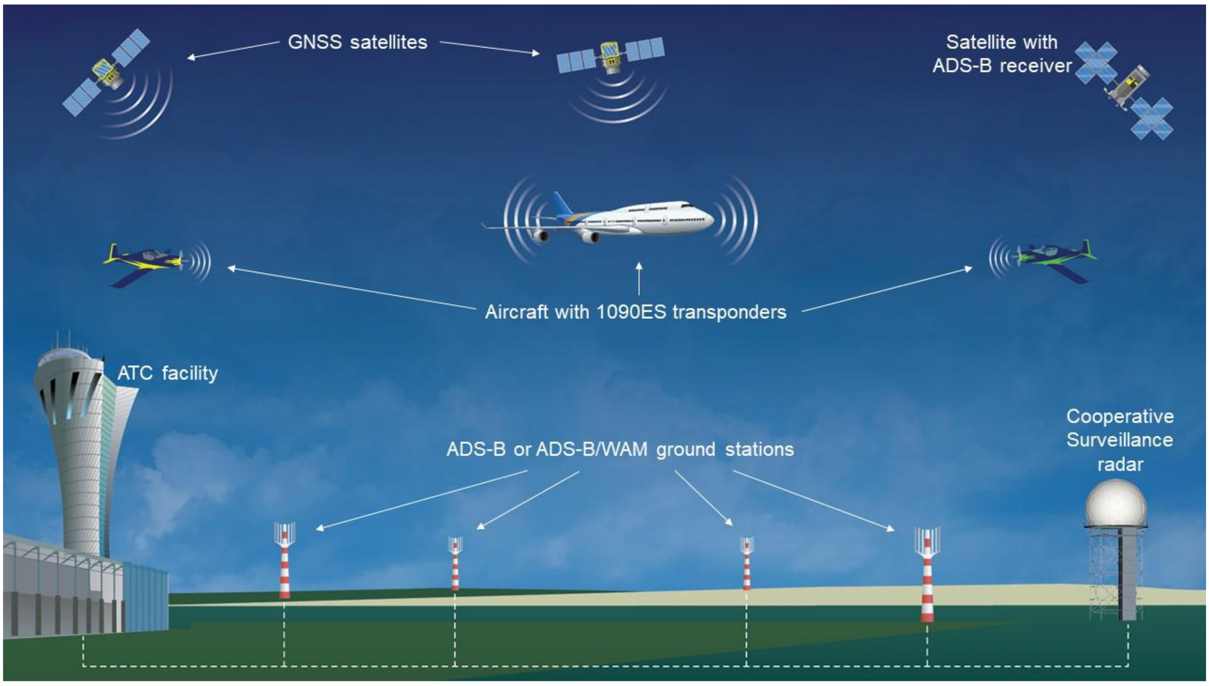


Figure 2.24. ADS-B diagram. Source: ICAO.

Regarding regulation framework, Commission Regulation (EU) No 1207/2011, of 22 November 2011, lays down requirements for the performance and the interoperability of surveillance for the single European sky. From 7 June 2020, all aircraft that weigh more than 5 700 kg, or have a max cruise speed greater than 250 knots, will need to be equipped with ADS-B capabilities to be operated in European airspace.

However, the applicable Regulation has been recently amended due to the outbreak of the pandemic of Covid-19 virus. Commission Implementing Regulation (EU) 2020/587, of 29 April 2020, states that the resulting impact of Covid-19 on the aviation sector has led to unforeseeable obstacles for aircraft operators to pursue their activities to bring the aircraft in compliance with certain requirements. As a result, the deadline for aircraft operators laid out in Article 5(5), Article 8(1) and Article 8(2) of Implementing Regulation (EU) No 1207/2011 should be postponed to 7 December 2020, and Implementing Regulation (EU) No 1207/2011 should be amended accordingly.

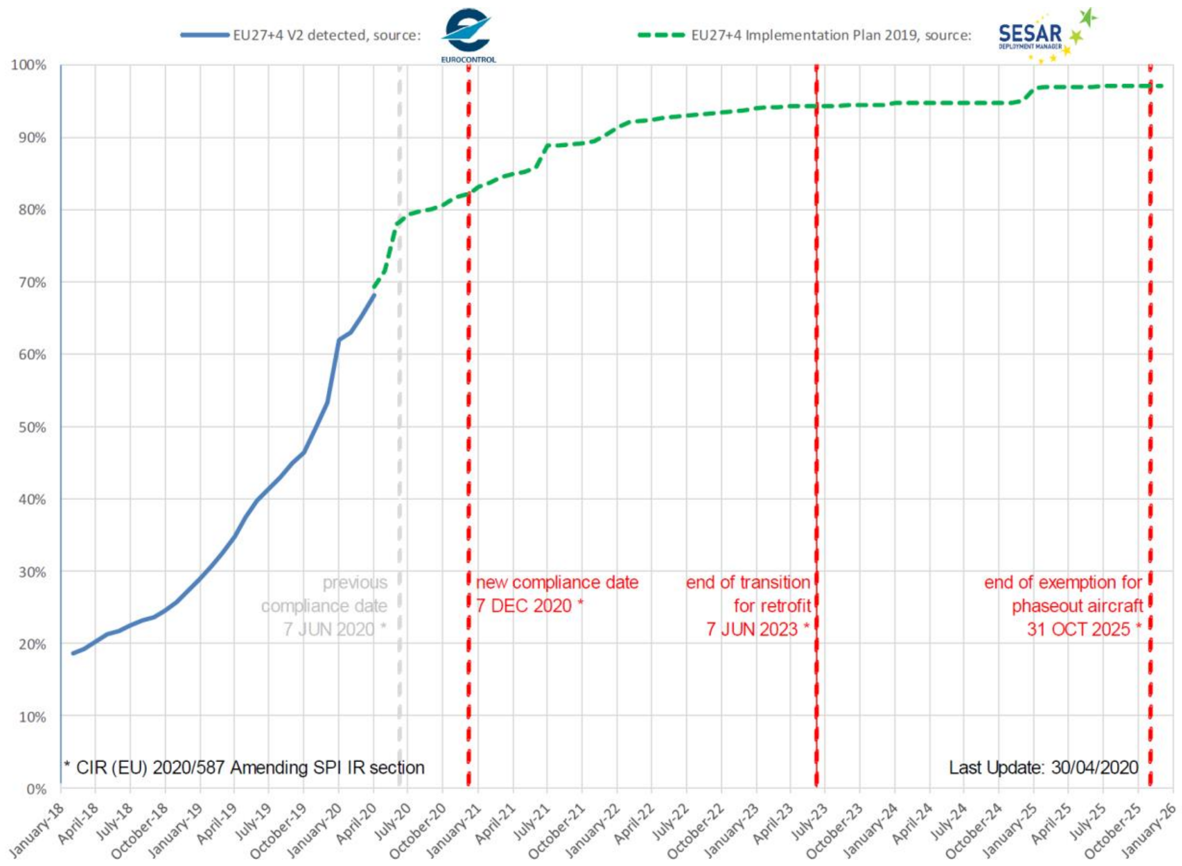


Figure 2.25. ADS-B Implementation Status. Source: https://ads-b-europe.eu/

Predictions up-to-2025

Since the beginning of the 21st century, European stakeholders have been addressing the issues related to the Single European Sky concept. The Single European Sky framework was set by EU Regulation No. 549/2004, in which it is stated that the objectives of the Single European Sky initiative are to enhance air traffic standards, to contribute to the sustainable development of the air transport system and to improve the overall performance of air traffic management (ATM) and air navigation services (ANS) for general air traffic in Europe, to meet the requirements of all airspace users.

One of the mechanisms by which these objectives were addressed by the Regulation was the creation of the so-called "Performance Scheme". The Regulation established that a Performance Scheme should be set up to improve the performance of air navigation services and network functions as much as the scheme aims to ensure that capacity is increased. As a result, flights will be significantly less delayed, saving unnecessary costs for airlines and passengers. In addition, the environmental impact of air traffic will be reduced due to more efficient and shorter flight paths. Air travellers should benefit from a punctual, greener and more cost-efficient mode of transport with a maintained or even enhanced level of safety. In this manner, the scheme should include Community-wide performance targets on the key performance areas of safety, environment, capacity and cost-efficiency. National plans to ensure consistency with this as established by this Regulation and Community-wide performance targets must be defined, and moreover, periodic review, monitoring and benchmarking of air navigation services and network functions should be conducted to ensure that targets are met.

The first attempt to lay down the principles of the Performance Scheme was EU Regulation No. 691/2010. After that, EU Regulation No. 390/2013 has defined the current Performance Scheme, which lays down the necessary measures to improve the overall performance of air navigation services and network functions within the European area. As the preceding one, this Regulation defines four key performance areas (safety, environment, capacity and cost-efficiency), for each of which a set of key performance indicators (KPI) and performance indicators (PI) are defined (see Table 2.8). The performance of air navigation services should be assessed against binding targets for each of these key performance indicators.

The Regulation states that national supervisory agencies (NSA) shall be responsible for the drawing up of the performance plans, and also for the oversight and monitoring of performance. The Regulation also establishes reference periods (periods of validity and application of Union-wide performance targets and the performance plans): the first reference period, known as RP1, covered the calendar years 2012-2014, the current one, RP2, includes the calendar years 2015-2019 and RP3 will start in 2020 and subsequent periods will cover five calendar years. Key performance indicators must remain invariable during each reference period.

KEY PERFORMANCE AREA	ANS PERFORMANCE INDICATOR
Safety	Application of severity classification scheme (RAT methodology) • Separation minima infringements (SMI) • Runway incursions (RI) • ATM-Specific occurrences (ATM-S) Effectiveness of Safety Management (EoSM) Presence of Just Culture (JC)
	Application of automated safety data recording Level of safety occurrence reporting Number of separation minima infringements, runway incursions and airspace infringements
Environment	Average horizontal en route flight efficiency of the actual trajectory Average horizontal en route flight efficiency of the last filed flight plan trajectory
	Effectiveness of booking procedures for FUA Rate of planning of Conditional Routes (CDR) Additional time in the taxi-out phase Effective use of CDR Additional time in terminal airspace
Capacity	En route ATFM delay per flight attributable to ANS Arrival ATFM delay
	Absence of ATFM slots Air traffic control pre-departure delay per outbound
Cost-efficiency	Determined Unit Cost (DUC) for en route air navigation services Determined Unit Cost (DUC) for terminal air navigation services

Table 2.8. Key performance indicators (KPI) and performance indicators (PI) as established by EU Regulation No.

The Commission has adopted Union-wide performance targets taking into account the relevant inputs from the Network Manager and the national supervisory authorities and after consultation with the stakeholders and other relevant organizations, such as EASA (see Table 2.9 for RP2 targets). The national supervisory authorities have to draw up performance plans at a functional block level that contain targets which are consistent with the Union-wide performance targets. As established in the Regulation, the national supervisory authorities and the Commission have to monitor the implementation of the performance plans, using the values reported on an annual basis. If during the reference period, targets are not met, the Member State will need to define and apply corrective measures and communicate them to the Commission. Transparency is a key element of the Performance Scheme thereby performance data is published and updated by the Performance Review Body (PRB) and is readily available to the general public. Member States are in charge of gathering the information from the providers and transmitting it to the PRB.

KEY PERFORMANCE AREA	ANS PERFORMANCE INDICATOR	RP2 TARGET (by the end of 2019)
Safety	Application of severity classification scheme (RAT methodology) • Separation minima infringements (SMI) • Runway incursions (RI) • ATM-Specific occurrences (ATM-S)	80-100% report of ATM Ground RAT severity for RI and SMI classified as A (serious), B (major) or C (significant) 80-100% report of ATM Ground RAT severity for ATM-Specific occurrences with categories AA, A, B or C
	Effectiveness of Safety Management (EoSM)	Level D for management objectives • Safety policy and objectives • Safety risk management • Safety assurance • Safety promotion Level C for management objectives Safety culture
Environment	Average horizontal en route flight efficiency of the actual trajectory	2.6%
	Average horizontal en route flight efficiency of the last filed flight plan trajectory	4.1%
Capacity	Average en route ATFM delay per flight	<0.5 minutes per flight
Cost-efficiency	Determined Unit Cost (DUC) for en route air navigation services	EUR_{2009} 56,64 for 2015 EUR_{2009} 54,95 for 2016 EUR_{2009} 52,98 for 2017 EUR_{2009} 51,00 for 2018 EUR_{2009} 49,10 for 2019

Table 2.9. Union-wide targets for performance monitoring during reference period 2 (RP2)

If data from ANS performance monitoring is collected and analysed, different outcomes can be stated. As an example, en route ATFM delay across the years 2008-2017 is shown in the following Figure 2.26:

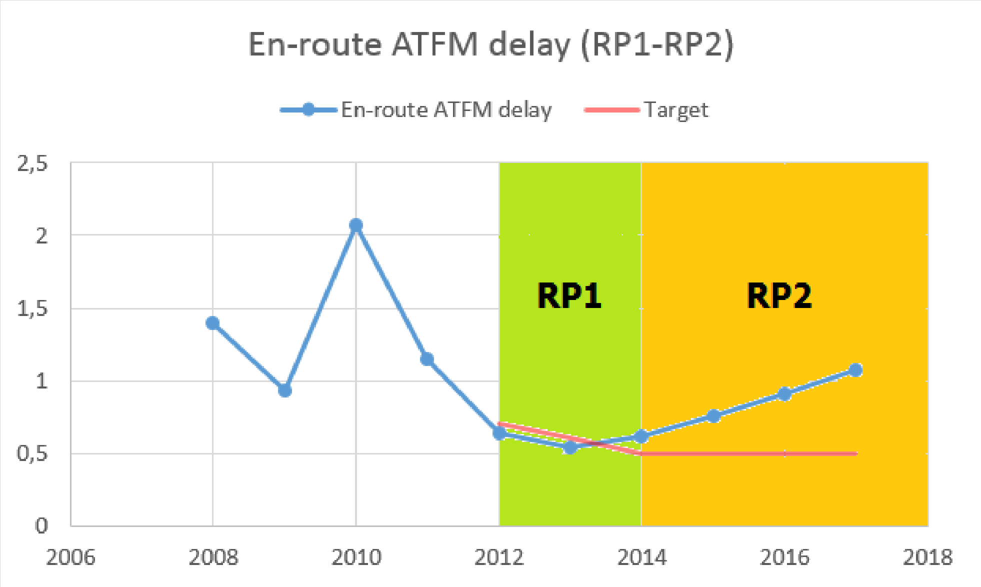


Figure 2.26. En route ATFM delay (RP1-RP2) (min/flight)

As can be proved, en route ATFM delay has changed along the past years. At the beginning of RP1, the average delay was lower than the target set for 2012 (0.63 vs 0.7) and, although the target has been even more restrictive every year, the average delay was also lower than the target in 2013 (0.54 vs 0.6). However, since 2014 until now, the average en route ATFM delay has been higher than the target set and, even worse, the average delay has continued increasing until set the maximum difference in the current year (1.07 vs 0.5). Therefore, as an increasing trend is underway, air traffic stakeholders must implement mitigating measures in order to chase the fulfilment of the targets for each reference period during the following years.

Consequently, if the measures taken are appropriate, parameters as average delays will be likely to decrease and other parameters as flight efficiency will be likely to increase.

This progress that can be achieved in the following years will facilitate the fulfilment of the main purposes of Goal 1 and, if these signs of progress become true, it would be a good starting point in order to keep developing the systems, procedures and equipment related to air traffic operation.

Evolutionary progress up-to-2050

The RP2 targets stated above should be put into context. Whereas these targets could seem appropriate for the current status of air traffic industry, the growth of air traffic expected to become real in the next decades must be considered and hence new targets must be studied and proposed.

For example, according to 2012 data, there are 1.4 billion passengers a year in 440 airports which means that there are 26000 flights a day crossing the European sky. In other words, there are 10 million flights each year and it is expected that it will grow by up to 5% per year.

This growth can be seen in different forecasts which show that 16.9 million flights are expected to cross European skies in 20 years, thus in 2030 as many flights will cross Europe as there are inhabitants of Beijing. Additionally, Flightpath 2050 aims that air traffic management system is capable of handling at least 25 million flights a year, almost three times the current number of flights in Europe.

Related to that, the overall goal of the Performance Scheme (Figure 2.27) is the modernization of Europe's air traffic management (ATM) system which still operates with basic technologies from the 1950s. This modernization aims to overcome a fragmented patchwork of 27 national airspaces through the following keys:

- Tripling the airspace capacity;
- Improving safety tenfold;
- Reducing environmental impact by 10%;

- Reducing air traffic management costs by 50%.

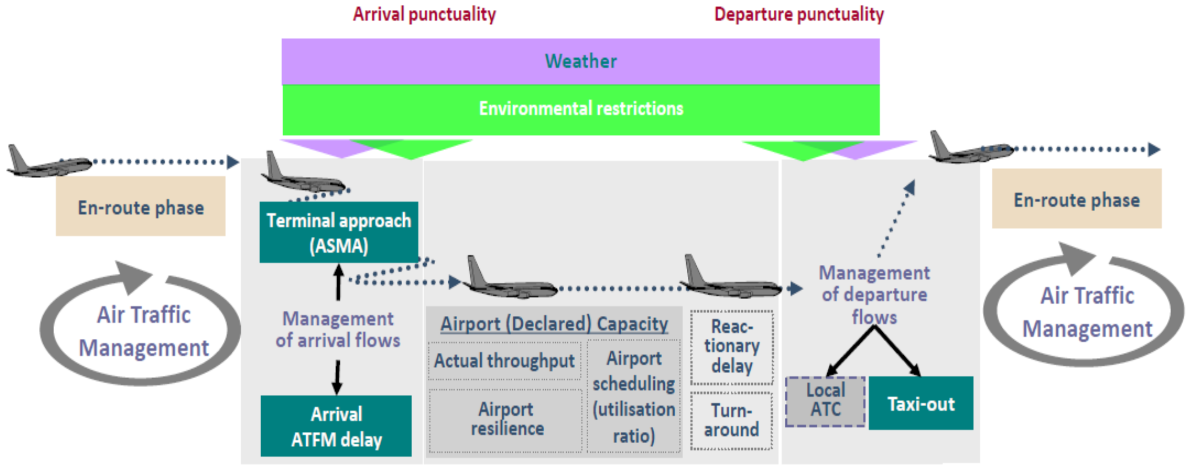


Figure 2.27. Operational ANS Performance. Source: Framework for the analysis of Operational ANS Performance at airports, Eurocontrol

Besides, it is likely that demand exceeds capacity in the next decades. This difference between demand and capacity will probably lead to bottlenecks in runway configurations, terminals, passenger and baggage processes if we talk about airports, and in the airspace, if we talk about the systems and equipment implemented in aircraft and ATC centres (ACCs and TWRs). As an example, a number of Member States' Plans risk being insufficient with regard to the capacity targets. These include France, Belgium, Netherlands, Germany, Luxembourg, Spain, Greece and Poland and hence these Member States should work with the Network Manager to reinforce their performance and try to reach the capacity targets.

Therefore, further efforts must be taken to make possible reaching the overall goal of the Performance Scheme, adapting periodically the requirements of each reference period to the developments carried out over the years regarding air traffic management (ATM) system.

Possible or predictable breakthroughs

The following breakthroughs could be expected:

- New developments regarding equipment, systems and procedures, including flexible use of airspace. Nowadays, for example, there are some flexible structures in the airspace, among which is the conditional routes (CDR). These routes or sections of routes are not permanent, in such a way that they only can be used under specific conditions within periods previously set. The CDR are divided into three categories: CDR 1 which can be planned permanently in the flight plan (RPL and FPL); CDR 2 which only can be included in FPL according to the conditions published daily, the day before the flight; CDR 3 which cannot be planned in the flight plan, it only can be used under ATC clearance. The publication of the information about flexible structure availability is carried out through two ways: Airspace Use Plan (AUP) which is published before 14:00 UTC of the day before the operation and its period of validity is 24 hours since 06:00 UTC of the following day; on the other hand, Conditional Route Availability Message (CRAM) is broadcasted to airlines, ARO offices, ACC/FMP, Airspace Management Cell (AMC) and CFMU at 15:00 UTC of the day before the operation and its period of validity is 24 hours since 06:00 UTC of the following day. In conclusion, availability of flexible structures is spread mainly one day before the operation, so stakeholders should focus on trying that this information is available live, allowing a real flexible use of airspace during the flight operation.
- Additional runways construction and even new airports construction in order to accommodate the increasing demand.
- Developments concerning aircraft designs in order to reduce fuel consumption, wake turbulence and noise.

- Development of both aircraft and ground systems allowing lower separation minima.
- New research about innovative technologies.

Identification of Gaps

If the current figures for air traffic in Europe are studied, it can be stated that Goal 1 implies to almost triple the current number of flights. Nowadays there are 10 million flights each year and it is expected to grow by up to 5% per year. This growth will require a huge effort from the stakeholders since it will be a hard task to handle.

However, these tasks related to the improvement of ATM framework are not new in Europe as the European Union has set different goals along the years in order to allow the growth of air traffic. As an example, the Commission stated in 2005 the political vision and high-level goals for the Single European Sky and its technological pillar for 2020 and beyond:

- Enable a 3-fold increase in capacity which will also reduce delays, both on the ground and in the air.
- Improve the safety performance by a factor of 10.
- Enable a 10% reduction in the effects that flights have on the environment.
- Provide ATM services at a cost to the airspace users which is at least 50%less.

These vision and goals were analysed by reference to the 2020 demand and resulted in specific initial targets for that particular year, notwithstanding the subsequent evolutions necessary to meet the growing demand. These targets are gathered in the following figure 2.28.

KPA	Key Performance Indicator (KPI)	Baseline		2020 Target	
		Year	Value	Absolute	Relative
Capacity	Annual IFR flights in Europe	2005	9.2 M	16 M	+ 73%
	Daily IFR flights in Europe	2005	29,000	50,000	+ 73%
	Best In Class (BIC) declared airport capacity in VMC (1 RWY), mov/hr	2008	50	60	+20%
	BIC declared airport capacity in VMC (2 parallel dependent RWYs), mov/hr	2008	90	90	+0%
	BIC declared airport capacity in VMC (2 parallel independent RWYs), mov/hr	2008	90	120	+25%
	BIC declared airport capacity in IMC (1 RWY), mov/hr	2008	25	48	+90%
	BIC declared airport capacity in IMC (2 parallel dependent RWYs), mov/hr	2008	45	72	+60%
	BIC declared airport capacity in IMC (2 parallel independent RWYs), mov/hr	2008	45	96	+110%
Cost Effectiveness	Total annual en-route and terminal ANS cost in Europe, €/flight	2004	800	400	-50%
Efficiency	Scheduled flights departing on time (as planned)			>98%	
	Avg delay of the remaining scheduled flights			<10 min	
	Flights with block-to-block time as planned			>95%	
	Avg. block-to-block time extension of the remaining flights			<10 min	
	Flights with fuel consumption as planned			>95%	
	Avg. additional fuel consumption of the remaining flights			<5%	
Flexibility	Accommodation of VFR-IFR change requests			>98%	
	Unscheduled flights departing on time (as requested)			>98%	
	Avg delay of the remaining unscheduled flights			<5 min	
	Scheduled flights with departure time as requested (after change request)			>98%	
	Avg delay of the remaining scheduled flights			<5 min	
Predictability	Coefficient of variation for actual block-to-block times: for repeatedly flown routes			<1.5%	
	Flights arriving on time (as planned)			>95%	
	Avg arrival delay of the remaining flights			<10 min	
	Total reactionary delay	2010			-50%
	Reactionary flight cancellation rate	2010			-50%
	Total service disruption delay	2010			-50%
	Percentage of diversions caused by service disruption	2010			-50%
Safety	Annual European-wide absolute number of ATM induced accidents and serious or risk bearing incidents	2005		No increase	
	Safety level (per flight)	2005			x 3
Environmental Sustainability	Avg. fuel savings per flight as a result of ATM improvements	2005			10%
	Avg. CO_2 emission per flight as a result of ATM improvements	2005			-10%
	Compliance with local environmental rules			100%	
	Number of proposed environmentally related ATM constraints subjected to a transparent assessment with an environment and socio-economic scope			100%	

Figure 2.28. Summary of the 2020 Performance Targets. Source: European Air Traffic Management Master Plan, Eurocontrol

If these targets are compared to today's data, it can be noticed that some of them will not be reached by 2020. It is the case of the target about annual IFR flights in Europe. There were 10 million controlled flights in 2016 and it is expected that there will be 11 million flights in 2020 (see the following figure 2.29), which is significantly lower than the target of 16 million flights in 2020 set in 2005.

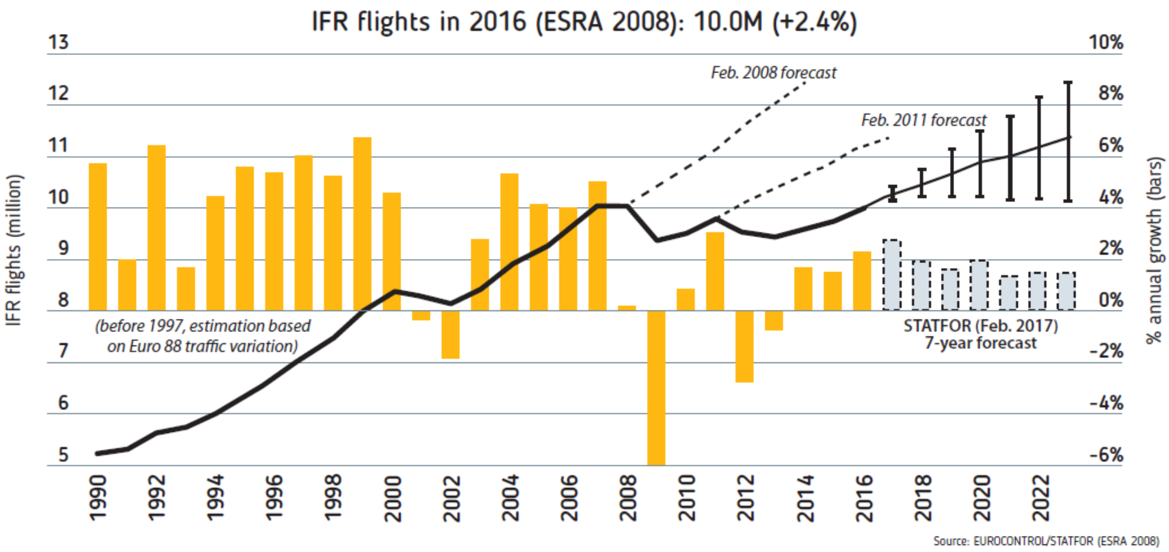


Figure 2.29. Evolution of European IFR flights (1990-2023). Source: Eurocontrol Annual Report 2016, Eurocontrol

Usually, macro-projects do not fulfil the expected research and implementation times, resulting in important delays or even cancellations. In this context, the differences among the real data and the targets set are due to a cluster of external and internal factors and it is expected that future research and developments follow the same guidelines. Indeed, some of the current developments related to new targets within the ATM Master Plan are suffering delays in their implementation.

For example, the implementation progress of the "Advanced Surface Movement Guidance and Control System (A-SMGCS) Level1" objective is completed at 79% but it is not fulfilling the expected deadline as can be seen in the following figure 2.30. As it is shown, it will present a 7-year delay when it is fully deployed in 2018. This is a problem in such a way that this objective is pre-requisite for other objectives and a first step in order to complete subsequent functions, producing important delays and related issues.

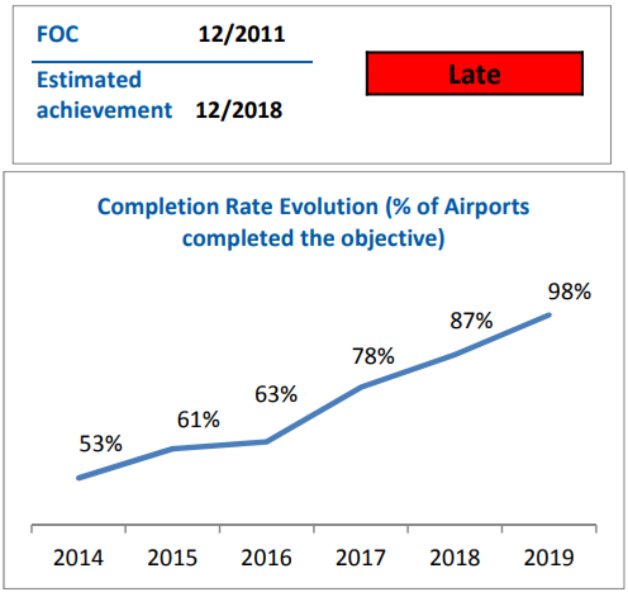


Figure 2.30. Advanced Surface Movement Guidance and Control System implementation progress. Source: ATM Master Plan monitoring, Eurocontrol

As a different example from the previous one, consisting of a project related to the flexible use of airspace, the implementation progress of the "Free Route Airspace" objective is completed at 61% and it is fulfilling the expected deadline as can be seen in the following Figure 2.31:

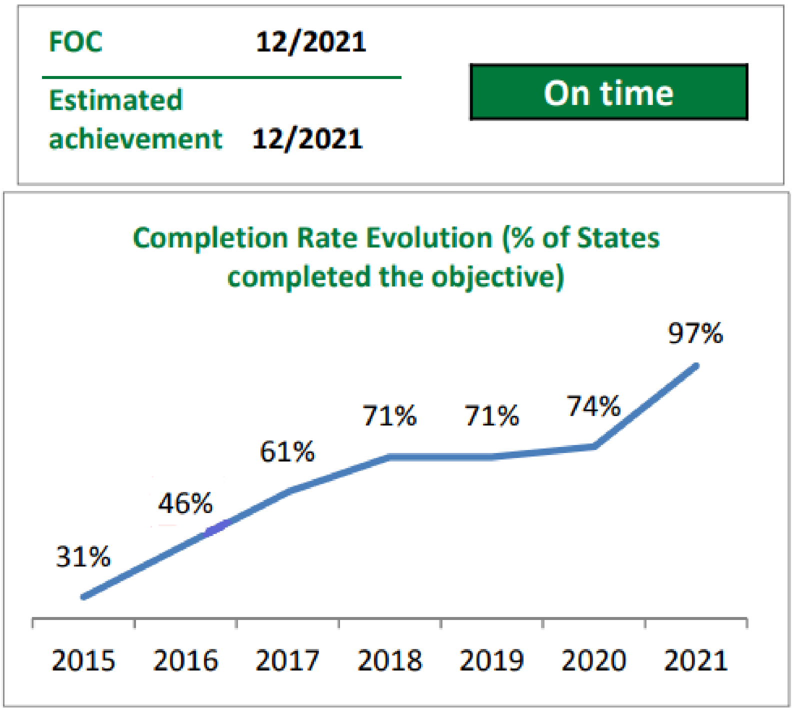


Figure 2.31. Free Route Airspace implementation progress. Source: ATM Master Plan monitoring, Eurocontrol

In this context in which is widely recognized that to increase performance, ATM modernization should look at the flights within a flow and network context rather than segmented portions of its trajectory as is the case today. Upcoming research and developments must be previously studied in order to make a wide research framework in which each project has both enough funds and duration to achieve its goals. The fact of trying that this wide framework is defined under previous studies will allow closing the gaps remaining between the goals set for 2050 and the actual improvements reached in 30 years.

If these studies about investment and duration are carried out properly, it is expected that the outcomes of the research are excellent, reducing en route and TMA direct costs per flight, reducing delays, fuel burn and flight time and improving the throughput at congested airports. The following Figure 2.32 illustrates the outcome for the optimized ATM infrastructure deployment option where performance benefits outgrow the investment ambition as of 2018, and cumulative benefits outgrow cumulative investments as of 2020 if all performance gains resulting from the performance scheme target-setting for the period 2014-2019 (RP2) are realized.

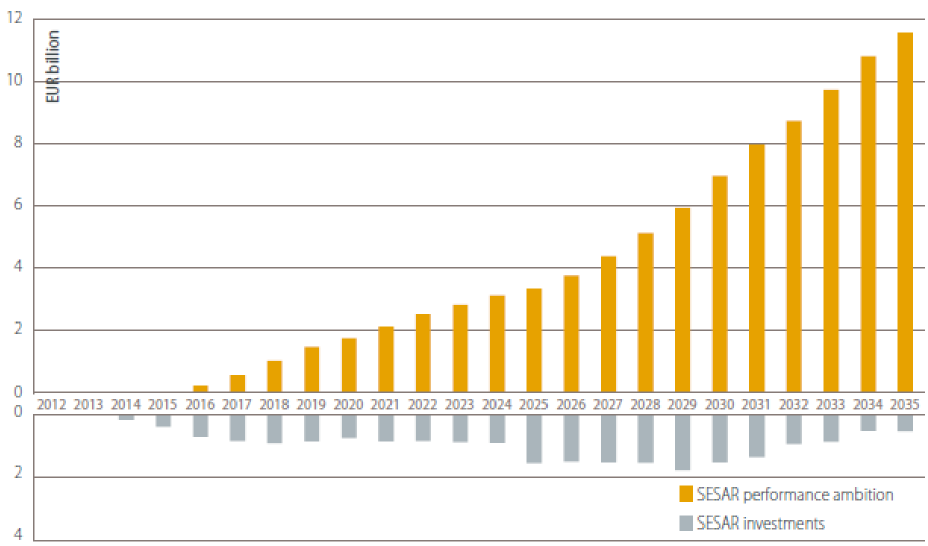


Figure 2.32. Comparison between investments and benefits. Source: European ATM Master Plan, Eurocontrol

2.2. Ground Infrastructure and Multimodal Transport

*Flightpath 2050 goal 2: "A coherent ground infrastructure is developed including: airports, vertiports with the relevant servicing and connecting facilities, also to other modes"

The movements around an airport consist of aircraft operations in the air (goal 1 and section 2.1) and also the taxying of aircraft and other vehicles on the ground. The ground movements in an airport can be quite complex involving besides taxying aircraft, on their own power or towed, but also a variety of other vehicles, such as passenger buses, fuel trucks, luggage trailers, catering services, etc. The potential for incidents, especially in fog and other low visibility conditions, should not be underestimated. The tracking of vehicles on the ground can be made more difficult by buildings or other obstructions. The optimization of aircraft ground movements can save fuel in taxying, energy of towing vehicles, reduce landing and take-off queues and contribute to the timeliness of passenger services. The optimization of the use of runways, parking areas, and passenger ingress and egress, and aircraft taxiways should not be compromised by movements of other ground vehicles that provide essential services.

Besides the issue of ground movements, that can be of considerable complexity, and offer the potential for gains in efficiency, there are other possible bottlenecks, such as (i) luggage handling; (ii) passenger check-in, passport and security checks; (iii) interfaces with other modes of transport. It may happen that the main impact of an airport on the surrounding community comes not from aircraft operations but rather from ground infrastructure, including airport access, that also affects passenger convenience.

As air traffic grows, a particular airport may reach its capacity limits, for one or more of several possible reasons: (i) runway capacity; (ii) terminal area air traffic congestion; (iii) available aircraft parking spaces; (iv) passenger and cargo management; (v) noise curfews or local restrictions on operating hours. The option of building more runways depends on land availability and community acceptance.

New airports to serve major cities tend to be built farther requiring faster transport to reduce access time.

Vertiports and heliports can be sited much closer to city centres, providing an alternative with faster access than airports, if noise and community issues can be resolved.

The integration of air transport ground infrastructure with other modes of transport is presented in the Key Topic T2.3 below:

KEY TOPIC T2.3 – GROUND AND AIR OPERATIONS

Introduction

Europe is a specific area with very high population density, with short distances between large urban centres. This makes Europe's transport system characterized by a dense network of connections at short distances, with large passenger flows between transport nodes. This situation also concerns air transport.

The European Union (EU) is a political and economic union of 28 Member States that are located primarily in Europe.

Therefore, it has consequences resulting from the combination of law systems and transportation systems in one. The fragmentation of different national systems that existed before the unification of the EU is still felt.

Contrary to the United States, Europe does not have a single sky, one in which air navigation is managed at the European level. Furthermore, European airspace is among the busiest in the world with over 33,000 flights on busy days and high airport density. This makes air traffic control even more complex.

The EU Single European Sky is an ambitious initiative launched by the European Commission in 2004 to reform the architecture of European air traffic management. It proposes a legislative approach to meet future capacity and safety needs at a European rather than a local level.

The Single European Sky is the only way to provide a uniform and high level of safety and efficiency over Europe's skies.

The key objectives include:

- Restructure European airspace as a function of air traffic flows
- Create additional capacity; and
- Increase the overall efficiency of the air traffic management system

The major elements of this new institutional and organisational framework for Air Traffic Management in Europe consist of:

- Separating regulatory activities from service provision, and the possibility of cross-border Air Traffic Management (ATM) services.
- Reorganising European airspace that is no longer constrained by national borders.
- Setting common rules and standards, covering a wide range of issues, such as flight data exchanges and telecommunications.

SESAR

As part of the Single European Sky initiative, SESAR (Single European Sky ATM Research) represents its technological dimension. It will help create a "paradigm shift", supported by state-of-the-art and innovative technology.

The SESAR programme will give Europe a high-performance air traffic control infrastructure which will enable the safe and environmentally friendly development of air transport.

SESAR aims to eliminate the fragmented approach to European ATM, transform the ATM system, synchronise all stakeholders and federate resources. For the first time, all aviation players are involved in the definition, development and deployment of a pan-European modernisation project.

By implementing the SESAR concept in 2020, ATM-related CO2 emissions should be reduced by 10% per flight (against a 2005 baseline);

- Improve the management of noise emissions and their impact through better flight paths, or optimised climb and descent solutions;

Improve the role of ATM in enforcing local environmental rules by ensuring that flight operations fully comply with aircraft type restrictions, night movement bans, noise routes, noise quotas, etc.

Taking into account the above facts, it can be stated that the specificity of the European air traffic market and the growing number of flights performed in the European airspace generate growing challenges, the most important of which are: airport capacity, sustainability, operating a highly-congested air traffic network, fully-exploiting SESAR, and climate change. Airspace capacity is a major challenge that can be eased by the use of alternative airports. This is a major contributor to face the airport capacity challenge as well.

European airports

The European air traffic network contains about 170.000 links between airports. Understanding the variety of airports in Europe, their distribution, their traffic patterns and their aircraft mix, is essential to understand the strengths of the air traffic network. Taking into account short distances between the European cities, transportation on the territory of Europe is performed mainly over short and medium distances, with the predominance of the former. The European transport market is, therefore, an area of competition between road, rail and air transport.

A characteristic feature of the European air transport service market is co-existence of several but large communication centres performing trans-continental links and dense net of local links between the majority of small cities and tourist resorts. In Europe, there are (Figure 2.33) about 45 main airports (large and medium hubs) and about 450 country and regional airports (commercial service airports) (Brusow et al., 2007). European airports have almost 1350 hard take-off runways (concrete or asphalt) and 740 airports have the necessary equipment to perform IFR flights (Brusow et al., 2007; Eurocontrol, 2007; Eurocontrol, 2016). In 2015, approximately 9.917 million IFR flights were performed in Europe and the forecast for 2022 assumes a 3.8 per cent increase in the number of IFR flights, which is an equivalent to 12.868 million take-offs, and the same number of landings, in the European airports (EUROCONTROL, 2016). There are serious bottlenecks in the air, especially in ECAC core areas caused by the situation where 85% of air activity is generated by 45 main airports (Brusow et al., 2007; Eurostat). This results in a very high air traffic density in the largest European airports and in their vicinity. What it involves is that the air traffic in the largest airports and their areas of operations approaches the capacity limits.

In 2016, the total number of passengers travelling by air in the European Union could be established at 973 million, an increase of 5.9 % compared to 2015. Figure 2.34 shows the total growth of air passengers by Member State between 2017 and 2018. The disparity is particularly marked at country level, with year-on-year growths ranging from -2.7 % in Belgium to +22.5 % in Bulgaria.

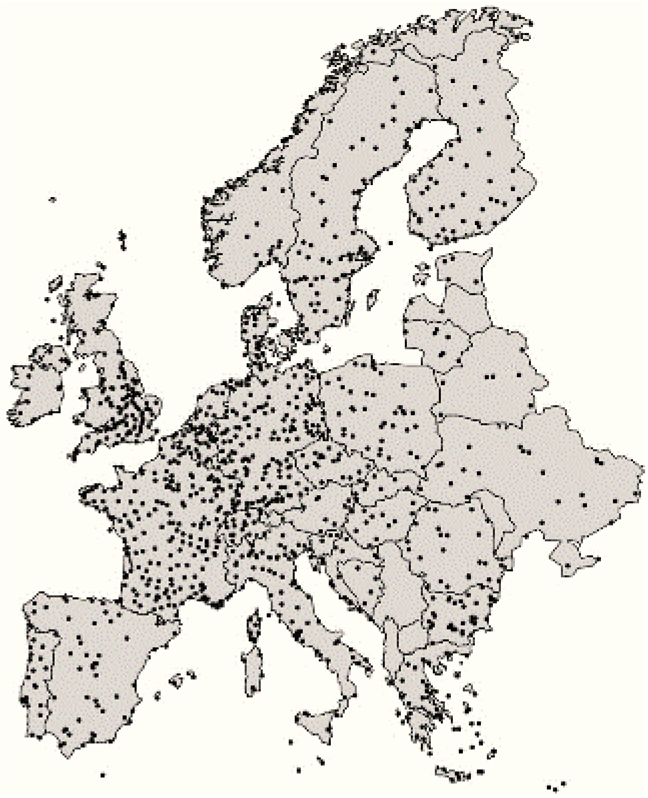


Figure 2.33. The map of airports in Europe[3]

[3] Brusow W., Klepacki Z., Majka A., (2007), Airports and Facilities Data Base.

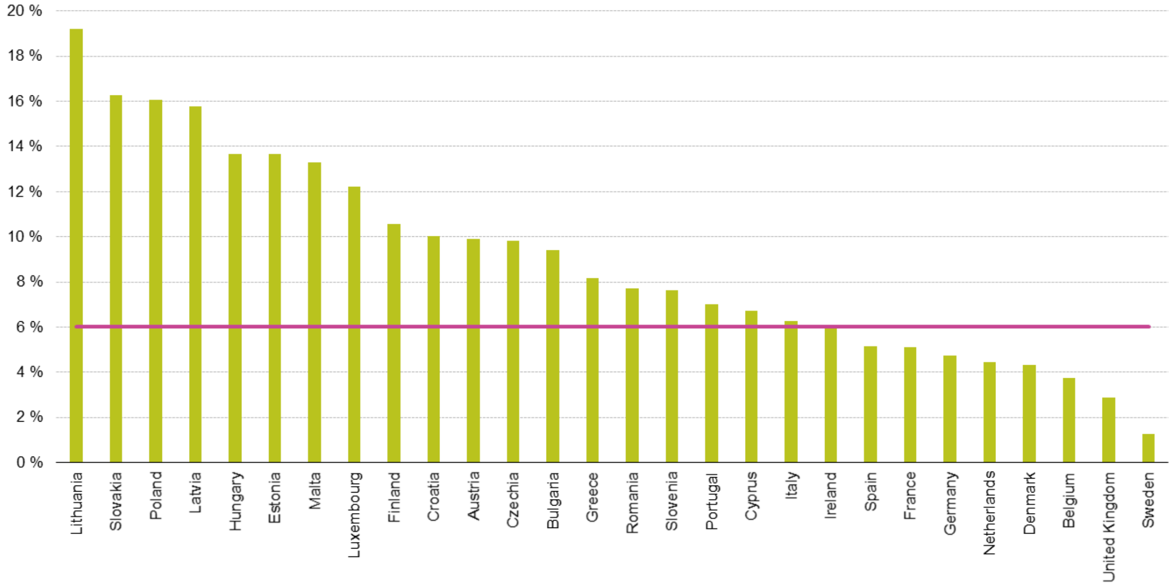


Figure 2.34. EU-28 growth in total passenger air transport by Member State, 2017-2018 (Eurostat)

The Figure 2.35 indicates that the intra-EU share in total transport could be established at 46 %. It was the main destination ahead of extra-EU transport (37 %) and domestic passenger transport (16 %).

In 2018 (Table 2.10), London/Heathrow remained the largest EU-28 airport in terms of passenger transport. Paris/Charles de Gaulle remained the second largest with almost 10 million passengers less than London/Heathrow.

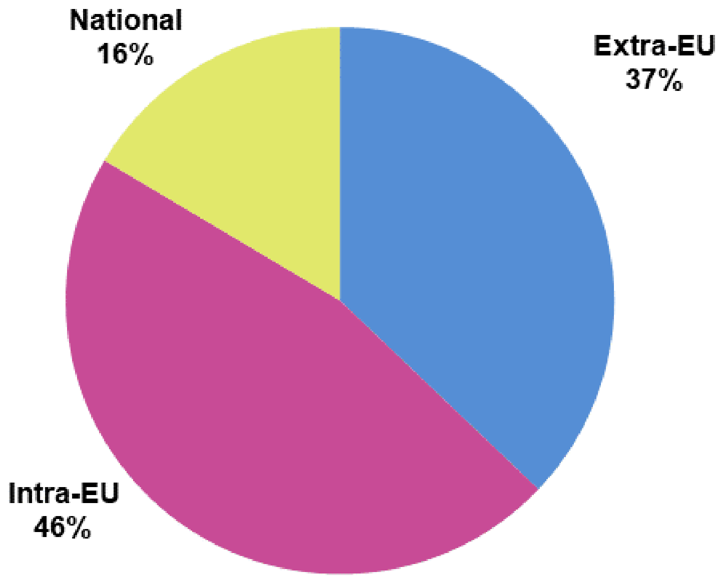


Figure 2.35. Overview of EU-28 air passenger transport in 2018 (Eurostat)

Rank	Country	Airport	Total air transport (in 1000 passengers)	of which			Growth of total air transport 2017-2018 (%)	Total number of passenger flights (in 1000)	Growth of total number of flights 2017-2018 (%)
				National air transport	International intra-EU-28 air transport	International extra-EU-28 air transport			
1	UK	LONDON/HEATHROW	80 100	4 793	27 730	47 577	2.7	477	1.2
2	FR	PARIS/CHARLES DE GAULLE	72 196	6 472	28 257	37 468	4.0	451	1.0
3	NL	AMSTERDAM/SCHIPHOL	70 979	1	42 151	28 828	3.7	487	1.1
4	DE	FRANKFURT/MAIN	69 386	7 601	30 684	31 102	7.8	483	8.0
5	ES	MADRID/BARAJAS	56 478	15 952	24 769	15 758	8.6	380	6.2
6	ES	BARCELONA/EL PRAT	49 594	13 427	27 190	8 978	6.0	318	3.9
7	DE	MÜNCHEN	46 206	9 662	22 951	13 593	3.8	394	2.2
8	UK	LONDON/GATWICK	46 081	3 729	28 633	13 719	1.2	283	0.1
9	IT	ROMA/FIUMICINO	42 894	11 464	18 056	13 374	5.0	308	4.3
10	FR	PARIS/ORLY	33 115	14 125	11 354	7 636	3.4	229	0.0
11	IE	DUBLIN	31 225	98	25 257	5 870	6.4	218	5.0
12	DK	KØBENHAVN/KASTRUP	30 192	1 836	19 746	8 609	3.7	254	2.6
13	ES	PALMA DE MALLORCA	29 069	7 012	20 833	1 224	4.0	207	6.8
14	PT	LISBOA	29 046	3 633	17 887	7 526	8.9	216	9.2
15	UK	MANCHESTER	28 256	2 552	17 778	7 926	1.7	193	-0.9
16	UK	LONDON/STANSTED	27 995	1 945	23 964	2 086	8.1	176	8.6
17	AT	WIEN/SCHWECHAT	27 025	581	17 546	8 897	11.1	234	7.6
18	SE	STOCKHOLM/ARLANDA	26 841	5 285	15 221	6 335	1.0	231	-1.6
19	BE	BRUSSELS/NATIONAL	25 637	3	17 174	8 461	3.5	208	-1.6
20	DE	DÜSSELDORF	24 256	4 184	12 530	7 542	-1.4	209	-1.4
21	IT	MILANO/MALPENSA	24 148	4 017	12 327	7 804	9.6	178	8.8
22	EL	ATHINAI/ELEFTHERIOS VENIZELOS	24 130	7 736	11 278	5 116	11.1	205	11.4
23	DE	BERLIN/TEGEL	21 991	8 112	9 958	3 921	7.5	180	8.0
24	FI	HELSINKI/VANTAA	20 990	2 976	12 510	5 505	10.6	181	9.0
25	ES	MALAGA/COSTA DEL SOL	18 927	2 738	14 680	1 510	1.9	130	3.9
26	PL	WARSZAWA/CHOPINA	17 772	1 749	10 213	5 810	12.8	172	7.2
27	DE	HAMBURG	17 198	5 161	8 551	3 487	-2.2	139	-3.7
28	CZ	PRAHA/RUZYNE	16 810	29	11 536	5 245	9.4	139	5.7
29	UK	LONDON/LUTON	16 767	1 197	13 685	1 884	4.9	105	0.5
30	HU	BUDAPEST/LISZT FERENC INTERNAT	14 801	0	11 226	3 575	13.6	102	12.6
34	RO	BUCURESTI/HENRI COANDA	13 819	1 379	10 145	2 295	7.9	114	5.6
55	CY	LARNAKA	8 057	0	4 979	3 078	4.3	58	3.4
60	LV	RIGA	7 037	11	4 984	2 043	15.8	78	13.0
61	BG	SOFIA	6 932	309	5 621	1 002	7.0	52	4.8
63	MT	LUQA	6 806	0	6 179	627	13.3	47	14.5
83	LT	VILNIUS	4 920	0	3 538	1 382	30.9	42	20.1
91	LU	LUXEMBOURG	3 988	0	3 599	389	12.2	55	8.1
96	HR	ZAGREB/PLESO	3 322	499	1 877	946	7.8	38	4.5
106	EE	LENNART MERI TALLINN	2 996	28	2 330	638	13.7	40	8.3
125	SK	BRATISLAVA/M.R.STEFANIK	2 273	13	1 606	654	17.9	29	86.6
139	SI	LJUBLJANA/BRNIK	1 811	0*	1 111	700	7.6	25	3.8

Table 2.10. Top airports in the EU-28 in terms of total passengers carried in 2018 (Eurostat).

More traffic in Europe will mean busier airports. In 2035, 20 airports will handle more than 150,000 departures a year in the most likely scenario, a level of traffic currently achieved only at 9 airports in Europe (Table 2.10). Some faster-growing airports in Southern and Eastern Europe will join the top 25 (Eurocontrol, 2013).

Airport movement

Traffic in the area of a civil airport consists of two types of activity. The first concerns the movement of aircraft in the area of the airport (ground and air operations), the second concerns the movement of all kinds of non-aircraft vehicles necessary for the operation of the airport.

Aircraft operations

Standard aircraft procedures consist of:

- Parking: intended for parking, maintenance and service an aircraft.
- Push back or power back operations.
- Towing the aircraft
- Taxi out and taxi in operations,

- Take-off,
- Landing.

Parking, push back or power back and towing procedures generally are called aircraft ground handling servicing. Taxi, take-off and landing constitute LTO (Landing and Take-Off) cycle. The main problem to be solved relates to increasing airport capacity and reducing delays and costs and reducing the environmental impact of air transport, especially in the airports surrounding areas. Sources of these problems lie in both handling procedures and LTO operations.

➢ Aircraft LTO Operations

Aircraft operations and procedures are highly regulated. For example, different recommendations are present for the take-off climb procedure for performance class A aeroplanes. According to Certification Specifications (EASA, 2017), the transition from the take-off to the en route configuration and the acceleration to the final climb segment speed must be completed before the aircraft reaches 1500 (ft) net altitude (CS-25.111 (a) – EASA, 2017). The take-off path is determined by a continuous take-off path or by synthesis from segments which relate to distinct changes in configuration, power or thrust, and speed (CS-25.111 (d) – EASA, 2017). Thus, the aircraft must be 'cleaned up' in a manner preordained in CS's. The regulations specify that whilst the transition is taking place, the aircraft must avoid all obstacles that are in the 'obstacle accountability area' by a minimum vertical interval of 35 (ft) or by the horizontal distance detailed in EU-OPS 1.495. The flight path determined for the aircraft commences therefore at the end of the take-off distance required at screen height and is constructed by assuming the critical engine to be inoperative (CS-25.115(a) – EASA, 2017).

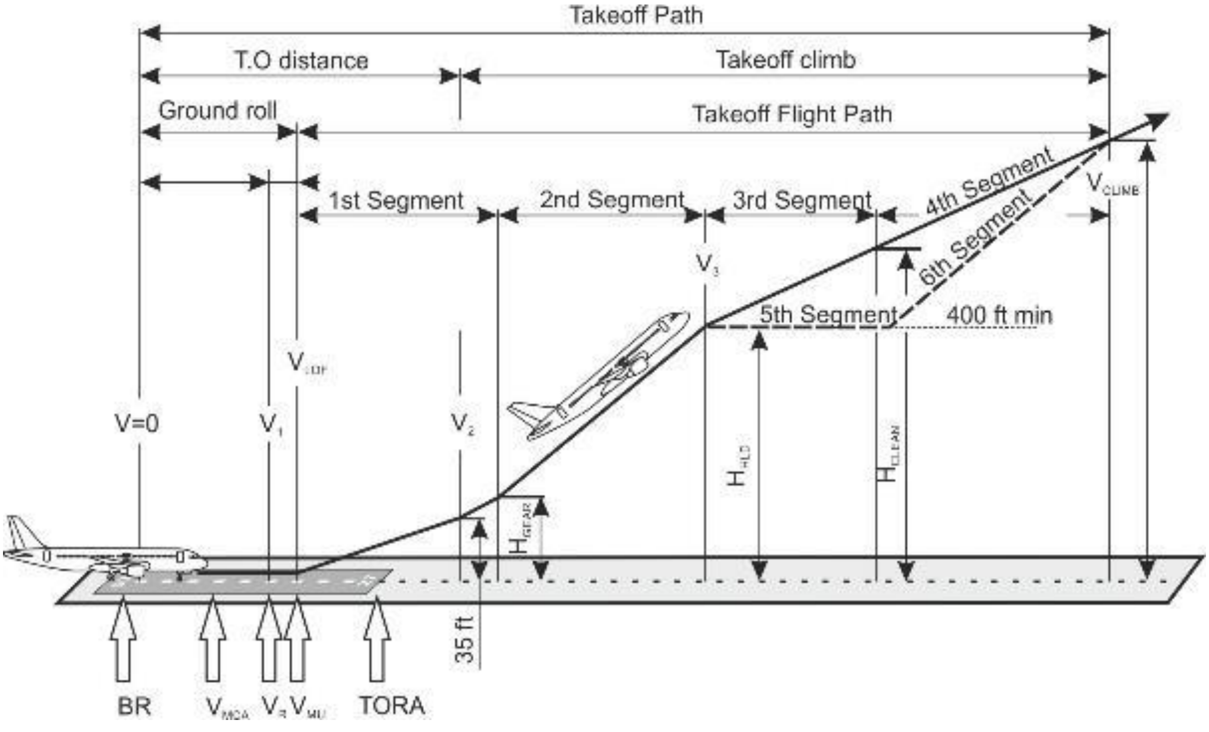


Figure 2.36. Typical six-segment net flightpaths. Source: Own elaboration based on EASA, 2017

As shown in the Figure 2.36, the segments of the flight path are also defined in detail. 1st Segment - this segment commences at screen height (CS-25.115(a) – EASA, 2017) at the end of the take-off distance required at which point the undercarriage 'UP' button is pressed. The speed is V2, free air safety speed, and the power set at maximum take-off power one engine inoperative. The segment ends when the undercarriage is fully retracted and is the start of the second segment. 2nd Segment - the speed and power are maintained until the aircraft attains flap retraction altitude (minimum 400 (ft) gross). The segment ends on the attainment of this altitude which is the commencement of the third segment. The first and second segments are referred to as the 'Initial Climb'. 3rd Segment - this segment is an acceleration segment; it may be level or still climbing if sufficient power is available. The segment ends when the aircraft, after flap retraction, achieves the final segment climb speed which signifies the beginning of the 'Final Climb'. The maximum height of flap retraction is dependent on the take-off thrust maximum time limit. 4th Segment - this is the final climb. The power setting must be reduced after 5 minutes from the brakes release point, to the maximum continuous power setting. The speed is maintained at the final segment climb speed. The net flight path ends at 1500 (ft) net height. 5th and 6th Segment - some low powered aircraft might require further two segments to reach 1500 (ft) and the en route climb speed.

At airports, aircraft emission amounts vary by aircraft operation modes and depend on the time spent at each mode/phase during the Landing and Take Off cycle (LTO). LTO includes all activities near the airport that take place below the altitude of 3000 feet (1000 m), which consists of taxiing-out, taking-off and climbing out for departures, and descending, touching down, and taxiing-in for arrivals.

Other Ground Movements

Handling activities related to aircraft during ground time may be a significant contributor to local air pollution at an airport. Such activities include all vehicles and machinery serving the aircraft on its parking position (e.g. high loaders, baggage belts, passengers' stairs) and circulating on airside operating surfaces and service roads (e.g. lavatory trucks, catering trucks, cargo tractors).

In the context of local air quality management, it is important to assess the emissions of different sources for various pollutants. Example emission by source groups for Zurich airport is presented in the Figure 2.37:

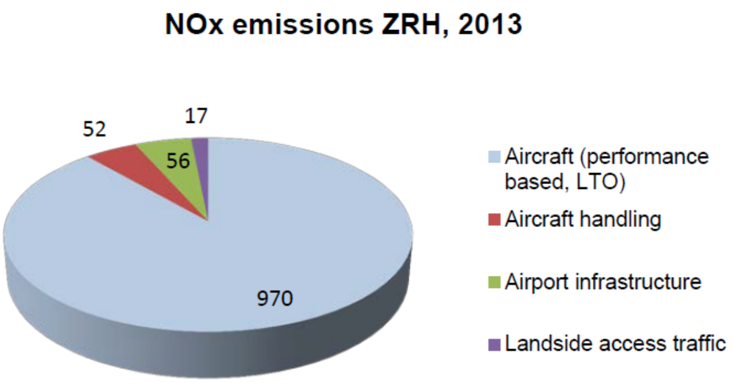


Figure 2.37. NOx emission by source groups (Fleuti, 2014).

The interdependencies of aircraft ground handling are qualitatively characterised in the Figure 2.38. It has to be recognised that the type and number of Ground Support Equipment (GSE) are determined by the aircraft (size) and the aircraft stand (location and installations) as well as applicable operational procedures at the airport (e.g. APU restrictions). In consequence, any default attribution of ground support equipment must be reflected by all factors.

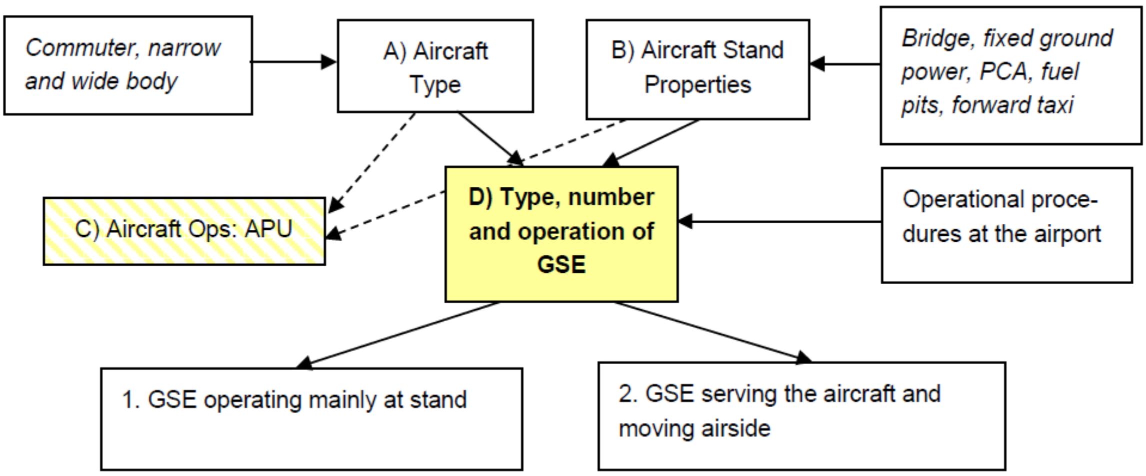


Figure 2.38. Characterization of GSE (Fleuti, 2014).

GSE is used the moment an aircraft lands and until it takes off. GSE is used for tasks as diverse as towing, powering, and servicing. There is great diversity in the type of equipment used, as well as in the variety of engines (diesel or gasoline) that power GSE. The commonly used types of GSE are:

- **Baggage Tugs** (or Tractors) transport luggage or cargo between aircraft and terminals.
- **Belt Loaders** are a self-propelled conveyer belt that moves baggage and cargo between the ground and the airport.
- **Forklifts, Lifts, and Cargo Loaders** include equipment for lifting and loading cargo.
- **Ground Power Units (GPUs)** provide electricity to parked aircraft.
- **Aircraft Tugs** (pushback tractors) tow aircraft in areas where aircraft cannot use their own engines for motion. These are generally the areas between the taxiway and the terminal and between the terminal and the maintenance base.
- **Air Start Units** are trailer or truck-mounted compressors that provide air for starting up the aircraft's main engines.
- **Air Conditioning Units** are trailer or truck-mounted compressors that deliver air through a hose to parked aircraft for cabin ventilation and engine cooling.
- **Deicers** are trailers equipped with tank, pump, hose, and spray gun to transport and spray de-icing fluid on aircraft (to ensure that no ice builds upon the body of plane or in turbines).
- **Lavatory carts** are used to service aircraft lavatories. Other types of carts can be used to transport equipment and personnel.
- **Fuel Trucks, Utility Trucks, Maintenance, Water and Service Trucks** are used on the airside of the airport for many diverse tasks.
- **Bobtail Tractors** are on-road trucks modified to tow trailers and equipment.

The objective of reducing emissions at airports may be served by not using aircraft engine power for taxiing but using tugs, and not using the aircraft APU (Auxiliary Power Unit), being replaced by GSE.

A cost-effective way to reduce emissions is to replace GSE powered by an internal combustion engine with electric equipment. Electric equipment has no exhaust emissions and replacing equipment powered by ICE (internal combustion engine) engines with electric equipment will reduce NOx emissions. Electric GSE is commercially available for a number of equipment types, including belt loaders, baggage tractors, aircraft tugs, lifts, and GPU's. Several airlines and airports have conducted electric GSE demonstration programs and fleet conversion programs. Much of the experience to date with electric equipment has been quite positive. In addition to air quality benefits, users have found that electric equipment is more "task-specific" than ICE equipment. Electric equipment often includes more ergonomic features and users find that it "rides better" than equivalent diesel equipment. However, the higher capital cost of electric equipment has prevented its widespread use to date. It may also be necessary to increase the electric power available at airports.

Other airport impact on climate change

The other airport infrastructure also affects the natural environment and contributes to climate change. It is possible to indicate the sources resulting, for example, from the need to supply electricity to airport buildings, heating and cooling in the airport's building, etc.

This impact can be reduced by:

- Reduction of energy consumption by retrofitting of LED technology or retrofitting of airport buildings (roof, air-conditioning, etc.)
- Use of renewable sources of energy, i.e. purchase of green electricity, production of energy from renewable sources (solar, co-generation, aquifer, biomass, etc.).
- Others.

Airports bottlenecks

Airport handling

Many processes take place while the aircraft is parking, which extends the aircraft handling time. Some of them can be carried out at the same time and some require a proper order. The workload and time of these processes have a significant impact on airport capacity and may be some kind of bottleneck.

The effectiveness can be characterised by turn-around time, which can be defined as the time between touch down and take off. The conceptual model of the activities in the turn-around process is presented at the Figure 2.39:

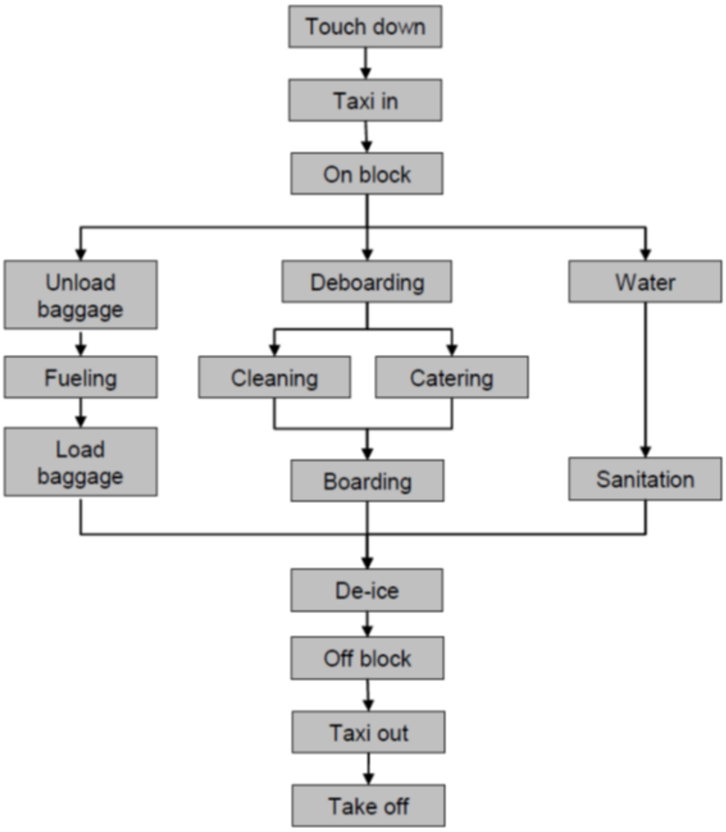


Figure 2.39. Typical turn-around activities (Norin, 2008).

➢ The Baggage Loading and Unloading Process

Checked in baggage can be stowed in the aircraft in two different ways. Either the bags are stowed in bulk (normally smaller aircraft) or pre-packed containers (for larger aircraft). As the containers can be packed before the aircraft arrives at the airport, the turn-around process time for loading baggage will be shorter with container loading than with bulk if the number of bags is large. The checked-in baggage on a flight has to be sorted, unless it is a charter flight (or other point-to-point flight) were all bags have the same priority and destination. Otherwise, there might be transferring of bags, high prioritized bags or odd-size bags etc.

➢ The Catering Process

The catering process involves removing leftover food from the previous flight and re-equipping the aircraft with new food. The catering can start when all passengers have left the aircraft. The catering companies use high-loaders to get the catering cabinets on and off the aircraft. All high-loaders do not fit all aircraft, so planning of which high-loader to use for which aircraft is required.

Catering takes between 5 and 75 minutes depending on how much food is needed and if there are pre-packs (pre-ordered commodities placed on the seat) or not. The catering teams need to go back to the depot between serving two aircraft to empty garbage and re-equip with new food.

The catering coordinator makes a rough plan from the air traffic schedule for how many workers are needed and the detailed planning of who is serving which aircraft is done manually during the day.

- The Cleaning Process

The airlines can request different types of aircraft cleaning. During the daytime, the cleaning can take from 5 (just empty garbage) up to 40 (garbage, seat-pockets, belts, vacuum-cleaning etc.) minutes. The latter is only performed on aircraft with longer turn-around-times. Longer and more careful cleaning is performed during night-time when the aircraft is on the ground for a longer time. On most aircraft, cleaning and catering can be performed simultaneously, but for some smaller aircraft, there is no space for both. In the latter case, it does not matter if cleaning or catering is performed first.

The cleaning teams can go directly between two aircraft, but during breaks and when they need new material (like pillows and blankets) they must go to the cleaning base. There is no significant difference between the cleaning teams, so all teams can be assigned to all aircraft and cleaning types.

- The Fuelling Process

Usually, fuelling can be performed in two different ways. There is a hydrant system with fuel pipes in the ground that dispenser trucks can connect to, to fill up the aircraft. At aircraft stands where the hydrant system is not available, fuelling is performed by tankers. There are different types of dispenser trucks; the large type that can serve all kinds of aircraft and the smaller type that only can connect to smaller aircraft. However, the small dispensers are preferred when the area around the aircraft is tight. Also, tankers vary in size. Normally they can take between 8 and 40 cubic meters of fuel.

Fuelling cannot be performed simultaneously with baggage loading and unloading since these services need the same area around the aircraft. Before the fuel company starts to fill up, they always check the water content in the fuel. The area around the aircraft has to be planned so that the dispenser truck or tanker has a freeway for evacuation. There are also some airline-specific rules about fuelling while passengers are on-board. Most airlines allow that, but only under certain conditions, e.g. there must be a fire engine ready in the immediate surrounding or there must be two-way communications between apron and aircraft. Usually, the fuelling is not allowed if there is a thunderstorm.

The time it takes to fill up an aircraft depends on the capacity of the pipes in the aircraft and, of course, of the amount of fuel needed. The pilot decides how much fuel is needed and must report that to the fuelling company before they can start to fill up the aircraft.

- The Water and Sanitation processes

The aircraft must be released from waste water and be re-equipped with fresh water. This is performed by two different vehicles which most often are operating on the opposite side of the aircraft body than baggage handling and fuelling. This means that water and sanitation can be performed simultaneously with baggage loading/unloading and fuelling, but not simultaneously with each other. However, it does not matter which one of them that performs its service first.

- The De-icing Process

Since even very thin layers of frost and ice on the aircraft have a negative effect on the lifting force and the control of the aircraft, de-icing is needed if any part of the aircraft is covered with snow or frost, or if there is precipitation that could cause this to happen. The de-icing period depends on the climate zone and specific weather conditions. The de-icing process is divided into two steps; during the first step, frost and ice are removed from the aircraft, usually by a warm, buoyant glycol mix (Type 1 fluid). The next step is called anti-icing and is performed to prevent new frost and ice from appearing on the aircraft before take-off by a thicker fluid (Type 2 fluid). The time from anti-icing to take-off (called hold-over time) is limited, as the effect of the Type 2 fluid wears off after a while. This means that it is not possible to de-ice an aircraft a long time before take-off. How long the hold-over time is depending on the type of fluid, temperature and type of precipitation. Therefore, it is important to find a de-icing truck that can serve the aircraft on the "right" time. If the aircraft is served late, the turn-around time will increase with a possible late departure as a result. If the de-icing is performed too early, the procedure might have to be repeated. Even so, this would be a fairly uncomplicated planning problem, if only the time windows were known in advance and could be considered reliable. Today, the de-icing coordinator will plan tactically based on weather conditions and the flight schedule, and operationally – when a truck is dispatched – based on a request from the pilot. At the moment the coordinator gets the request, he or she decides which truck that should be allocated to the aircraft in question. Today, there is no pre-planned schedule that the decision can be based on. This means that the truck-drivers do not know in advance which aircraft they are going to de-ice during the day.

Interfaces with other modes of transport

➢ High-Speed Train

High-speed train (Figure 2.40) both competes with and complements short-haul passenger air transport. Over 50 city-pairs will be connected by new or improved links between 2019 and 2035. Operating at high speeds, the train can offer comparable transport times for distances up to 800 km. It can also successfully attract passengers by providing in some cases a lower risk of delay, less security hassle, shorter distance to the city centre. Passengers opting for rail will reduce the demand for flights by a little over 0.5% in 2035, often easing the pressure at congested airports rather than reducing the number of operated flights (Eurocontrol, 2013).

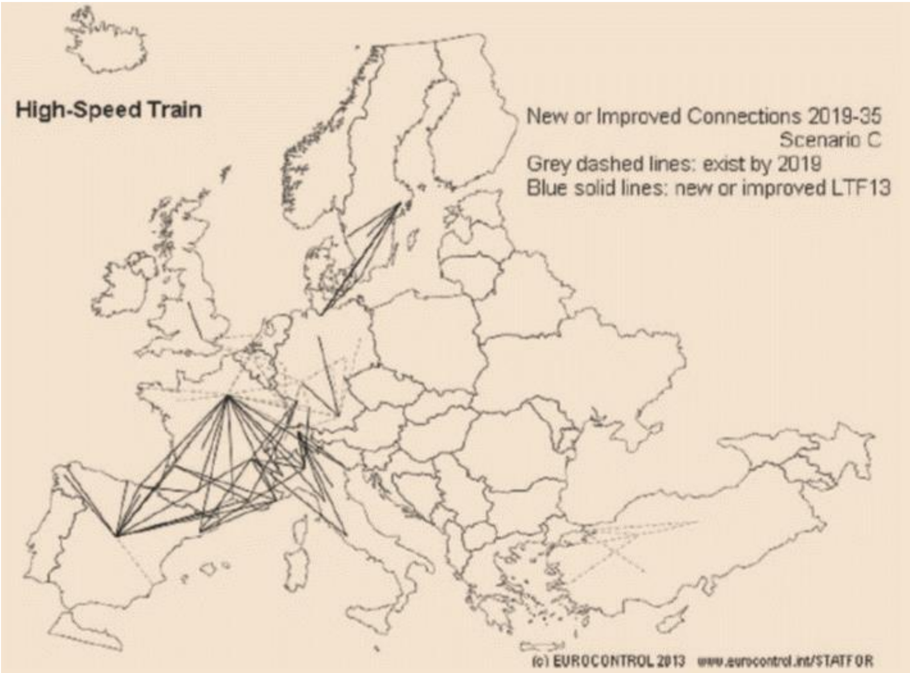


Figure 2.40. High-speed rail network mostly develops in Western Europe (Eurocontrol, 2013)

Airport capacity limits

Airspace capacity is the decisive factor in allocating the maximum number of air operations that can be performed, especially in the airport areas (bottlenecks). That capacity is also dependent on the principles of performing air operations in the airport areas

Airports are constrained in different ways by different types of capacity. Airport capacity is the number of passengers and amount of cargo which an airport can accommodate in a given period; it is a combination of runway capacity and terminal capacity (ICAO, 2016). Capacity definitions can be categorized by considering the constraining element (Figure 2.41), and then divide definitions into technical capacity, acceptable capacity and allowed capacity (Boonstra et al, 2016).

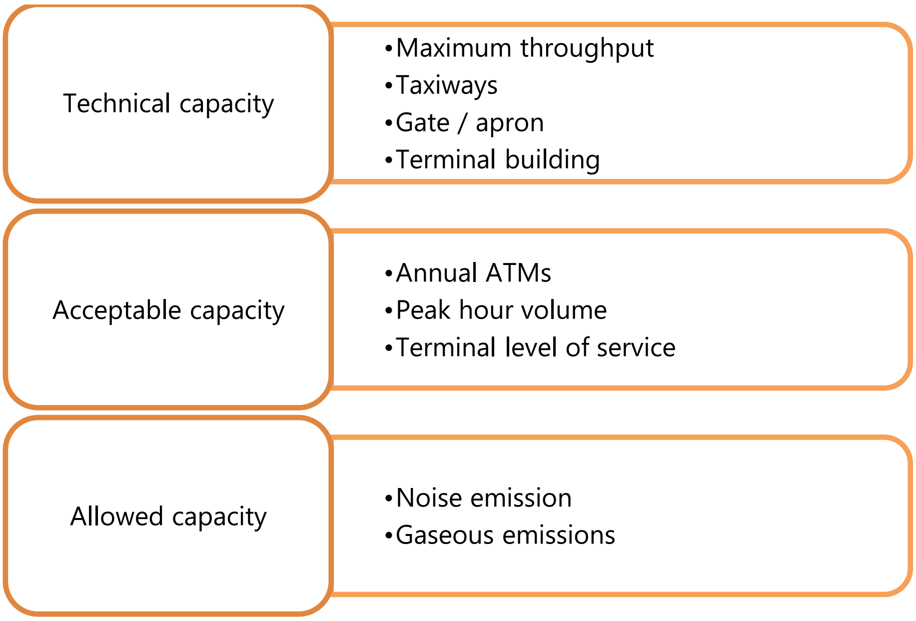


Figure 2.41. Airport Capacity Constraints

Technical capacity is defined as the maximum number of aircraft or passengers that can be accommodated in a certain period when there is continuous demand. It is affected by the physical constraints of the available infrastructure, such as the maximum throughput figure of a runway or the maximum number of passengers based on the limited terminal space available.

Acceptable capacity is the maximum number of aircraft or passengers than can be accommodated in a certain period, taking into account a maximum allowable delay or waiting time per step in the airport process.

Allowed capacity is defined by regulations and legislation that balance economic importance against any problems that may be caused for the local population. For instance, a government or other authority might limit the annual number of ATMs based on the limits of maximum noise or gaseous emissions. No additional aircraft (or passengers) would then be allowed at an airport, even if there was physical room for expansion.

Runway capacity

Runway capacity is the number of aircraft movements which aeronautical authorities determine can safely be operated, usually stated as the total number of landings and take-offs per hour, taking into account such factors as the physical characteristics of the runways and the surrounding area, altitude, the types of aircraft involved (larger aircraft may mandate greater separation) and air traffic control (approach and aerodrome control) capabilities (ICAO, 2016).

A queue at the taxiway will occur when the maximum runway capacity is reached. This queue will only arise in the case of maximum peak hour capacity, and not necessarily in the case of maximum annual ATMs, which is more theoretical. If maximum environmental capacity is reached at one runway, aircraft may be required to use a different runway.

The capacities of the airports are driven by several factors. The number of runways is one of the main factors. The airports use one or several runways with finite capacity, which allocates the number of aircraft that the airport can handle safely. As the number of runways affects the capacity of the airport very strongly, the number of rapid exit ways or the meteorological conditions also influences the capacity. Because aircraft must be separated to avoid conflicts and wake vortices at the same time on the same runway, only one aircraft can take-off or land. The separations between the aircraft are necessarily higher at lower visibility conditions, or in a special case, a strong side-wind can radically limit the capacity of a runway. Besides, as recent events show (e.g. in London), extreme meteorological conditions and thus the capacity of the supporting equipment's (such as de-icer) could also limit the overall runway capacity.

Another problem is the saturation of major airports in Europe. The safe separation on approach is determined by the wake vortices. The larger the leading aircraft and smaller the following aircraft, the larger separation should be used. At most of the airports is not possible to build new runways because of the lack of territory, environmental considerations or public opinion.

The issues of improving airport capacity and efficiency were taken up in the SESAR programme. Currently, they are continued under the SESAR 2020 programme within the key feature 'High Performing Airport Operations'. Some important projects implemented in this area are:

- PJ01 - Enhanced arrivals and departures. As a part of the project, concepts, tools and procedures will be developed to increase the capacity of Terminal Manoeuvring Areas (TMAs) in a safe, cost-effective and environmentally sustainable manner. This will be achieved by taking advantage of the latest technological developments from both an airborne and a ground-system perspective and through the secure sharing of data. The needs of all Airspace Users will be addressed including General Aviation and Rotorcraft (WWW. SESAR JU).
- PJ02 - Increased Runway and Airport Throughput. As a part of the project, the concepts supporting increased runway and airport throughput were broken down into the following sub-elements: optimal Wake Turbulence Separation, enhanced arrival procedures, minimum Pair Separations based on Required Surveillance Performance (RSP), independent Rotorcraft operations at the airport, improved access into small/medium airports in Low Visibility Conditions (LVC), traffic optimisation on single and multiple runway airports and enhanced Terminal Area for efficient curved operations (WWW Eurocontrol).
- PJ04 - Total airport management. The project is aimed to Integration of airports into the ATM network through sharing information in a timely manner between the network operations plan and the individual AOPs (Airport Operations Plan) using SWIM (System Wide Information Management) technology.

Other projects implemented under the SESAR 2020 program also influence improving safety, efficiency, capacity and reducing the environmental impact of airports.

Another problem that has appeared in recent years is the integration of operations of manned and unmanned aircraft (RPAS - Remotely Piloted Aircraft System) at the airport area (ground and air operations). Several projects are currently devoted to this problem, including:

- SESAR 2020
  - PJ02 - General Aviation, RPAS and rotorcraft integrated into a multi-aircraft and manned flight environment.
  - PJ03 - Integration of RPAs, GA and Rotorcraft into the airport operations
  - PJ.10 Separation Management En Route and TMA (PJ10.05 Integration of RPAS IFR flight, also in the TMA)
- Enhanced RPAS Automation (ERA) project funded by the European Defence Agency (EDA) and led by Airbus Defence and Space. The main objectives of ERA are to establish the technological baseline for automatic take-off and landing, auto-taxi, nominal/degraded mode automation functions and emergency recovery. This will be done alongside support to the regulation and standardisation of these capabilities, by providing safety assessments, procedures, simulation and flight demonstrations.

Terminal Area air traffic congestion

The terminal capacity is the number of passengers and tonnes of cargo per hour which can be processed in a terminal building (sometimes referred to as passenger throughput or cargo throughput). The type of passenger or passenger mix can influence the rate of passenger throughput. International passengers who must clear customs and immigration require more time and space than domestic passengers who are not subject to these procedures. Domestic and international cargo presents a similar situation (ICAO, 2016).

Available aircraft parking spaces

After passing the terminal, the passenger arrives at the gate: the area of an airport that provides a waiting area for passengers before boarding their flight. The maximum gate capacity of one gate must be in accordance with the type and size of aircraft at the corresponding apron.

The apron is the airside area of an airport used to park aircraft. Static apron capacity is the number of stands available or the number of aircraft that can occupy the apron at any given moment. Dynamic apron capacity is the number of aircraft per hour that can be accommodated, considering the time interval between successive occupancies by two different aircraft. Apron capacity becomes constrained when the number and size of aprons do not match the actual number and size of aircraft using the aprons.

Impact of capacity constraints on air fares

Airport capacity congestion is already being felt in markets across Europe and is expected to be one of the greatest bottlenecks for the future growth of the aviation industry. Under the current policy framework, the growth of airport capacity will not be able to keep up with aviation demand growth.

EUROCONTROL (Eurocontrol, 2013) predicts that by 2035 more than 30 European airports will be congested. These airports are operating at 80% or more of their capacity for more than 3 hours per day. In 2035, around 1.9 million flights (accounting for 12% of the demand) can not be accommodated in EUROCONTROL's 'most likely' traffic growth scenario. In Eurocontrol's highest growth scenario, this number rises to 4.4 million flights.

In a situation where demand for airport capacity exceeds the supply of airport capacity, and where the airport is in a position of substantial market power in the passenger market, prices are used to balance the level of demand with the capacity available. If the airport prices efficiently through its airport charges, scarcity will be reflected in higher (peak period) charges, hence in higher costs to the airlines and, in turn, and depending on the market situation, in higher fares charged to passengers for travel at peak periods.

In a study for the UK Airports Commission (Burghouwt et al. 2017), it was found that airport capacity constraints are being associated with higher air fares for a selection of European airports. For all routes in the dataset, the study finds that fare revenue per passenger mile increases by 18% when the capacity utilisation increases from a non-constrained level to a severely constrained level (>95% capacity utilisation). It was also found that the fare premium in relative terms is higher at smaller airports than at larger airports. Also, the study finds that the effect is strongest at airports operating at 99% of their stated runway capacity and less so at airports operating at around 80% of stated capacity. Below 80% of capacity use, the estimated effect on fares becomes stronger again.

Environmental impact

All transport, including air transport, contributes to the degradation of the natural environment and has a negative impact on people. Although the aircraft noise can be troublesome for the people of the settlements located near airports, the negative impact of air transport on the environment is primarily associated with the emission of gases and particles which alter the atmospheric concentration of greenhouse gases. Aircraft emit gases and particles directly into the upper troposphere and lower stratosphere where they have an impact on atmospheric composition. These gases and particles alter the concentration of atmospheric greenhouse gases, including carbon dioxide CO2), ozone (O3), and methane (CH4); trigger the formation of condensation trails (contrails); and may increase cirrus cloudiness-all of which contribute to climate change.

As it concerns the environmental impact of European Aviation, a complete and updated picture of the current situation is available on the second European Aviation Environmental Report (EAER) 2019[4], prepared by European Environment Agency, European Union Aviation Safety Agency (EASA) and Eurocontrol.

[4] "European Aviation Environmental Report 2019" ISBN: 978-92-9210-214-2 doi: 10.2822/309946

As evidenced in the EAER 2019, the contribution of aviation activities to climate change, noise and air quality impacts is increasing, thereby affecting the health and quality of life of European citizens. Although, thanks to the research investments, improvements are being made (by technology, operations, airports, market-based measures), as shown in the dashboard in Table 2.11, their combined effect has not kept pace with the recent strong growth in the demand for air travel, leading to an overall increase in the environmental impact.

EAER DASHBOARD[2]

	Indicator	Units	2017	% change since 2014	% change since 2005
Traffic	Passenger kilometres flown by commercial flights[1]	billion	1,643	+20%	+60%
	Number of city pairs served most weeks by scheduled flights[1]		8,603	+11%	+43%
Noise	Number of people inside L_{den} 55 dB noise contours[2]	million	2.58	+14%	+12%
	Average noise energy per flight[3]	10^9 Joules	1.24	-1%	-14%
Emissions	Full-flight CO_2 emissions[1]	million tonnes	163	+10%	+16%
	Full-flight 'net' CO_2 emissions with ETS reductions[1]	million tonnes	136	+3%	n/a[4]
	Full-flight NO_x emissions[1]	thousand tonnes	839	+12%	+25%
	Average fuel consumption of commercial flights[1]	litres fuel per 100 passenger kilometres	3.4	-8%	-24%

(1) All departures from EU28+EFTA
(2) 47 major European airports
(3) All departures and arrivals in EU28+EFTA
(4) ETS not applicable to aviation in 2005

2 Red shading indicates a worsening of the relevant indicator and green shading an improvement.

Table 2.11. European Aviation Environmental Report (EAER) Dashboard 2019 summarizing the most relevant parameters affecting the environmental impact of aviation.

Aviation participates moderately (2-3%) to the global environmental pollution and the concentration of greenhouse gases and toxic compounds produced by aircraft is particularly high close to the airport areas and in the upper troposphere. If nothing is done and current trends continue, a 5% increase in global pollution could be easily reached by 2050.

As a result of the 11th meeting of the ICAO Committee on Aviation Environmental Protection, an updated version of the ICAO Global Environmental Trends was developed with a range of scenarios for the assessment of future fuel burn and GHG emissions trends[5].

- Scenario 1 for fuel burn and CO2 emissions includes the operational improvements necessary to maintain current operational efficiency levels but does not include any technology improvements beyond those available in current production aircraft.
- Scenario 2 (low technology) assumes fuel burn improvements of 0.96% per annum for all aircraft entering the fleet after 2010 and before 2015, and 0.57% per annum for all aircraft entering the fleet beginning in 2015 out to 2050.
- Scenarios 3, 4 and 5 (moderate, advanced and optimistic technology) assume fuel burn improvements of 0.96%, 1.16% and 1.5% per annum respectively for all aircraft entering the fleet

[5] https://www.icao.int/environmental-protection/Pages/ClimateChange_Trends.aspx

after 2010 out to 2050, in combination with the latest operational initiatives, e.g., those planned in NextGen and SESAR, and additional fleet-wide CAEP/9 IE operational improvements.

Scenario 1 for NOx emissions considers no new aircraft technologies and maintains the baseline operational efficiency, which is sufficient to meet the unconstrained forecasted demand. Scenarios 2 and 3 assume moderate and advanced aircraft technology improvements, and achievement of 50% and 100% respectively of the CAEP/7 IE NOx Goal by 2036 with no further improvement thereafter, in combination with CAEP/9 fleet-wide operational improvements.

Fuel

As shown in Figure 2.42, by 2045, considering a 3.3 times growth in international air traffic (expressed in revenue tonne kilometres), fuel consumption is projected to increase by 2.2 to 3.1 times compared to 2015 (approximately 160 megatons - Mt), depending on the technology and ATM scenarios. The long-term fuel burn from international aviation is lower by about 25% compared with the prior trends projections and this lowering can be attributed to a combination of more fuel-efficient aircraft and a reduction in the forecasted long-term traffic demand. The 1.37% long-term fuel efficiency computed herein includes the combined improvements associated with both technology and operations. The individual contributions from technology and operations are 0.98% and 0.39%, respectively.

GHG

Significant uncertainties exist in predicting the contribution of sustainable aviation fuels in the future. However, a number of near-term scenarios indicate that up to 2.6% of fuel consumption could potentially consist of sustainable aviation fuels by 2025. Moreover, it would be physically possible to meet by 2050 100% of international aviation jet fuel demand with sustainable aviation fuels but this level of fuel production could only be achieved with extremely large capital investments in sustainable aviation fuel production infrastructure and substantial policy support. The effect of such an expansion in the use of sustainable aviation fuels on net CO2 emissions from international aviation is shown in Figure 2.43.

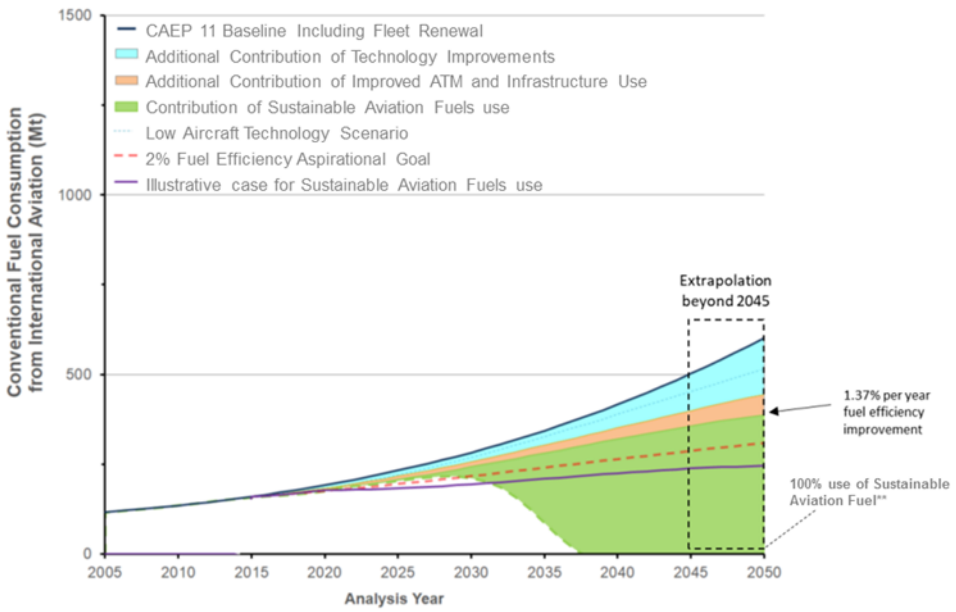


Figure 2.42. Conventional Fuel Consumption from International Aviation, 2005 to 2050, Including Potential Use of Sustainable Aviation Fuels. Source: https://www.icao.int/environmental-protection/Pages/ClimateChange_Trends.aspx

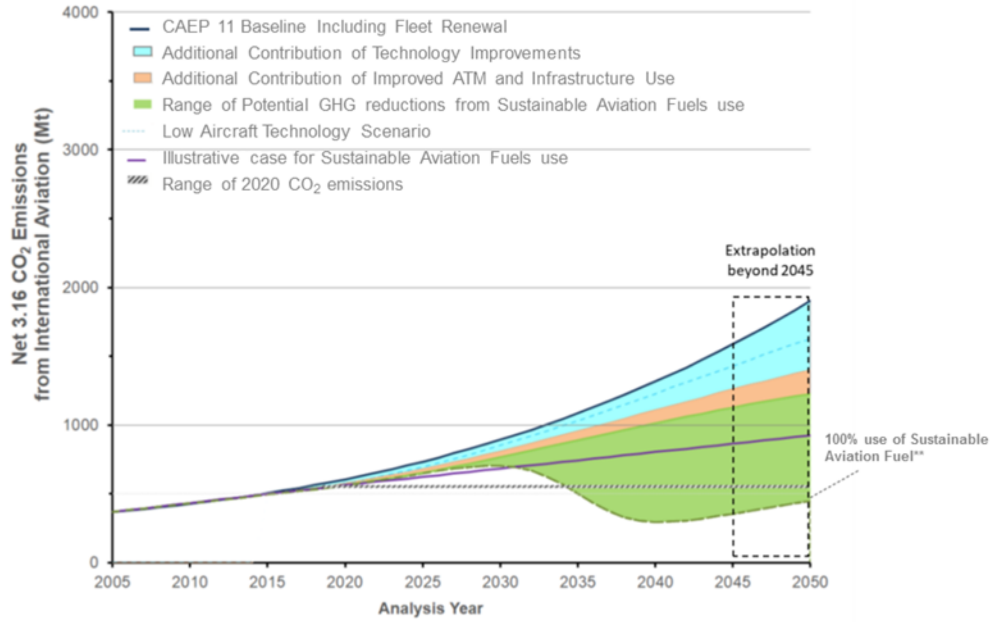


Figure 2.43. Net CO2 Emissions from International Aviation, 2005 to 2050, Including Sustainable Aviation Fuels Life Cycle CO2 Emissions Reductions. Source: https://www.icao.int/environmental-protection/Pages/ClimateChange_Trends.aspx

As shown in Figure 2.44, in 2045, the full-flight NOx emissions projection ranges from 5.53 Mt to 8.16 Mt, which represents a 2.2 to 3.3 times growth compared to 2015, against the 3.3 times forecasted growth in international air traffic. As with fuel burn, the long-term full-flight NOx from international aviation is lower by about 21% compared with prior trends projections. This lower NOx emissions projection can be attributed to a combination of aircraft with lower NOx engines entering the fleet, as well as a reduction in forecasted long-term traffic demand.

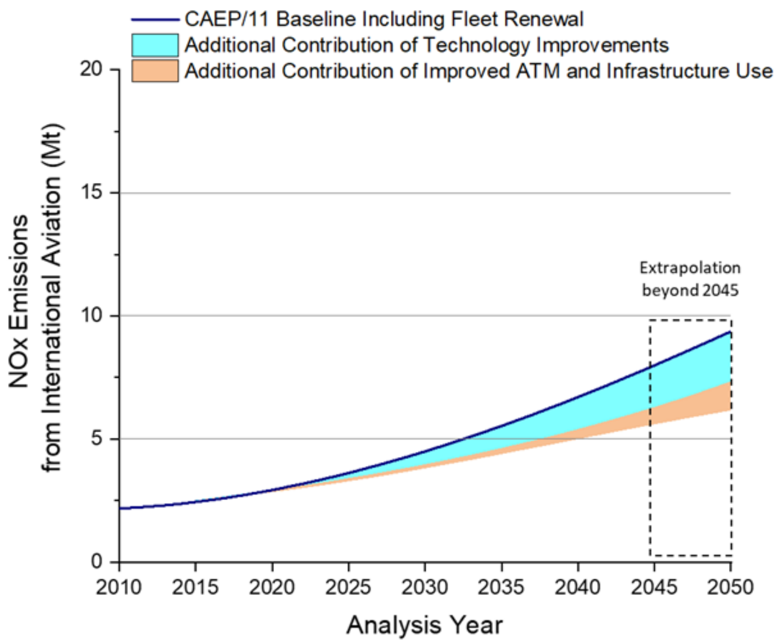


Figure 2.44. Full Flight NOx Emissions from International Aviation, 2010 to 2050. Source: https://www.icao.int/environmental-protection/Pages/ClimateChange_Trends.aspx

Climate change

The EU plays a leading role in international efforts to limit climate change and increased its climate finance contributions to €20.2 billion in 2016. This is backed up by a legally binding commitment and legal framework at EU level to reduce greenhouse gas emissions, increase the use of renewable energy and improve energy efficiency. These 'climate and energy' targets for 2020, which the EU is on track to meet, and 2030 are summarised below:

2020

- 20% cut in greenhouse gas emission (from 1990 levels)
- 20% of EU energy from renewables
- 20% improvement in energy efficiency

2030

- At least 40% cut in greenhouse gas emission (from 1990 levels)
- 32% of EU energy from renewables, with an upwards revision clause by 2023
- 32.5% improvement in energy efficiency, with an upwards revision clause by 2023

The EU has also agreed on a '2050 low carbon economy' roadmap that suggests the following targets:

- 60% cut in greenhouse gas emission by 2040 (from 1990 levels)
- 80% cut in greenhouse gas emission by 2050 (from 1990 levels), including a 60% reduction in transport emissions.

The European Commission presented its vision for long-term EU greenhouse gas emissions reductions in accordance with the Paris Agreement in November 2018, showing that decarbonisation is possible by 2050, including aviation

The goal agreed under the Paris Agreement is **to limit the global temperature increase to well below 2 degrees Celsius compared to pre-industrial levels**, while pursuing efforts to limit the increase to 1.5 degrees. While this covers all man-made emissions, including aviation, measures to reduce these emissions are covered by the Nationally Determined Contributions under the Paris Agreement as well as global measures developed through the relevant international organizations, such as ICAO.

From an aviation perspective, the EU has invested approximately €5 billion over the last 10 years to support these commitments through various programmes (e.g. Clean Sky, SESAR, Life, Horizon 2020, Connecting Europe Facility) and a set of measures (e.g. EU ETS, CORSIA, aeroplane CO2 certification standard).

The European Green Deal

The EU aims to an economy with net-zero greenhouse gas emissions is at the heart of the recent European Green Deal launched by the European Commission that intends to reach climate-neutrality by 2050. Figure 2.45 illustrates the elements (mobility is relevant to the aviation sector) of the Green Deal.

Figure 2.45. The European Green Deal. Source: Communication from the EC – COM (2019) 640 final - The European Green Deal.

In particular, the Commission's vision is in line with the Paris Agreement objective to keep the global temperature increase to well below 2 °C and pursue efforts to keep it to 1.5 °C. To reach this goal mobility as well as all parts of economic sectors will play a role.

As part of the European Green Deal, the Commission proposed on 4 March 2020 the first European Climate Law to enshrine the 2050 climate-neutrality target into law. The European Parliament endorsed the net-zero greenhouse gas emissions objective in its resolution on climate change in March 2019 and resolution on the European Green Deal in January 2020.

By summer 2020, the Commission will present an impact assessed plan **to increase the EU's greenhouse gas emission reductions target for 2030 to at least 50% and towards 55% compared with 1990 levels in a responsible way.** To deliver these additional greenhouse gas emissions reductions, the Commission will review by June 2021 all relevant policy related to climate[6].

Moreover, EU Member States are required to develop national long-term strategies on how they plan to achieve the greenhouse gas emissions reductions needed to meet their commitments under the Paris Agreement and EU objectives.

As it concerns mobility, to achieve climate neutrality, a 90% reduction in transport emissions is needed by 2050. Road, rail, aviation, and waterborne transport will all have to contribute to the reduction. Achieving sustainable transport means putting users first and providing them with more affordable, accessible, healthier and cleaner alternatives to their current mobility habits. The Commission will adopt a strategy for sustainable and smart mobility in 2020 that will address this challenge and tackle all emission sources.

In aviation, work on adopting the Commission's proposal on a truly Single European Sky will need to restart, as this will help achieve significant reductions in aviation emissions. Automated and connected multimodal mobility will play an increasing role, together with smart traffic management systems enabled by digitalisation. The EU transport system and infrastructure will be made fit to support new sustainable mobility services that can reduce congestion and pollution, especially in urban areas. The Commission will help develop smart systems for traffic management and 'Mobility as a Service' solutions, through its funding instruments, such as the Connected Europe Facility.

The price of transport must reflect the impact it has on the environment and health. As for the aeronautic sector, the Commission intends to reduce free allowances in the European carbon market (known as the European Trading Scheme) – increasing the cost of the pollution due to this sector and ending the kerosene tax exemption.

[6] Communication from the EC – COM (2019) 640 final - The European Green Deal

As it concerns, the **sustainable alternative transport fuels, t**he Commission will promote actions to boost their production and uptake, by proposing more stringent air pollutant emissions standards for combustion-engine vehicles. Air quality should be improved near airports by tackling the emissions of pollutants by aeroplanes and airport operations

Local restrictions on operating hours and other limits

There are a number of measures to mitigate noise used by airports including (EY, 2016)

- Nighttime and other scheduling of runway operations to remove concentrations of noise over particular areas or at particular times;
- Changes or restrictions to on-field aircraft operations including engine trials and taxiing procedures;
- Adaptations to descent and approach procedures.

➢ Night Time and other restrictions

The airports recognised that noise impact at night are particularly troubling for local populations and have put in place measures to address this. Airports can be split into two categories (EY, 2016):

1. Airports with bans on flights in nighttime hours.
2. Airports applying additional limits to, but not bans, on night flying.

The airports which have put in place complete limits on night-time flying include:

- Sydney –no flights scheduled between 23:00 and 06:00 except freight flights and up to 24 international flights a week.
- Frankfurt –no flights between 23:00 and 05:00 and set limits for evening shoulder periods.

The remaining airports have put in place measures to constrain the number of flights and aircraft that may operate at night. For example:

- Paris Charles de Gaulle –Limited to 55 flights per night.
- Schiphol –Limit of 32,000 flights per annum and a total noise limit applied over a year.
- O'Hare –There is no night flight limitation; however, proposed changes to the Fly Quiet procedures include rotating runway used in night hours to allow respite periods.

➢ Other Constraints on Aircraft Movement Numbers

In addition to the constraints on night flights, several airports operate under additional restrictions on aircraft movements.

Typically, the measures take the form of (EY, 2016):

- Limiting the number of flights either per hour or per day.
- Restricting the use of noisier aircraft through either charge incentives or operating restrictions.
- Managing flight paths away from population concentrations.
- Rotating runway use to spread noise patterns across wider areas.
- Restrictions on ground handling procedures such as engine run-ups, use of reverse thrust and ground power units.

➢ Descent and Departure Adaptations

A common measure put in place to moderate the impact of noise on surrounding communities is the adaptations of descent and departure paths. Fraport (FRA) for example has extensive measures in place and under development to moderate the noise impact of arrivals and departures. These include (EY, 2016):

- Limiting take-off speed,

- More frequent continuous descent operations,
- Increasing the glide angle,
- Raising the minimum downwind approach altitude,
- Raising the final approach height.

Measures currently under development include:

- Continuous climb operations,
- Increasing ILS,
- Steeper approach procedures,
- Amending the point merge procedures.

Ultimately in the UK the structure and operation of local airspace will be a matter for the airport and regulatory authorities to agree; however, the extensive list above shows the types of measures that might be deployed.

Vertiports and heliports

Every day, millions of hours are wasted on the road worldwide. On-demand aviation has the potential to radically improve urban mobility, giving people back time lost in their daily commutes. A network of small, traditional or electric aircraft that take off and land vertically (called VTOL aircraft for Vertical Take-off and Landing, and pronounced vee-tol), will enable rapid, reliable transportation between suburbs and cities and, ultimately, within cities.

The development of infrastructure to support an urban VTOL network will likely have significant cost advantages over heavy-infrastructure approaches such as roads, rail, bridges and tunnels. It has been proposed that the repurposed tops of parking garages, existing helipads, and even unused land surrounding highway interchanges could form the basis of an extensive, distributed network of "vertiports" (VTOL hubs with multiple take-offs and landing pads, as well as charging infrastructure) or single-aircraft "vertistops" (a single VTOL pad with minimal infrastructure).

In the U.S. there are 5,664 helipads with all but 66 for private use (UBER, 2016), that is, developed for use by the property owner without public assistance. Most of this infrastructure is essentially unused. After years without use, many helipads have been declared inactive and for emergency use only. Many of these are located in highly desirable downtown locations that could provide rapid access to urban areas. Los Angeles alone has over 40 high-rise helipads in the immediate downtown. Cities such as San Francisco also have many high-rise building helipads, however, none has permitted use due to local ordinances that are highly restrictive due primarily to noise concerns.

In Europe, there are far fewer heliports than in the US. Unconfirmed reports say indicates less than 100 civilian type heliports.

Over the past two years, NASA has studied the idea of VTOL air-taxis operating in dense urban areas (UBER, 2016). Specifically, they chose San Francisco as one metropolitan area to provide detailed geographic, land use, infrastructure, weather, and operational constraint considerations to bring real-world issues into their study.

A VTOL fleet will likely be supported in a city through a mixture of both vertiports and vertistops. Vertiports would be large multi-landing locations that have support facilities (i.e., rechargers, support personnel, etc.) for multiple VTOLs and passengers. Following the heliport examples used in New York City and other locations, vertiports would be limited to a maximum capacity of around 12 VTOLs at any given time to achieve a compact infrastructure size while enabling capacity for multiple simultaneous VTOL take-off and landings to maximize trip throughput. Vertistops, on the other hand, would be single-vehicle landing locations where no support facilities are provided, but where VTOLs can quickly drop off and pick up passengers without parking for an extended time. An example of a vertistop includes small helipads that are atop high-rise downtown buildings today (UBER, 2016).

However, this picture is too optimistic and must be moderated. The number of car movements in a large city in one day is of the order of the number of flights in the world in a year as well as urban air transport will be a small fraction of urban transport until ATM issues are resolved. On the other hand, eVTOL can be viewed as an extension of current experience with helicopters, with noise and cost issues and, even though eVTOL are less polluting than helicopters, tend to be slower and have less range.

Delay effects

It is obvious that the lack of airport capacity will create a congested network, but there is an associated side effect of operating near capacity: delays. Delays have been classified as primary (i.e. ATFCM and non-ATFCM delays) and reactionary (i.e. knock-on delays incurred by previous flights) (Eurocontrol, 2013).

In 2012, the airport ATFCM (Air Traffic Flow and Capacity Management) primary delays were only 0.9 minutes out of an average of 5.7 minutes of primary delay per flight and out of 10 minutes per flight of total delay including the reactionary delay. In 2013, airports were a minor contributor to delays, the main caused and the biggest part of primary delays was related to airline causes (Eurocontrol, 2013).

Within a network where 20 airports operated (2013) at 80% or more of capacity during 6 consecutive hours or more, it is likely to expect that any deviation (e.g. late bags, missing passengers) from the plan will generate delays that will accumulate rapidly along the day.

The Figure 2.46 shows the growing delay challenge at airports for the summer months, where for 2012 only a minority of them suffer delays greater than 5 minutes per flight (Eurocontrol, 2013). This is reflected in the 1.12 minutes/flight of ATFCM delay measured, that is slightly higher than the whole year value of 0.9 mentioned above. In 2035, the picture is drastically different with a high level of delay present across the network and a significant number of airports that present total delays greater than 20 minutes per flight.

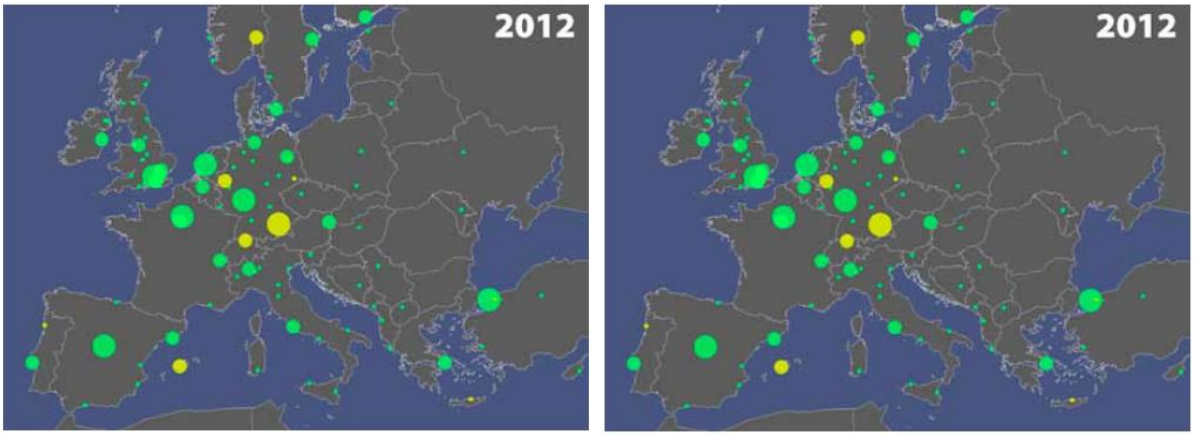


Figure 2.46. Increasing number of airports with summer delay (in minutes/flight).

Main delay causes at the top 10 affected departure airports (Eurocontrol, 2013) for departure (Figure 2.47) and arrival (Figure 2.48) are presented below

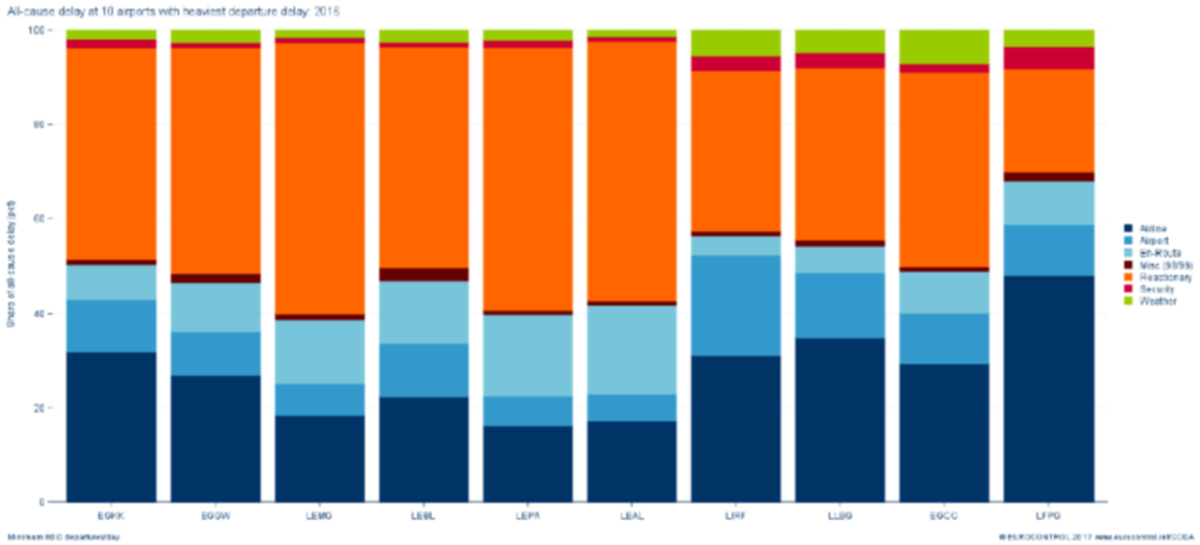


Figure 2.47. Main Delay Causes at the Top 10 Affected Departure Airports (Eurocontrol, 2017)

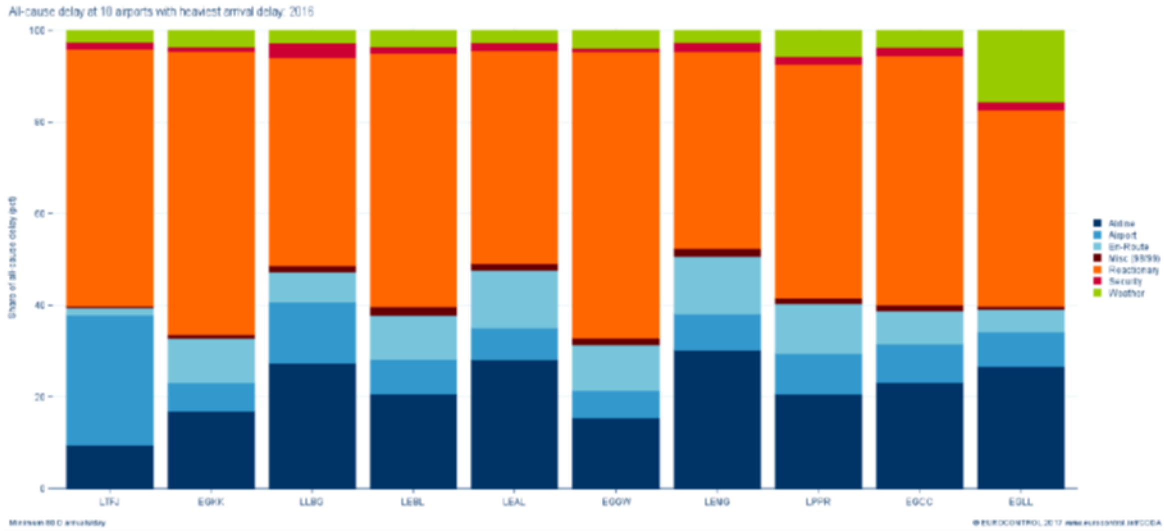


Figure 2.48. Main Delay Causes at the Top 10 Affected Arrival Airports (Eurocontrol, 2017)

The fuel cost, cost of the flight crew, cost of leased aircraft, airport expenses and the unmeasured costs (e.g. customer complaints and disloyalty cost) are some of the examples that airlines have to cope with as a result of an increase in the delays.

Delays in the handling chain not only provoke impacts on the quality of the service experienced by the passengers, but also affect the operational efficiency, and as a result, the costs of the airline. Delays resulting from ground handling comprise one of the highest costs of the airlines, even though handling related delays are a cheaper and easier way of reducing departure delays, and consequently the costs, when compared to the difficulty of reducing other reasons for delays, such as weather conditions and air traffic control (ATC).

2.3. Choice of Most Efficient Mobility Solutions

*Flightpath 2050 goal 3: "European citizens are able to make informed mobility choices and have affordable access to one another, taking into account: economy, speed and level of service (that can be tailored to the individual customer). Continuous, secure and high-bandwidth communications are provided for added value applications".

The progress in mobile communications and the availability of information may ensure that the passenger can make informed choices among several available travel options. The issues of interference with and security of communications at passenger information level are comparable to other societal services. A more serious constraint may come from physical limits of transportation infrastructure and the underlying issue of land planning: (i) in the expansion of existing airports or addition of more runways; (ii) in the construction of new airports, vertiports and heliports; (iii) in the road/rail infrastructure that provides fast access; (iv) in the efficient organization of ground movements within the confines of the airport.

The choice of air travel compared with other means of transport depends not only on flight time but also on the ground movements to and from the airport that is an issue addressed in the Key Topic of intermodal transport.

KEY TOPIC T2.4 – MULTIMODAL TRANSPORT

Scope of the Goal

Ground infrastructure and multimodal transport

Goal 2:

A coherent ground infrastructure is developed including: airports, vertiports, heliports with the relevant servicing and connecting facilities, also to other modes

Comparison with 2017 SRIA document	Why	Lacks
Coherent	It fits to the SRIA document content. It is essential to improve the ground infrastructure processes in order to offer customers a vastly improved, seamless travel experience. This applies to airports, vertiports and any other ground infrastructure supporting airborne passenger or cargo services. It is important to achieve better performance in punctuality, predictability, delay, waiting times, convenience and availability of information.	There are no omissions. It is very similar to the SRIA document

Benchmarks

A coherent ground infrastructure implies the design and implementation of an integrated, intermodal transport system as part of which airport evolve into integrated, efficient and sustainable air transport interface nodes.

The operation of airports as an efficient node of the transport system can be analysed from three perspectives (scales or points of view).

The first corresponds to the efficient operation of all processes within the airport itself. A certain number of issues and process of the airport operation can become bottlenecks or offer the potential for increasing efficiency such as the ground movements but also main process inside the airport as luggage handling, passenger check-in or passport and security checks. The airport of the future should offer customers improved, seamless travel experience. Airside and landside processes at airports need to be optimised for customer comfort, predictability, performance and better integration of transport modes. In terms of performance, it would be fair that airports provide equivalent quality and efficiency on the processing of travellers and flight of service as the one demanded to the ATM system, and therefore by extension it will be fair to envisage an efficient 2050 airport where flights depart within 1 minute of the planned departure time.

From the technological and operational dimension processes for passenger, baggage and freight handling must be continuously improved to achieve in punctuality, predictability, delay, waiting times, convenience and availability of information. Innovative, collaborative decision-making built upon total node (airport) management is required to create seamless passenger and cargo concepts, technologies and procedures.

The second corresponds to the interconnection among the different airports of the European Networks. Technological and operational development will allow that information of traffic departing from the origin airport will be promptly and precisely shared with all the ACC centres in the plane trajectory as well as with the destination airport. As soon as the aircraft takes-off it will become of the interest of the arrival airport that will receive promptly and updated information of the flight as it evolves. This information will be exploited at the destination airport for optimum allocation of resources minimizing waiting and processing times once the plane arrives at its destination. Any disruption during the flight will also soon be acknowledged at the destination so that the system can accommodate deviations from planning and disruptions.

Finally, **the third** corresponds to the integration of the airport with other modes of transport.

The interfaces of the airport with other modes of transport must allow 90% of travellers within Europe to be able to complete their journey, door-to-door within 4 hours. That means that connections with other modes of transport should allow passengers to arrive from their houses at the plane in a time interval compatible with the 4 hours door-to-door requirement. Airport access has been improved accordingly trough an innovative approach towards safe, efficient, frequent, comfortable transport systems and services and connections with another mode of transport must facilitate easy and quick access to the plain.

The Figure 2.49 shows the (great-circle) distance flown by departures from the 528 biggest in Europe. Nearly three million departures travel a distance of 250-550km. On a coarser scale, the Figure 2.50 shows that at smaller airports, departures most often travel less than 300km, and the number of more distant connections declines rapidly. Even at the large and very large airports, the 400km distance bracket is the most common, showing how they are connected to the local network as well as to a long-haul one. The very large airports have only a small number of 1500-3500km flights, but they have the largest share of the 3500km+.

According to Eurocontrol, the average flight length of 80% of the flights within Europe is 504NM while the average flight length of the flight outside the regions (20%) is 878NM. That means that the average flight time of 80% of the flights in Europe does not exceed an hour. This will leave a maximum of 3 hours for the passenger to arrive from its departing point to the plane and to get from the plane to its final destination, including the processing times at the airport and all the connections with other modes of transport.

This is relevant considering that the cities closest to Europe's busiest airports have between 4 and 46 airfields within 100Km od the city centre, for 8 of the 10 cities close to Europe's biggest airports, a single airport handles 80% or more of all the departures within 100km. The situation is nevertheless not homogenous around Europe. In northern Europe, beyond 150 Km the area of influence of the airports begins to overlap, with Köln/Bonn airport 138km from Frankfurt, Brussels International 160km from Amsterdam, etc. But in the South, city separations are wider: Madrid may have the 4th or 5th largest airport 13km from the city centre, but the next airport with more than 100 departures/ day is 290km away, at Valencia. The longest distances for flight within Europe like London-Athens or Lisbon-Helsinki can exceed 3000km or 3 hours flight time. It is clear that the 4-hour door-to-door time can apply only to flights of less than 1000-2000km. An alternative would be to make door-to-door time dependent on the distance between airports, besides on local access to and from airports.

The technological and operational dimension will be of high relevance to achieve the average 3 hours target time of connection and processing time. However, the **social dimension** of such integration will become very relevant as it may happen that the main impact of an airport on the surrounding community comes not only from aircraft operations but also from ground infrastructure required to access to the airport and to connect the airport with other modes of transport.

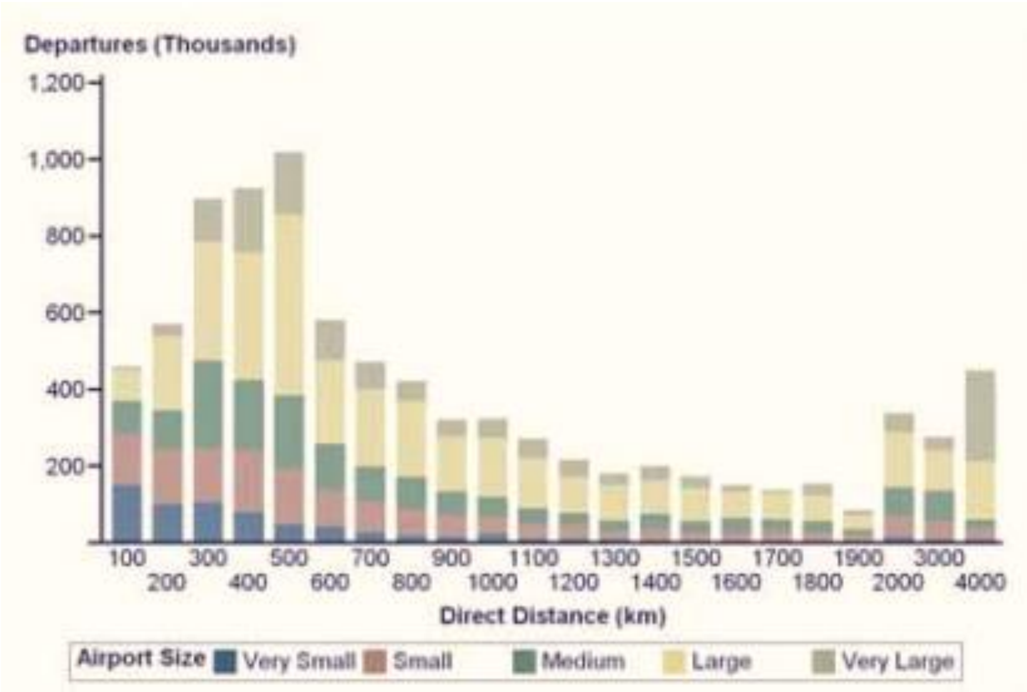


Figure 2.49. Great-circle distance flown by departures from the biggest 528 airports in Europe. Source: Eurocontrol Trends in Air Traffic Volume 3. A place to stand: Airports in the European network

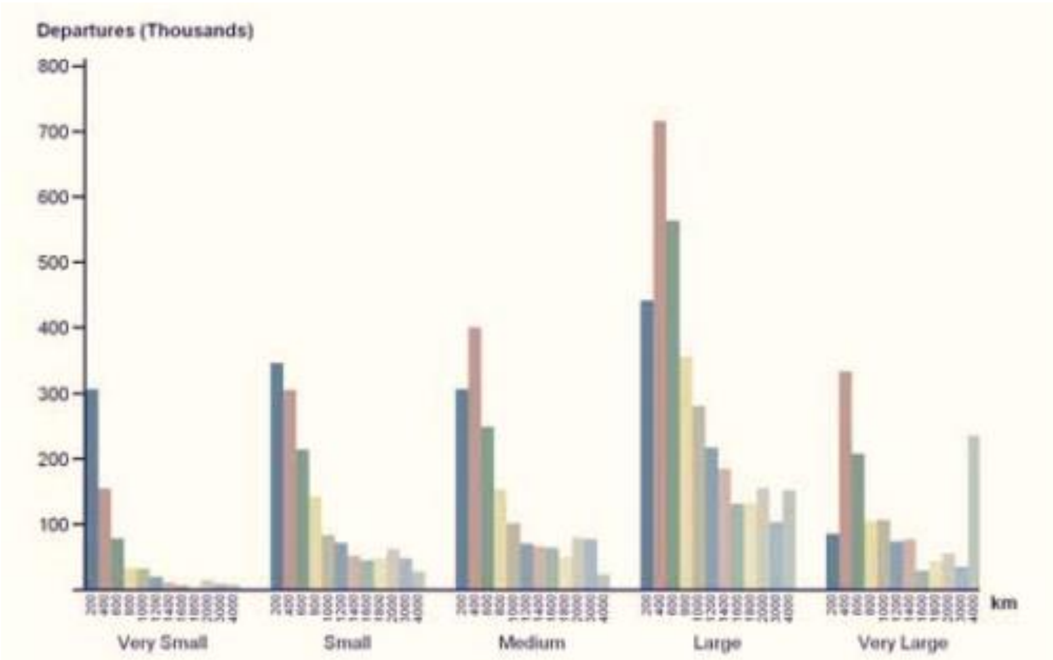


Figure 2.50. Departures grouped by airport size. Source: Eurocontrol Trends in Air Traffic Volume 3. A place to stand: Airports in the European network

The Figure 2.51 illustrates the benchmarks discussed for goal 2.

GROUND INFRAESTRUCTURE & MULTIMODAL TRANSPORT

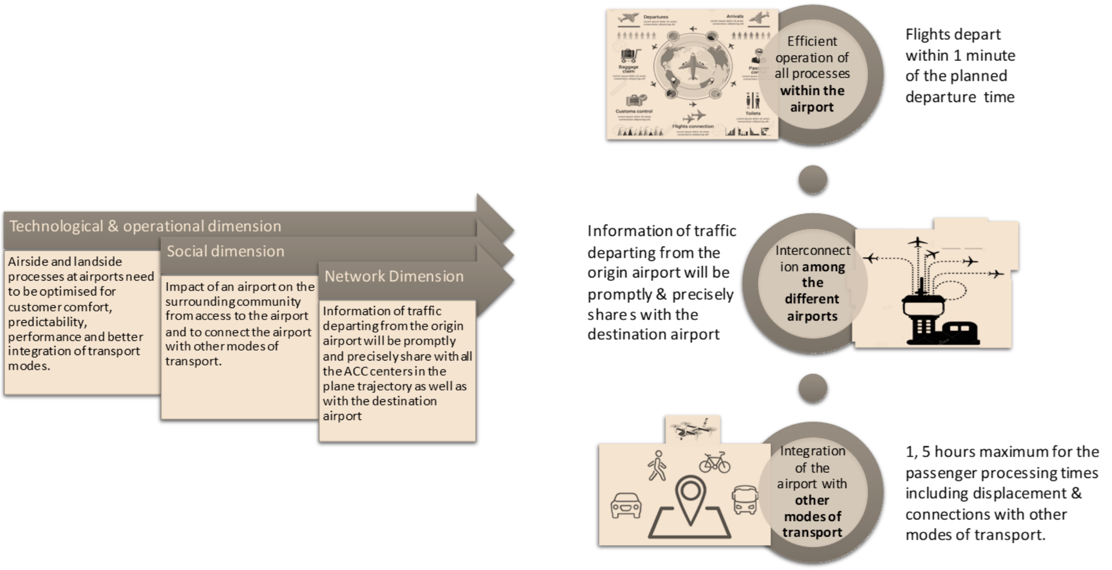


Figure 2.51. Technological, operational, societal/human and network dimension of goal 2 Benchmarks

Reference State in 2010

Three main aspects are addressed to understand the reference state for goal 2 in 2010:

A. The efficiency of the airport processes.

B. The airport interconnection and delay propagation.

C. The intermodality.

Airport efficiency

Air transport depends on a complex network architecture, where several facilities, processes and agents are interrelated and interact with each other. In this large-scale and dynamic system, the **airport represents the interconnection nodes that facilitate aircraft distribution through the network and transport model changes for passengers**.

Almost 800 million passengers used EU airports in 2010, a third of the world market, almost three times more than when air traffic was liberalised in the early nineties. However major airports are already congested, and traffic flows are harder and harder to cope with. **In 2010 5 major European airport hubs were at saturation** - operating at full capacity: Düsseldorf, Frankfurt, London Gatwick, London Heathrow, and Milan Linate (*Eurocontrol PRR 2010*). The **EC Action Plan on Airport Capacity** was launched in January 2007, urged by the fear that 60 airports will be heavily congested by 2025. The Eurocontrol Study '*Challenges of Growth 2008'* envisaged that, on continuing 2010 trends, 19 key European airports will be at saturation, including, for example, Paris CDG, Warsaw, Athens, Vienna and Barcelona[7]. The resulting congestion could mean delays affecting 50% of all passenger and cargo flights. The Table 2.12 illustrates the forecast on airport congestion in 2010[8].

Airport	2010	2017	2025	Capacity assumptions

[7] http://europa.eu/rapid/press-release_MEMO-11-857_en.htm#footnote-1

[8] The updated study EUROCONTROL 'Challenges of Growth 2013' (CG13) confirmed and reiterated the capacity challenge identified in previous studies. In the most-likely (capacity constrained) scenario, there will be 50% more flights in 2035 than in 2012. Nearly two million flights will not be accommodated (12% of total demand for travel) because of reduced airport expansion plans. That is equivalent to an estimated 120 million passengers unable to make their return flights (in total, 240 million passengers per year). In addition, by 2035, more than 20 airports will be running at or close to capacity, compared to just three in 2012 causing difficulties for managing the network (so called 'hotspot airports').

Amsterdam Schiphol	Demand exceeds capacity during part of day	Demand exceeds capacity during part of day	Demand exceeds capacity during part of day	Assumes annual movement cap raised to 510,000 in November 2010 but no further increase
Dublin	Sufficient capacity most or all day	Sufficient capacity most or all day	Sufficient capacity most or all day	Second runway built when needed
Düsseldorf	Demand exceeds capacity most or all day	Demand exceeds capacity most or all day	Demand exceeds capacity most or all day	Assumed 10% increase in capacity in 2015 but no further increase
Frankfurt	Demand exceeds capacity most or all day	Sufficient capacity most or all day	Demand exceeds capacity during part of day	New runway (2011) and terminal (2015) allow increases from 83 to 126 movements/hour
London Gatwick	Demand exceeds capacity most or all day	Demand exceeds capacity most or all day	Demand exceeds capacity most or all day	Assumes no new runway but an increase of 2-3 movements/hour on current runway
London Heathrow	Demand exceeds capacity most or all day	Demand exceeds capacity most or all day	Demand exceeds capacity most or all day	Assumes no third runway, or mixed-mode, or relaxation of annual movement cap.
Madrid Barajas	Demand exceeds capacity during part of day	Demand exceeds capacity during part of day	Demand exceeds capacity during part of day	Assumes ATC improvements increase capacity from 98 to 120 movements/hour by 2020 (increase phased in from 2014)
Milan Linate	Demand exceeds capacity most or all day	Demand exceeds capacity most or all day	Demand exceeds capacity most or all day	Assumes no amendment to Bersani Decree
Munich	Demand exceeds capacity during part of day	Sufficient capacity most or all day	Demand exceeds capacity during part of day	Assume third runway operational by 2017
Palma de Mallorca	Sufficient capacity most or all day	Sufficient capacity most or all day	Sufficient capacity most or all day	Assume additional capacity added when required
Paris CDG	Demand exceeds capacity during part of day	Demand exceeds capacity during part of day	Demand exceeds capacity most or all day	Assumes increase from 114 to 120 movements/hour by 2015, but no further increase (e.g. fifth runway)

Paris Orly	Demand exceeds capacity most or all day	Demand exceeds capacity most or all day	Demand exceeds capacity most or all day	Assumes no relaxation of annual slot cap
Rome Fiumicino	Demand exceeds capacity during part of day	Demand exceeds capacity during part of day	Demand exceeds capacity during part of day	Assume improved ATC allowing 100 movements/hour but no new runway
Vienna	Demand exceeds capacity during part of day	Demand exceeds capacity during part of day	Demand exceeds capacity during part of day	Assume third runway operational in 2020, initially allowing 80 movements/hour increasing to 90 movements/hour by 2025

Table 2.12. Forecast airport congestion (SAMPLE AIRPORTS)

Consequently, a significant portion of delay generation occurs at airports, where aircraft connectivity acts as a key driver for delay propagation. Delays have a substantial impact on the schedule adherence of airport and airlines, passenger experience, customer satisfaction and system reliability. **Passengers and luggage processing, as well as "rotation"** (flight cycle through the airport and its surrounding airspace, from inbound to outbound processes) have a great influence on punctuality and the operational efficiency of the entire system.

In 2010 the quality and efficiency of services at airports was demanding a significant improvement. **70% of all delays to flights were caused by problems due to the turnaround of aircraft at airports** (delays caused by airlines or their ground-handlers, airports or other parties involved in the turnaround process) (*Eurocontrol PRR 2010*). Additionally, network disruptions experienced in 2010 have shown the **need for increased coordination of ground operations for European airports and the network as a whole (knock-on effects) so as to ensure continuity of airport operations**.

The unprecedented drop in traffic reduced demand far below planned capacity levels in 2009. The resulting spare capacity in most areas (airlines, airports, ATC) translated in a significant improved on-time performance in 2009. However, air **transport punctuality in Europe in 2010 was the worst recorded since 2001 although traffic was still below 2007 levels** and traffic growth was modest. In December 2010, **the average delay per delayed flight (ADD) for departure** traffic from all causes of delay **was 50 minutes**. This was an increase of 22% compared to December 2009. Also, the percentage of flights delayed (by 5 minutes or more) went up by 13.4 percentage points to 62.9% in comparison to December 2009. The percentage of flights delayed by more than 15 minutes increased from 29.1% to 41.5%.

Some of the main causes contributing to this poor performance were ANS-related delays, primarily due to industrial actions, and higher than usual weather-related delays (snow, freezing conditions) during winter 2009 and in December 2010. The volcanic ash cloud in April/May 2010 had a limited impact on punctuality, as most of the flights were cancelled. Seasonal weather conditions predominantly affected operations in December, resulting in severe disruption to European traffic with an estimated 35,000 scheduled flight cancellations. Cold weather conditions and snowfall were experienced resulting in a significant increase in the proportion of weather-related delay from 27% to 33%. December was a record month for all causes of delay in comparison to the historically high 2009 figure, with a peak in the average delay per delayed flight seen on the 20th December of 82 minutes. Many European airports suffered from snowfall. Paris, Frankfurt, Munich and London saw disruption, Frankfurt particularly due to a lack of parking stand availability at the airport.

The next Figure 2.52 illustrates airport departure delays in 2010 in comparison with delays in the previous years.

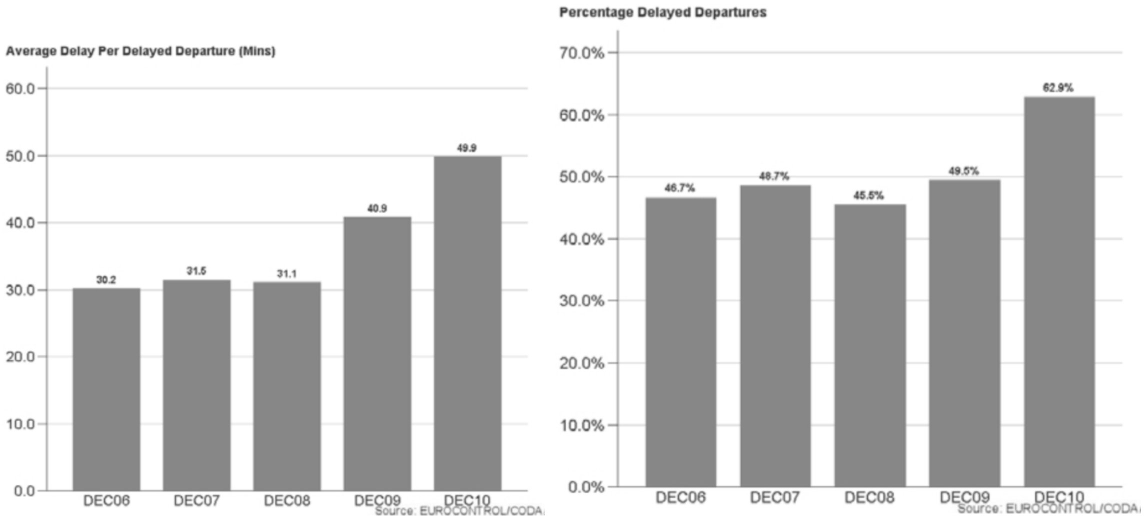


Figure 2.52. Evolution of airport departure delays in 2010. Source: Eurocontrol CODA Digest: Delays at Ari Transports in Europe December 2010

The **average delay per departure (ADM) from all causes increased by 55% to 31.4 minutes in December 2010 when compared to December 2009**. Regarding arrivals, the average delay per arrival increased by 56% month on month to 32.6 minutes, when compared to December 2009. These delays (Figure 2.53) were a record high for all causes of delay[9].

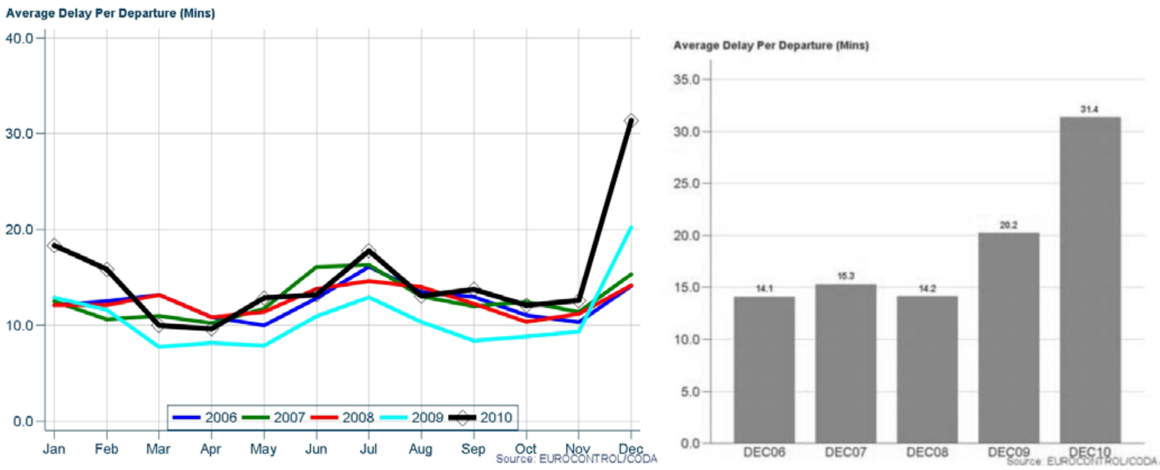


Figure 2.53. Average delay per movement (all causes) for Arrivals. Source: Eurocontrol CODA Digest: Delays at Ari Transports in Europe December 2010

An analysis of the delay causes and categories (grouped by IATA code) shows (Figure 2.54) an increase (in percentage points) in Reactionary delay of 4.4 points. A small increase in share was also seen in Weather-related delay (up 0.9 points). Continuing the 2010 trend there was a decrease observed in Technical and Aircraft Equipment related delay share (down 1.1 points). ATFM weather at destination saw an increase (up 1.3 points).

[9] All-causes departure delay' is calculated as the difference between the scheduled time of departure (STD) as communicated to the passenger and the actual off-block time (AOBT). In Europe, delay because assignment takes places on the ramp on departure with many airlines applying the IATA delay codes and sub-codes published in the IATA Airport Handling Manual 730 and 731. All-causes delays can be split between primary and reactionary delays. Reactionary delays are delays that are caused by the late arrival of aircraft, crew, passengers or loads from a previous journey. Primary delays are all other delays and occur during the turnaround process of the aircraft. The cost of one minute of tactical delay varies by size of aircraft, but on average is estimated at €79/minute (Ref: University of Westminster for EUROCONTROL PRC, 2004, for EUROCONTROL PRU, 2011).

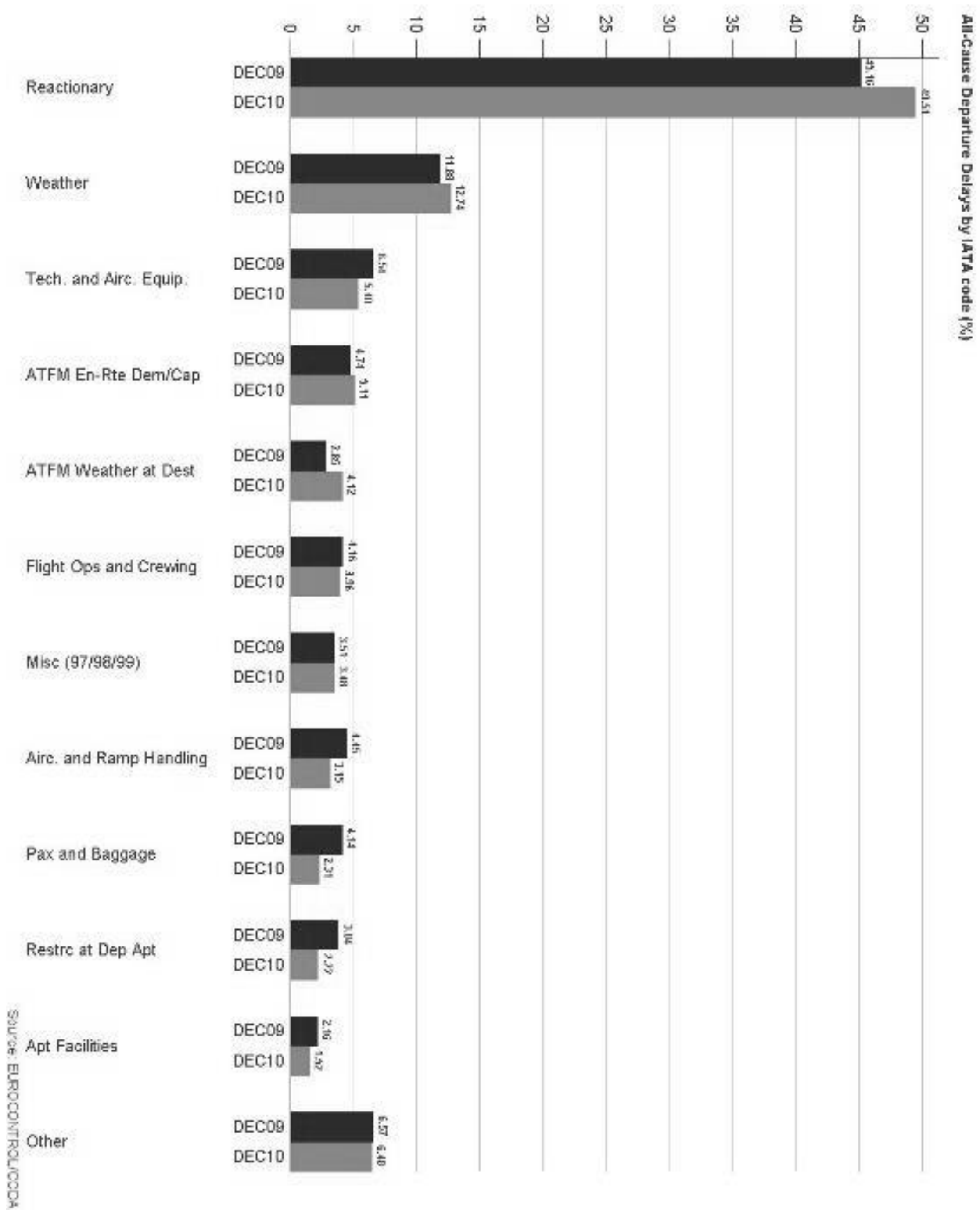


Figure 2.54. Primary and reactionary all-cause delay, by IATA code (%). Source: Eurocontrol CODA Digest: Delays at Ari Transports in Europe December 2010

Finally, the next Figure 2.55 illustrates the causes-7drivers of departure delays. For a better understanding various delays reported were grouped into the following main categories:

- Turn around related delays (non-ATFCM): are primary delays caused by airlines (technical, boarding, etc.), airports (equipment, etc.) or other parties such as ground handlers involved in the turnaround process.
- ANS-related delays: are primary delays resulting from an imbalance between demand and available capacity.

- Weather-related delays (non-ATFCM): This group contains delays due to unfavourable weather conditions including delays due to snow removal or de-icing. Weather-related delays handled by ANS are not included.
- Reactionary delays are secondary delays caused by primary delays on earlier flight legs which cannot be absorbed during the turn-around phase at the airport. Due to the interconnected nature of the network, a reactionary delay can propagate throughout the network and therefore have a considerable knock-on effect on subsequent flights.

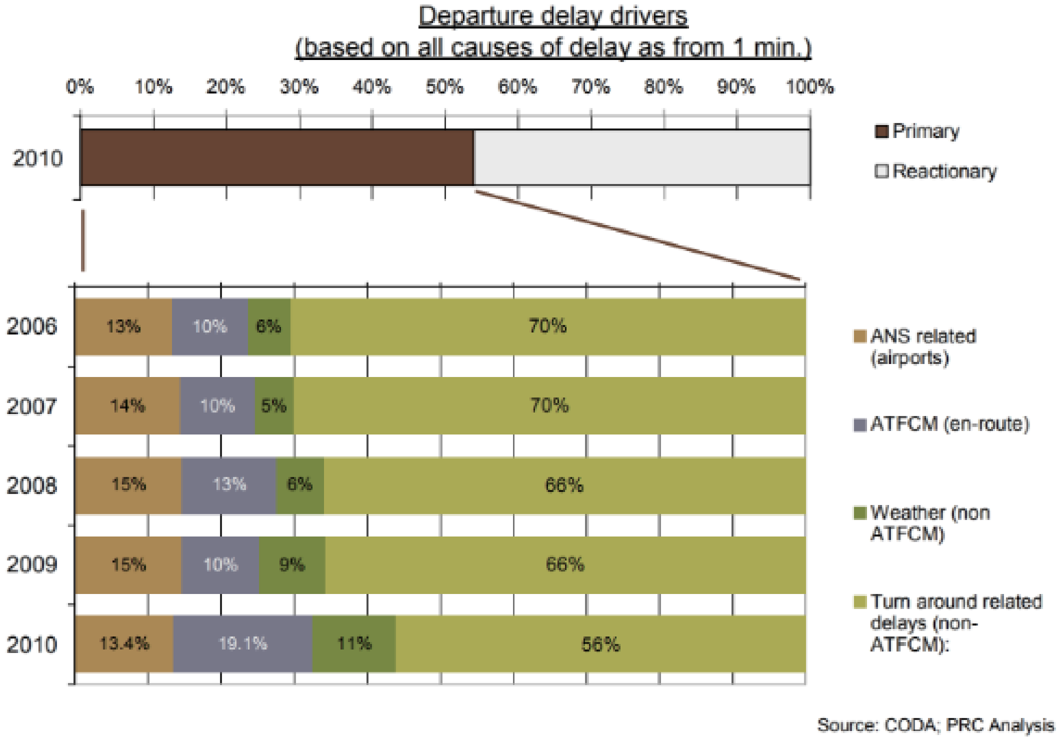


Figure 2.55. Drivers of departure delays (2007-2010). Source: Eurocontrol PRR 2010

In 2010 the concept of ACDM start to be applied at major airports to solve the previous issues. **Airport Collaborative Decision Making (ACDM)** is a system that designed by the EUROCONTROL and adopted by European Civil Aviation Conference (ECAC) Transport Ministers in the European Air Traffic Management Strategy to control the overall European airspace and airports[10, 11.] This is a concept that changes the system, hardware, human interactions with software, technology and the culture to understand the operational processes of each related parties (Air Traffic Control, Airport Operation, Pilots, Airlines, CFMU and ground Handling). Thus, enhance the airport efficiency by reducing delays, improving current airport facilities, maximize the capacity of landing allocations and slots as well as utilize the resources[12.] The development of ACDM is based on the historical data that provided by the airport authorities from each airport, by sharing and exchanging information and process would enable the best air traffic performance being implemented at European airports. ACDM is also parallel with AFTM, which is an integration of the SMEAN and SESAR programs.

In 2010 **Munich Airport is the first airport to be considered fully Airport CDM compliant** and has demonstrated the local benefits such as a reduction in average taxi times and an improvement in CFMU CTOT conformance. **Analysis of the impact of Airport CDM on delays has highlighted a room for improvement of 33%-50%**. Such a gain in terms of delay, allows the European targets to be kept in terms of delays. **If Airport**

[10] EUROCONTROL. (2010). *Airport Collaborative Decision Making*. Retrieved from EUROCONTROL on 3rd October 2010

[11] MUNICH AIRPORT. (2010). *Collaborative Decision Making (CDM) - a new concept*. Retrieved from Munich Airport on 3rd October 2010

[12] EUROCONTROL. (2010). *What is Airport CDM*. Retrieved from EUROCONTROL on 3rd October 2010

CDM were implemented in the main 42 delaying European airports with the same result in performance as Munich has experienced, then an increase in sectors declared capacity could be expected by up to 4%; that corresponds to an increase of 1 or 2 extra aircraft per hour per sector.[13]

Airport interconnection and delay propagation

Due to the networking nature of Air transport potential incidents, failures and delays (due to service disruption, unexpected events or capacity contains) may propagate throughout the different nodes of the network, making it vulnerable. The situation has led in recent years to system-wide congestion problems and has worsened due to the strong growth in the number of airport operation during the last decades. Broadly, two elements determine the magnitude of delay propagation:

- the primary delay parameters (i.e. time of the day, length of the delay, etc.) and,
- the ability of the air transport system to absorb primary delay (i.e. aircraft and crew utilisation including scheduled block times and turnaround times, airline business model, contingency procedures, turn around efficiency at airports, the effectiveness of airport CDM processes, etc.)

Reactionary delays are by definition a network issue and a better understanding of the contribution of airports, airlines and ANS towards those network effects and possible measured to mitigate those effects is desirable. Even though reactionary delays have a great impact on air traffic performance, the research effort to better understand and handle them in practice was limited in the past. One of the most complete studies in 2010 highlights that:

- **50 percent (12 minutes) of delays in low-cost operations are reactionary delays**. **Hub-and-spoke operators have by far the lowest ratio as reactionary delays account for nearly 40 percent of all delays (7 minutes)**. Point-to-point operations lie in between the other two with around 45 percent of reactionary delay (9 minutes).
- **The larger the share of aircraft which exceed the scheduled block-to-block time, the less delay can be absorbed in the block-to-block phase.** Buffer time is included in the scheduled block-to-block phase of all types of operation. However, low-cost operators are best positioned to absorb delays in the block-to-block phase.
- **Depending on the airline business model, between 60 and 90 percent of flights exceed the scheduled turn-around time. However, only half as many flights exceed their scheduled turn-around times when additional minutes due to the aircraft arriving ahead of its scheduled arrival time are removed.** Low-cost airlines appeared to have only a limited ability to absorb delay in the turnaround phase. Instead, they even added the highest level of new primary delays. Overall, hub-and-spoke and point-to-point carriers can absorb approximately the same amount of delay during the turn-around phase, but hub-and-spoke carriers added more new primary delays than point-to-point carriers.
- Irrespective of the airline business model, the time of the day and the length of the delay, **the majority of the root delays can be recovered within the first leg after the root delay occurred**. Those sequences (with one affected leg) accounted for 50 to 60 percent of all the analysed sequences.
- **The analysis of major European airports demonstrates that propagation is stronger in non-hub operations where reactionary delays account for up to 50 percent of total reported delays.**
- **Root delays originating from major European hubs daily effect on average between 30 and 50 other airports within the ECAC area.**

Technological and operational interconnection among the airports in the network is practically null in 2010. The only incipient attempt to interconnection is the Airport CDM initiative. Airport Collaborative Decision

[13] Eighth USA/Europe Air Traffic Management Research and Development Seminar (ATM2009) Airport CDM Network Impact Assesment Eduardo GOÑI MODREGO, Mihai-George IAGARU, Marc DALICHAMPT, Roger LANE EUROCONTROL Experimental Center, Bretigny s/ Orge, FRANCE

Making (A-CDM) involves all airport partners in the tactical phase (i.e. up to 3 hours look-ahead time). It ensures that airport partners get accurate data at the right time in the right place, thus improving shared information as well as the quality of subsequent decisions resulting from improved data.

Intermodality

The airport of the future is conceived as the central link of intermodal transport. Intermodality is understood as the transport of goods and passengers using several transport modes in one trip and involves the inter-coordination of those different transport modes. This coordination is made thanks adequate intermodal infrastructure, and to intermodal agreements concluded by transport operators. Agreements allow for common reservation for the whole trip, coordinated timetables, a common checking, and the certainty to travel to the final destination despite delays faced by one or several transport modes during the trip, etc.

Airport intermodality in Europe in 2010 is the result of **political and financial** actions, **airport connections** and **user's expectation**.

- Political and Financial Approach:

At late 90's European Union established guidelines for developing a trans-European transportation network that comprises roads, railways, airports, seaports, inland ports and traffic management systems that serve the entire European Union. National governments, local governments, and private transportation companies—such as airport and rail companies—all take part in the development of intermodal capabilities at airports.

Beginning XXI century, many airports owned or operated by private airport management companies, have taken the lead in planning and funding major intermodal facilities on airport property. For example, **Fraport, a private company that manages Frankfurt's airport, and Deutsche Bahn, the German rail company, invested over 300 million euros in building a station for long-distance and high-speed trains at the Frankfurt airport.** Additionally, some European rail systems are also privately operated. (Germany and France have established private companies to operate their nations' rail systems). However, the national government still takes the lead in planning and funding the building of the overall rail infrastructure, such as dedicated high-speed rail tracks. Once this infrastructure is built, it is then turned over to these private companies that operate and manage this infrastructure. At the Frankfurt airport, Deutsche Bahn and Fraport funded the construction of the long-distance train station, but all the track infrastructure was funded by the German national government. Local governments also are involved in providing intermodal transportation services to airports, with local government-owned transit agencies providing either rail or local bus service to the airport. For example, **the Rhein-Main Verkehrsverbund regional transit system provides 230 daily connections and service to about 4,000 passengers per day from the Frankfurt airport.** [14] In the past, KLM airlines took a 10% share in high-speed rail NS in the Netherlands to ensure a high-speed connection to Brussels from Amsterdam airport. Due to the difficulties with the high-speed train connection (the Fyra trains are no longer operational) the share was withdrawn. (Note that trains going east to Germany no longer stop at Schiphol airport either due to lack of passengers).

It is interesting to note that **there is intense cooperation within the same transport mode, for both air and train.** For example, airlines cooperate amongst themselves especially when they are part of the same group as Sky Team, One World or Star Alliance. This enables them to share the codes and provide combined tickets for onward travel with an associated airline at lower prices. The same intra modal agreements have been reached in the rail sector with the Interrail and Eurail passes. In air cargo, providers of parcel and mail services have an integrated transport chain from door to door. These integrator companies combine all transport modes within one company including aircraft, warehouses, vans etc. It seems that intermodal passenger

14 GAO. Potential Strategies Would Redefine Federal Role in Developing Airport Intermodal Capabilities. 2005

transport (where more independent organizations with different commercial objectives and funding arrangements need to work together) is far more difficult to organize.

➢ User Expectations:

Besides the political strategies and financial issues, satisfying the customer´s needs and assuring a positive and seamless travel experience is central to the success of intermodal passenger transport. Modair project has examined those variables which are relevant from the perspective of the passenger before, during and after the journey and depending on the type of passenger. These variables are numerous and wide-ranging; however, a number of key themes have emerged, some of which are cross-cutting:

- **Accessibility**, a clearly important requirement for passengers is to easily access reliable, impartial and real-time information, both for pre-trip planning and to be kept informed of relevant developments during the journey.
- **Single ticket,** taking the client from start to their final destination without the use of various tickets and the availability of multi-modal check-in facilities, avoiding the passenger having to carry their luggage between the different modes throughout the journey.
- **Confidence**, passengers being able to confidently find their way between modes and experiencing a feeling safety and comfort within the spaces they inhabit throughout their journey.
- **Accountability**, where there are a number of transport providers, the issue of accountability and passenger rights is raised, highlighting the need for effective coordination between operators.

All these variables concerning passenger requirements raise some obvious challenges for the transport sector (operators and infrastructure managers) in terms of logistics, operations, infrastructure, organisation and cultural factors etc., particularly with regards to single ticketing, multi-modal check-in and the provision of reliable and impartial information.

We revised hereafter the status in the first decade of the XXI century (according to ModAir survey) of some of these elements relevant for the users.

- **Intermodal information**: **Most airports had a simple link on their website to car rental, taxi, bus and rail companies and in some cases time schedules of bus and train connections are provided**. **None had a customer-oriented approach** where the customer is automatically informed about intermodal connections from arrival at the airport to the final destination and verse versa. There was no intermodal focus on door-to-door travel. The information was focused on travel from airport to airport. The current set up makes it mandatory for passengers to visit several websites to plan a door to door trip. Websites do not provide information about transit times between different travel modes, nor real-time information about delays in ground transportation.
- **Single ticket and other services:** Some airlines offered single tickets or combined tickets to passengers that allow multi-modal travel by plane and train. Examples are:
    - TGVair; A combined ticket offered for rail/ flight connections by TGV in France to Paris Charles de Gaulle and Orly.
    - Air and Rail: a combined ticket between Brussels and Paris CDG airport.
    - Air and Rail: a combined ticket between Brussels and Amsterdam.
    - Rail and Fly: the opportunity to buy an airline ticket and a train ticket at the same time in Germany

Besides these ticketing possibilities, there are services for luggage drop-off for airline passengers at remote locations. In Vienna, for example, passengers can check-in and drop off their luggage in downtown Vienna as a service by selected airlines.

- **Bus connections.** Low-cost Carriers often use regional airports to avoid the high fees that need to be paid at hub airports. As these airports are located outside the big cities, LCC cooperate with a direct bus connection to these cities. There is no single ticket, but the schedule of these busses matches the departure and arrival times of the LCC aircraft.

In bigger cities, some airlines own their own bus company that offers a bus-link to the downtown city. An example is Air France offering a bus service to downtown Paris. The passenger needs to buy a separate ticket for that service. Another service that is worth mentioning is the possibility to check-in at the US customs at Dublin and Shannon airports, thus avoiding long queues when entering the USA.

Airports Accessibility and Connectivity.

During the first decade of the XXI century, there were more than 1270 airports and 1230 aerodromes in Europe, 543 airports of them serving commercial air transport. There were also a number of new airports planned, constructed or reclassified from General Aviation to commercial operations. Many regional airports served seasonal traffic. The Low-Cost Carriers that operated on these airports served leisure travel during the summer (and in some cases only during the winter). The distances flown by LCC are in general beyond 600 - 800 km point to point. Low-Cost Carriers had in 2010 a substantial market share of about 40% in European air travel.

Regarding the **accessibility**, all of them could be accessed by car. 97%, 525 airports out of 543 were being served by taxi. 70%, 379 airports were served by regular bus services. Only 10%, 56 airports were served by local rail and light rail/tram to nearby cities or regions. At that moment there were a few high-speed rail lines (HST) in Europe, focused on massive volumes of passengers and connections between major cities.

The interconnectivity at European airports is often still limited to urban transport, with very few (high-speed) train stations located at airports. Some of the existing intermodal links do not fully meet the passengers' expectations, leading to low usage. As an example, in the UK train stations at regional airports have been closed due to the small number of passengers that made use of the facility.

Air/rail intermodality seems to offer promising opportunities for the future of the transport system by limiting the isolated use of road or air traffic (both responsible for congestion and air pollution) and providing combined trips, generally with rail. However, so far intermodal agreements are not very numerous in Europe. Funding and the possibility of signing exclusive agreements between airlines and train operator are essential enablers to foster intermodality.

In the first decade of the XXI century, there are so far few examples where intermodality at airport impacted air traffic. However, the number of these examples could increase with the level of airport intermodality, and the air traffic level and distribution could then be affected significantly.

Very high-speed train point to point connections (travelling at 250km/hour) can be more time-efficient than air transport over a distance up to about 600 km, although load factors are lower than in aviation (85% on average). Experience has shown that indeed there is some **substitution** taking place between air travel and HST up to that distance for example in France and Spain. In these countries, regional flights have been discontinued in favour of rail travel. Eurocontrol is expecting that the annual growth in the number of European flights by 2030 may be reduced from 3.9% by 0.7% to 3.2% if all High-Speed Rail plans are realized (assuming that the European economy will grow at an average 2.7% per annum). High-speed rail plans might have resulted in partial substitution of regional air travel by high-speed train especially in Spain, France, UK and Denmark. A modest substitution effect may be expected in Finland, Italy, Sweden, Poland, Croatia, Germany, Greece and Portugal if all HST plans are executed. However, due to the economic crisis, some high-speed rail planning was put on hold.

However, according to Eurocontrol and also ModAir connections analysis, HST connections are not expected to affect long-distance flights and most of the Low-Cost Carrier operations as well as the intercontinental flights. Rather than focusing on substitution, the focus should be on the benefits of directly connecting air travel to high-speed rail travel:

- By substitution freeing airport slots, which is relevant for crowded HUB airports where runway capacity and slots are scarce;

- ➢ Creating additional airspace capacity which is scarce in Europe due to the fact that large parts of the airspace are still reserved for military operations;
- ➢ Enlarging the catchment area of HUB airports;
- ➢ Enabling airports to be interconnected via high-speed rail, allowing a better distribution of air traffic over different airports.

The next Figure 2.56 summarises the Europe map of existing & planned rail connections to airports. (Source ACI June 2012)

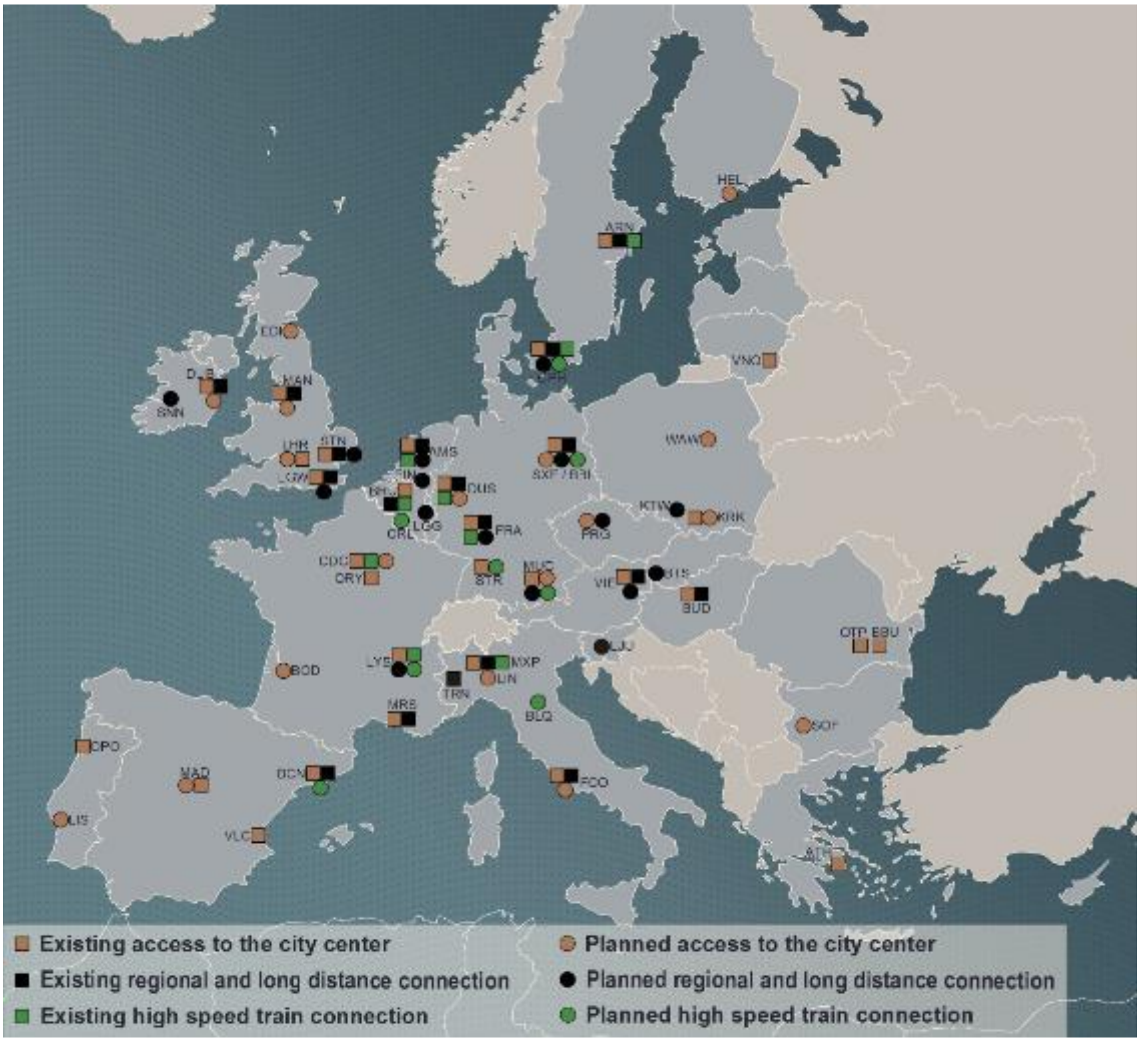


Figure 2.56. EUROPE map of existing & planned rail connections to airports (ACI June 2012)

Progress Up-to-now

Airport efficiency and airport interconnection

Recent R&D projects and initiatives have concentrated its efforts on the development of (at different TRL) concepts, tools, technologies and solutions to improve the turnaround process at the airport. Hereafter are described some research and development initiatives developed during the last decade that might contribute highly to the improvement of the Airport efficiency.

- ➢ <u>Airport Operations Centres (APOC) and the Airport Operations Plan (AOP)</u>

Given that it is essential to integrate airports more closely into the network, collaborative concepts are being developed under the SESAR programme, building on the success of the A-CDM (airport collaborative decision-making) project. Two of these concepts are Airport Operations Centres (APOC) and the Airport Operations Plan (AOP) on the airport side, as well as the collaborative Network Operations Plan (NOP) on the network side.

An APOC manages an airport's operations in both normal and exceptional conditions. The AOP is a rolling plan that covers the pre-tactical and tactical phases by providing dynamic data updates as an operational situation evolves. Through the timely two-way exchange of relevant airport and network information between airports and the Network Manager, AOP-NOP integration improves both the airport's and the network's operational performance. Situational awareness is heightened, and issues can be contained before they can affect other parts of the network. The exchange with the Network Manager through the AOP-NOP integration delivers local throughput status information earlier than was previously the case. This information can also be shared with other airports, airspace users and ANSPs (air navigation service providers), so facilitating improved decision-making. This is expected to improve network predictability and add to the improvements brought about with A-CDM.

Major airports in Europe have implemented these advanced concepts: Frankfurt, London Heathrow, Paris Charles de Gaulle, Paris Orly, Amsterdam Schiphol, Barcelona - El Prat, Madrid - Barajas, Palma de Mallorca, Brussels or Stockholm Arlanda.

- INTERACTION (INnovative TEchnologies and Researches for a new Airport Concept towards Turnaround coordinatION)

INTERACTION project has developed and validated (at Athens Airport) a solution that integrates the information on the different airport processes within the same system, which has allowed to analyse the evolution of each process by itself and to predict the impact of on disruptions on one process on the overall turnaround process. The system integrates a Centralised Information Platform, Mobile application for passengers and a Handling processes tool. Additionally, the project has dealt with some advanced solutions for airport process improvement:

1. Unification of passenger and baggage process and Pooling of Equipment (GSE);
2. Cargo portal solution: the concept consists of a support platform for the cargo process which was developed in a prototype;
3. Machine Learning for Estimation of Landing Time solution;
4. Time-efficient passenger and baggage processes able to move passengers at up to 2 m/s;
5. A new gate concept aimed at reducing the movement and space of the apron operations that implies the standardisation of the gate design for aircraft type C such as Airbus A-320 family;
6. Conceptualising a passenger boarding bridge that can dock not only the aircraft front door but also the rear door, by going over the aircraft wing;
7. Fleet, mobile vehicles and equipment management;
8. Aircraft Navigation lights powered by tow tractor converter;
9. Feasibility study for more electrical tractor;
10. Assisted/Automated cargo loader to aircraft docking;
11. Slot assignment for passenger security screening;
12. Prediction of consumed potable water and catering goods;
13. A collaborative decision-making enhanced framework was developed which aims to avoid the delay propagation between airport sub-processes satisfying all stakeholder business models.
14. Aircraft RFID tag identification;
15. Communication between aircraft and airport;
16. New concepts related to passenger boarding methods via passenger boarding bridges were explored and were left at concept maturity level.

➢ Total Airport Management

The full integration between Airport and Network Operations has still to be achieved (airport performance strongly depends on the performance of the Network). Management of predicted airport performance deterioration, therefore, needs to be aligned with the Network. Collaborative recovery procedures and support tools in coordination with all the relevant ATM stakeholders are required to facilitate the pro-active management of predicted performance deteriorations. Total Airport Demand and Capacity Balancing processes and tools require further integration with the execution tools (Arrivals and Departure Management systems and Advanced Surface Movement Guidance & Control Systems) and resource allocation planning tools (Stand/Gate Allocation Planner). Airport landside/airside performance monitoring and management processes need to be integrated refining as well the turnaround monitoring within the Airport Operations Centre (APOC) in coordination with the Airspace Users. Environmental impacts and all aspects of de-icing are currently not integrated into the planning and execution timeframes of the Airport Operations Plan (AOP). Impact assessment tools available to the APOC need to better integrate information about MET forecast uncertainty. Post-Operations Analysis processes, support tools and reporting capabilities need to be developed. This project has developed solutions that are expected to have a very positive impact on the Network through:

- A performance-driven airport through KPIs monitoring and detection of deviations, collaborative decisions using support tools and what-if functions, the post-operation analysis used as a learning process. A Better situational awareness through SWIM information sharing, enabling provision and reception of Airport CDM data including MET and AIM.
- A significant increase in the predictability, efficiency, environmental sustainability and flexibility of airport operations;
- Better use of existing airport capacity;
- Increased safety in the airport environment due to reduced uncertainty of operations and reduced congestion through better planning.

➢ META CDM

META CDM project has worked on laying the foundations for an extended CDM concepts that integrates Landside and Airside CDM united into the concept of Total Airport CDM. The benefits of this concept can be split into two areas.

- If the aviation system is operating normally or with mild delays, passengers will receive more information that enables them to streamline their journey and to reduce uncertainty; for example, better estimates of when to leave home for the airport based on real-time information about traffic, check-in and security queues.
- In case of a major disruption with long delays and/or cancelled flights, passengers benefit from earlier and better information about any changes to their flight, and a greater range of alternative options if their flight is cancelled.

➢ TITAN Project

Titan project works to improve the turnaround process and expect to generate 2 % of operational cost reduction.

➢ Fantassy Project

Fantasy project investigated the design of the aircraft as a combination of a "carrier" and a "passenger pod" proposing 2 preliminary aircraft configurations and design studies: one that employs external attachment of the pods (EPC-External Pod Configuration) and one that accepts the pods internally (IPC-Internal Pod Configuration).

The project studied how the pod system contributes to reducing the turn-around time of the aircraft thus minimizing waiting time for the passenger but most importantly increase the aircraft/passenger throughput of the airport. As pods can be loaded in a convenient time before the in-bound aircraft is ready for take-off, the whole process is not sequential and thus less prone to delays.

It also studied how the pod system might contribute to a seamless intermodal travel finding that the most effective way to accomplish that is to develop dedicated automated lines to carry the pods between the airport and city centre terminals where crossing to local transport can be easier. This option facilitates both security and operational requirements.

Intermodality

ModAir project has identified R&D needs to favour intermodality finding that:

- Regarding integrated ticketing and luggage transfer, there is a need for an updated and further detailed study on the real latent demand for integrated ticketing through broader research on passengers' demand.
- Regarding air-rail experiences in Europe, there is a need to continue with the recently initiated cooperation between stakeholders. Although some of these experiences target their local markets and it would be difficult to broaden their scope (e.g. Eurostar from London to Paris which is directly using IATA codes for its stations and operating through GDS), it is remarkable that cooperation between stakeholders has begun. Agreements on the delays, railways available in GDSs, cooperation in situations like when volcano Eyjafjälla paralyzed the European air traffic, and other experiences make the final solution closer.
- Regarding stakeholders' perceptions, passengers are welcoming better information related to intermodality, comprehensibility of the reservation systems (including better prices when booked air and rail are together), flexibility on their bookings and a secure framework with clear operators' liability conditions. On the other side, from the supply point of view, there are disparities in their opinions. Some think that air-rail integration is already solved, and everybody should use the alternative they are providing (these still demur appearing in a common information system with competing means of transport). Others state that only a common agreement is needed and, consequently, all agents should be involved in a global working group. Most of them are enthusiastic but only if the demand for air-rail can be proved first. Greater market potential is expected for the long term.
- Regarding technologies covering intermodality (and in particular, air-rail intermodality) they are already available, however, no one has been placed yet as the global solution for the air-rail market, one strives to make available developments compatible.
- Main challenges to overcome in order to achieve the desired framework for intermodality relate to standardisation and funding, but also to remote check-in and luggage handling and schedule and delays.
- Regarding standardisation issues, the project focus on standardisation among railway services procedures from different companies is envisioned, and standardisation between air and rail must be addressed. The main targets within standardisation are:
    - A neutral display of air-rail alternatives over the air-air ones;
    - The provision of a common and global nomenclature system for the stations' description like airport IATA codes;
    - Discussion about those rail trips with no need of reservation, or the booking of those where one seat can be booked from a to b and the same seat from b to c;
    - Harmonisation of journey classes and social discounts;
    - The need to ensure data sharing, open access and data quality;
    - A branding strategy to avoid different nomenclatures for similar services.

- Regarding luggage transfers, knowing what is happening to their baggage is one of passengers' top three priorities (Passenger IT Trends Survey 2013). Access to baggage information wherever actors are located (including on mobile devices) has to be developed. By the end of 2016, over 60% of airlines expect to be sending bag location updates and enabling missing bag reports via smartphones (Airline IT Trends Survey 2013). Efficient and cheap tag technologies (paper, RFID, Bluetooth…) must be developed, with standardized tags and data formats between modes.
- On the funding side, it will be very important to quantify the existing latent demand for air-rail integration. This demand will determine the expected benefits for the different stakeholders in comparison with their actual demand figures. Also, it will be essential to achieve the proper cooperation between stakeholders to discuss the details of the funding based on their particular business plans. Furthermore, most of them believe that EU funding may prove to be valuable regarding, at least, the investments in standardisation.

Predictions Up-to-2025 and Evolutionary Progress Up to 2050

How To optimize An Airport

Today's globalized world would not be possible without air transport. Airlines respond to a growing demand for air transport by adding new routes and offering more connectivity to their customers. As a result, air traffic volume is growing at an average rate of about 5% per year, which is equivalent to traffic tripling in 14 years. This impressive growth has also led to a number of big challenges that today's aviation is facing:

- Maintain and improve mobility despite more and more congested airspace and airports.
- Improve competitiveness and cost-efficiency of air transport.
- Address aviation's environmental footprint in terms of greenhouse gases, noise and air quality.
- Maintain and improve the safety level of aviation.
- Provide hassle-free security processes while maintaining at least the current security level.

First of all, the main objective is to optimize airports; analysing the way the different media act, times, delays, connections, etc. It is about getting an airport as efficient as possible. The critical elements for the 2050 airports are the following:

- Air traffic management will be related to a network of airports rather than local and individual airports.
- Landside and airside components need to be re-thought and **intermodal** means of transport described.

Connections between hubs and secondary airports will be possible through efficient and environmentally friendly public transport but will also include an optimised network for private transportation that will enable the efficient, safe use of personal ground transport. Ships may be used to connect secondary airports, depending on their location.

Air transport will include current-configuration aircraft, plus other actors such as personal air transportation vehicles or aircraft with passengers pre-loaded into standard fuselage boxes. In addition, different types of runways as well as take-off and landing assistance systems will be available to provide services for conventional take-off and landing aircraft, short-take-off and landing air vehicles or convertible vehicles. Airport networks should be designed to accommodate all of them.

Interconnections within this network will be provided by multimodal transport, including high-speed trains for the national or international network, trains, subways, tramways or suburban trains at regional airports, electric ground vehicles, environmentally-friendly ships or even air-buses.

The airport will use new technologies to make passengers' stay at the airport as short and as comfortable as possible. One of the most important challenges will be achieving public confidence in automation, although this will demand significant advances in technology. Automation will mean that users are informed about the current status of their journey and alternative options, periodically or on-demand. Information points will be distributed around the terminals and interactive devices embedded in transport systems so that passengers can access travel information at any time using smartphones or interactive panels/screens situated along with the intermodal transport network.

The airport landside is the interface between air transport service providers and passengers. Therefore, future landside infrastructure and services must focus on passenger's needs and comfort. Future airport terminals will be much less time consuming for the passenger and they will have short walking distances for passengers. Moving walkways and individual automated guided vehicle systems will cover long distances conveniently and quickly between different terminals and within large terminals.

Many airports deliberately increase passenger walking distances, forcing a passage through shops, whose sales are one of the main sources of revenue for the airport.

Passengers will have information available at all times, providing a comprehensive choice of the modes of transport, before travel as well as in the case of rescheduling or unforeseen disruptions.

In terms of operations, by 2050, the Single European Sky (SES) four-dimensional space-time (4D) air traffic management system will have been fully implemented. It will be important to provide airport networks with the capability to coordinate/ manage ground operations with 4D airborne operations.

In the short term, the airside will take advantage of improvements resulting from the SES programme and will evolve towards higher automation. The airport infrastructure will include revolutionary architecture adapted to any new aircraft configuration and propulsion mode (i.e. blended wing body and new fuels, such as hydrogen or biofuels).

Considering weather operations, revolutionary concepts for the increase of capacity independent of weather conditions include:

- On-board equipment allowing landing with significant tail or crosswinds.
- On-board equipment to display weather information and airport infrastructure in low visibility conditions.
- Fans or other equipment to blow fog and wake turbulence away.
- Ground-based runaway heating.

Efficient and Connected Airport

In this context, it is necessary to know about **intermodality.**

A main goal for the future intermodal transport system is to reduce dependence on the automobile as the major mode of ground transportation and increase the use of public transport, especially in the case of the future air transport system.

Intermodality can be envisaged at several levels, from local public transport to international connections:

City centres and suburban areas have to be accessible using the tramway or subway connecting with railway stations located on the airport landside.

- At the regional level, connections to a high-speed train is a strong advantage for an airport's attractiveness if it is rapid and serves the nearby cities.
- For national / international connections
  - Integration of airports within a regional/national railway network or other future modes of public transport.
  - National railway stations at airports must be part of the landside, where the passenger journey starts with passenger check-in and luggage deposit.
  - High-speed train connections to connect regional megacities.
  - Connections between regional airports to major hubs with a high-speed train as an alternative to short-haul air services, releasing slots and relieving airport congestion.

One of the most important things in relation to interoperability is the **airport network**. The airports of 2050 will be integrated into a network of air, ground and even water transport that will enhance capacity and make transportation more efficient, one of the goals that are tried to achieve. The airport network (Figure 2.57) will be mainly composed of hubs connected to secondary airports that will provide services to a greater number of users and operators.

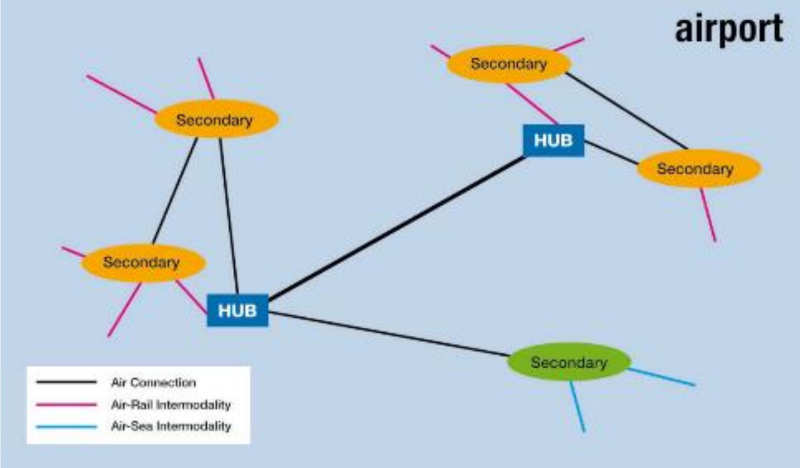


Figure 2.57. The airport network. Air Transport System 2050 Vision to Planning for Research and Innovation. EREA

The airport landside should provide inter-terminal shuttles to provide convenient, fast and reliable services for the passenger and luggage. Automatic subway trains and/or tramways should be considered instead of buses.

In addition, CDM airport concept, which is explained in goal 1, is another new idea directly related to the airport network. CDM airports will improve the connection between airports. For this reason, it is considered appropriate to include it in this section.

New ticket initiative

Regarding the connectivity of the airports, IATA proposes a new industry-led initiative intends to replace the multiple and rigid booking, ticketing, delivery and accounting methods, using the data communications advances made possible by the implementation of the New Distribution Capability. ONE Order, the name of this initiative, aims to modernize the order management process in the airline industry. This is the concept of a single Customer Order record, holding all data elements obtained and required for order fulfilment across the air travel cycle, such as customer data, order items, payment and billing information, fulfilment data and status.

Also, One Order will result in the gradual disappearance of multiple reservation records as well as e-ticket/EMD (Electronic Miscellaneous Document) concepts to be replaced by a single reference travel document.

A new standardized and expandable reference will become the single access point for customer orders by third parties (interline partners, distribution channels, ground handling agents and airport staff, among others). Thanks to this new project, it will provide easier product delivery and settlement between airlines and their partners with one simplified and standardized order management process.

All parties will follow a single process to service customers throughout their entire product purchase and delivery experience.

Likewise, One Order will enable “network airlines” and “low-cost carriers” to interact and provide combined services to customers. Through a new optimized process, both airline communities will be able to manage customers seamlessly and homogeneously despite having different business models and operational environments.

Due to this new kind of “single ticket”, it will provide multiple advantages for all airspace users.

Alternatives to Resolving the Expected Demand

According to the data provided, it is expected that by 2030, and therefore by 2050, demand will continue to grow. This will mean new measures in capacity.

Consequently, the alternatives proposed by EUROCONTROL are the following:

- Growth of airports. It will be necessary to increase the capacity of airports by increasing the number of runways or the size of these.
- Using the nearby airports, wherever possible. In this case, reference is made to those geographical areas that have a main airport and that should use their nearest airports.
- New airports. In the case of it cannot manage the great demand that is expected to be achieved, it will be necessary to have new airport infrastructures.

Also, EUROCONTROL proposes several mitigation measures, which have been explained in detail in the goal 1 that they affective directly in the airport's mobility. Consequently, these measures are (Figure 2.58):

Alternative airports	SESAR improvements	Schedule smoothing	High Speed train investment	Shifting to larger aircraft

Figure 2.58. Mitigation Measures for Traffic Capacity

VTOL: an approach as an innovative technology

Every day, millions of hours are wasted on the road worldwide. In many global megacities, the problem is quite serious.

Aviation has the potential to radically improve urban mobility, helping to decrease the time spent by people in their daily commutes. Urban air transportation would use three-dimensional airspace to alleviate transportation congestion on the ground.

A possibility is the use of **VTOL** (Vertical Take-off and Landing) aircraft. It would enable rapid transportation between suburbs and cities and, ultimately, within cities.

Several companies, with different design approaches, are working to make electric VTOL aircraft a reality. The closest equivalent technology in use nowadays is the helicopter which has longer ranges and is more polluting than VTOL prototypes.

An example of a VTOL aircraft is shown in Figure 2.59. One of the key features needed to allow the deployment of VTOLs in the future is the noise generated by their rotors. It is claimed that at flying altitude, noise from advanced electric vehicles will be barely audible. However, VTOLs will need to meet the requirements regarding noise generation during take-off and landing within cities.

Figure 2.59. Aurora's VTOL aircraft use eight lifting propellers for vertical take-off, and a cruise propeller and wing to transition to high-speed forward cruise.

As VTOL designs differ from conventional rotorcraft or fixed-wing aircraft, EASA developed a complete set of dedicated technical specifications in 2019 in the form of a special condition for VTOL aircraft in order to allow the type certification of this type of product. This special condition addresses the unique characteristics of these products and prescribes airworthiness standards for the issuance of the type certificate, and changes to this type certificate, for a person-carrying VTOL aircraft in the small category, with lift/thrust units, used to generate powered lift and control.

Some other key features needed are:

- Development of Infrastructure

The development of infrastructure to support an urban VTOL network will likely have significant cost advantages over heavy-infrastructure approaches such as roads, rail, bridges and tunnels.

It has been proposed that the repurposed tops (Figure 2.60) of parking garages, existing helipads, and even unused land surrounding highway interchanges could form the basis of an extensive, distributed network of vertiports (VTOL hubs with multiple take-off and landing pads, as well as charging infrastructure) or single-aircraft vertistops (a single VTOL pad with minimal infrastructure). As costs for traditional infrastructure options continue to increase, the lower cost and increased flexibility provided by these new approaches may provide compelling options for cities and states around the world.

Furthermore, VTOLs do not need to follow fixed routes. Trains, buses, and cars all funnel people from A to B along with a limited number of dedicated routes, exposing travellers to serious delays in the event of a single interruption. VTOLs, by contrast, can travel toward their destination independently of any specific path, making route-based congestion less prevalent.

The economics of manufacturing VTOLs are still uncertain. At first, VTOL vehicles are likely to be very expensive as they will be required to obtain a type certificate, but ridesharing model could help to amortize the vehicle cost using paid trips, so the high cost should not end up being prohibitive to getting started.

Figure 2.60. Top of an eight-story downtown parking garage converted to vertiport capable of supporting 12 VTOLs (UBER Elevate)

- Aircraft Performance

There is a burgeoning VTOL aircraft ecosystem, including several companies that are already developing and flying early vehicle prototypes, such as Zee, Aero, Joby Aviation or Airbus. The following pictures (Figure 2.61 and 2.62) shows some of this kind of aircraft:

Figure 2.61. Joby S2

Figure 2.62. Airbus A3 Vahana

The VTOLs envisioned within a ridesharing network will need to address four primary barriers to commercial feasibility: safety, noise, emissions, and vehicle performance. The two most important technologies to overcome these challenges are Distributed Electric Propulsion (DEP) and autonomous operation technologies.

Figure 2.63. Boeing VTOL during the first flight

In addition, VTOL operations will involve the ability to take off with a rapid climb at a steep glide path angle to reach a cruising altitude up to a few thousand feet, then decelerate to land vertically at the end of the trip. There will likely be a limited need to hover for durations not exceeding one minute, with most vertical take-off and landing transitions taking place in approximately 30 seconds.

In this case, it should be noticed the following aircraft characteristics:

- Speed and range;
- Battery requirements;
- Payload;
- Autonomy (autonomous systems can be introduced). VTOL autonomy is likely to be implemented over time, as users and regulators become more comfortable with the technology. However, recent proofs related to drone usage show exactly the opposite, and this is especially critical in the vicinity of airports and within CTRs. Numerous drone sightings have been reported by commercial pilots which ended up being unauthorized drone flights within CTRs. Therefore, the deployment of VTOLs within the air traffic management network will be a major challenge in the future.

➢ Applicable Regulation

One of the most important point to keep in mind is safety. Therefore, concerning the regulations applicable to this project, all aspects related to the safety of operations must be considered.

As previously explained, EASA has developed a complete set of dedicated technical specifications in the form of a special condition for VTOL aircraft in order to allow the type certification of this type of aircraft.

The type of certification will at least include the following parts[15]:

- Regarding flight performance:
  - Mass and centre of gravity.
  - Performance data.

[15] Special Condition for small-category VTOL aircraft (SC-VTOL-01). EASA.

    - Flight envelopes.
    - Take-off performance.
    - Climb requirements.
    - Climb information.
    - Landing.
    - Controllability.
    - Control forces.
    - Flying qualities.
    - Stall characteristics and stall warning.
    - Vibration.
    - Flight in icing conditions.
    - Operating limitations.
- Regarding structures:
    - Structural design envelope.
    - Interaction of systems and structures.
    - Structural design loads.
    - Flight load conditions.
    - Ground and water load conditions.
    - Component loading conditions.
    - Limit and ultimate loads.
    - Structural strength.
    - Structural durability.
    - Aeroelasticity.
    - Design and construction principles.
    - Protection of structure.
    - Materials and processes.
    - Special factors of safety.
    - Emergency conditions.
- Design and construction:
    - Flight control systems.
    - Landing gear systems.
    - Flotation.
    - Means of egress and emergency exits.
    - Occupant physical environment.
    - Fire protection.
    - Fire protection in designated fire zones.
    - Lightning protection.
    - Design and construction information.
- Lift/thrust system installation.
- Systems and equipment.
- Flight crew interface and other information.

Traditionally, the end-to-end certification process (type and production) takes about two to three years for a type certificate, plus another year for a new production certificate for a simple case. However, the introduction of a new type of aircraft requires a new certification basis, developed in parallel with the type certificate, and this could extend the certification process from 4 up to 8 years.

The following Figure 2.64 shows a time estimate in relation to infrastructure, aircraft and the necessary regulations to start up the vertiports project:

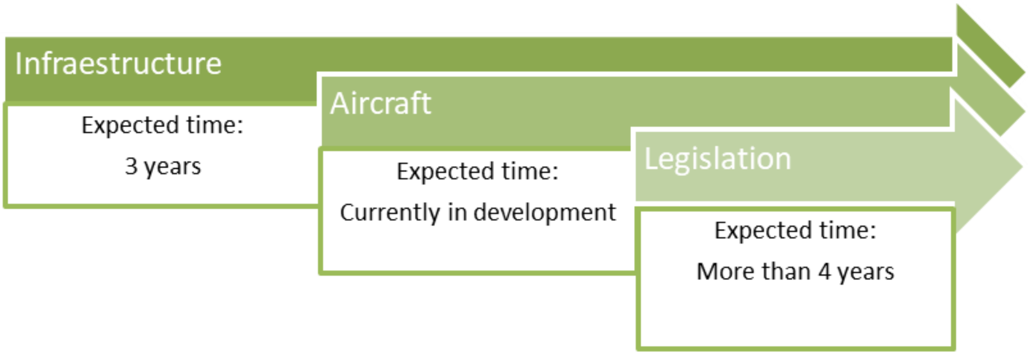


Figure 2.64. A possible timeline regarding VTOLs development

2.4. Overall Ground Plus Air Travel Time

*Flightpath 2050 goal 4: "90% of passengers within Europe are able to complete their journey, door to door within 4 hours. Passenger and freight are able to transfer seamlessly between transport modes to reach the final destination smoothly, predictably and on time".

The goal 4 (section 2.4) is a combination of all other goals 1,2,3,5 (sections 2.1, 2.2, 2.3 and 2.5) in the same set. Air travel times can vary significantly in Europe, from 1 hour in central Europe (Paris-Frankfurt) to 4 hours between extremities of the continent (Lisbon-Bucharest). Assuming that most flights do not exceed 2 hours, leaves within the four-hour total time frame, 1 hour to travel to and from the airport and go through airport services. This objective is achievable if all elements of the chain perform nominally: (i) no take-off queue, no holding pattern at landing, no major weather or ATM disruptions; (ii) efficient check-in, passport and security checks; (iii) fast luggage handling; (iv) efficient airport ground movements and operations; (v) uncongested local transport to and from home or work.

The Goals 3 and 4 are closely related and addressed as three Key Topics: 2.5 to 2.7.

KEY TOPIC T2.5 – AIR TRANSPORT AND OTHER MOBILITY CHOICES

Introduction

Goal 4 was defined in Flightpath 2050 as "90% of travellers within Europe are able to complete their journey, door-to-door within 4 hours. Passengers and freight are able to transfer seamlessly between transport modes to reach the final destination smoothly, predictably and on time".

Comparing the scope in both Flightpath 2050 and SRIA it can be stated that both proposals are coherent between themselves. It is a key factor in air transport development that the total travel time decreases substantially when passengers travel by plane. This key factor is not only focused on fulfilling passenger's requirements but also in competing with other transport modes that have gained market share in short-haul trips (about or below 700km).

For example, since the 1980s, high-speed rail (HSR) has become an important competitor to airlines, presenting railway transport in a new form and notably improving the quality of the service offered. Focusing in Spain, this problem has come to reality since the launch of AVE (acronym for Spanish High Speed) in 1992 when it began to operate the route Madrid-Seville. During the last 25 years, the number of passengers has sharply increased reaching, for example, 3.23 million of passengers on the Madrid-Seville route in 2016 which supposes more than 89% of the market share against the air transport on this route. This also happens on the Madrid-Barcelona route which has reached 7.4 million passengers in 2016, meaning 62% of the market share against air transport. These differences between air transport and high-speed rail are due to the total travel time spending by passengers in each transport mode. For example, whilst the Madrid-Seville route duration by high-speed rail is approximately 2 hours and 30 minutes, the Madrid-Seville route duration by plane is approximately 1 hour. However, the total time that passengers must spend if they travel by plane increases so that it could take approximately over 3 hours. This huge difference between the actual travel duration and the total travel time is since airports are usually far away from city centres and that airports processes are not fast enough hence passengers have to be at the airport at least 2 hours before of the estimated time of departure.

Therefore, it has been noticed that new developments concerning the optimization of the total travel time in air transport should be done to allow reaching the objectives stated in goal 4.

Benchmarks

Allowing passengers to be able to complete their journey to their destination within 4 hours is a difficult task that includes a cluster of key factors to be improved. Since the beginning of the air transport expansion in the 1990s until nowadays, all the systems and infrastructures related to air transport have been involved in a steady process of improvement. Some examples of these developments have been the construction of new runways in airports that needed more capacity to accommodate the growth of flights or the implementation of new navigation systems on the aircraft. Besides, this growth of passengers set a new desire for improving the connection of the airports with the city centres, developing other transport modes like underground or train. Besides, other issues related to the air transport capacity like airport ground infrastructure and air traffic management should be also considered. However, as it will be studied in other goals like goal 1, 2 or 5, it has not been considered in this document.

Nowadays, airports have evolved to become intermodal nodes where passengers can arrive at the airport in several ways. However, most of these ways make passengers spend on average, using Madrid as an example, more than 30 minutes to get to the airport. In this manner, it would be interesting to develop the current transport modes both taxi and public transport, infrastructures included. Researching new ways to get to the airports from the city centres nevertheless would be the first key to actually reduce the travel duration. Relating to that, it would be interesting taking into account new developments that are being made in unmanned aircraft and the systems that would allow them to flight in the airspace over the cities and near the airports.

For example, several companies are researching new ways to transport people. One of this breakthrough technologies in the use are the VTOLs (Vertical Take-Off and Landing Aircraft) which consist of a new concept of unmanned aircraft designed specifically to transport people. As an example, UBER is currently researching it, known as UBER Elevate, in order to implement it in the near future. These VTOLs could allow carrying people from "veliports" placed somewhere in the cities to others "veliports" placed as nearest as possible to the airports.

In this manner, it is essential to involve both top manufacturer companies such as Airbus or Boeing and also small companies in order to develop successfully these VTOLs, which will likely be developed across a number of different speed and range capabilities. A VTOL optimized for shorter trips (less than 50 miles) won't require as much speed as a VTOL capable of meeting the needs of long-distance commuters. As an example, Airbus is developing a new VTOL concept named as "Vahana" (Figure 2.65) with a flight range about 50 miles, seeing it as being used by everyday commuters as a cost-comparable replacement for short-range urban transportation like cars or trains.

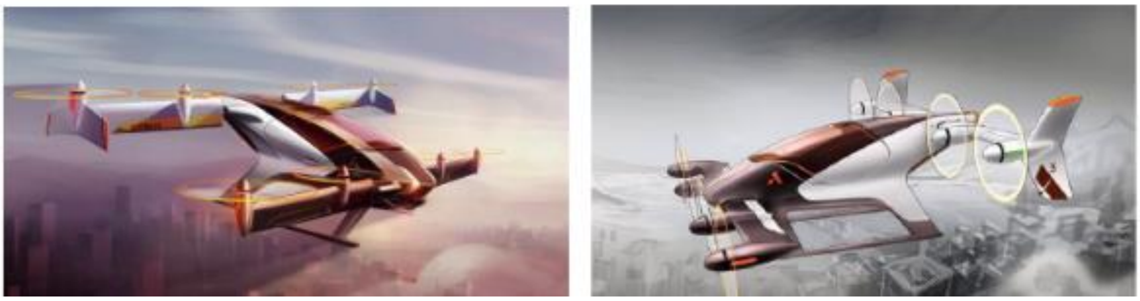


Figure 2.65. "Vahana" VTOL concept by Airbus

Therefore, also a new regulatory framework may be necessary concerning new UAVs, VTOLs and new ATC systems. This new framework should be assessed in order to handle this exponential increase in complexity, with low altitude operations being managed through new concept systems. One new concept system could be a server request-like system that can de-conflict the global traffic, while allowing UAVs and VTOLs to self-separate any potential local conflicts with VFR-like rules, even in inclement weather. Some of the new systems are already being developed, for example, NASA (Figure 2.66) is studying the entry of the UAS in the low-altitude airspace, considering UAS operations inside uncontrolled Airspace (class G), UAS operations inside controlled airspace, but segregated from controlled air traffic and UAS operations integrated into the controlled air traffic flows.

Figure 2.66. NASA's concept for a possible UTM system

This complete study could become important because UAS can be used for many tasks (Figure 2.67) such as infrastructure monitoring, precision agriculture, public safety, search and rescue, disaster relief, weather monitoring, and delivery of goods.

Figure 2.67. Applications of small UAS (NASA UTM)

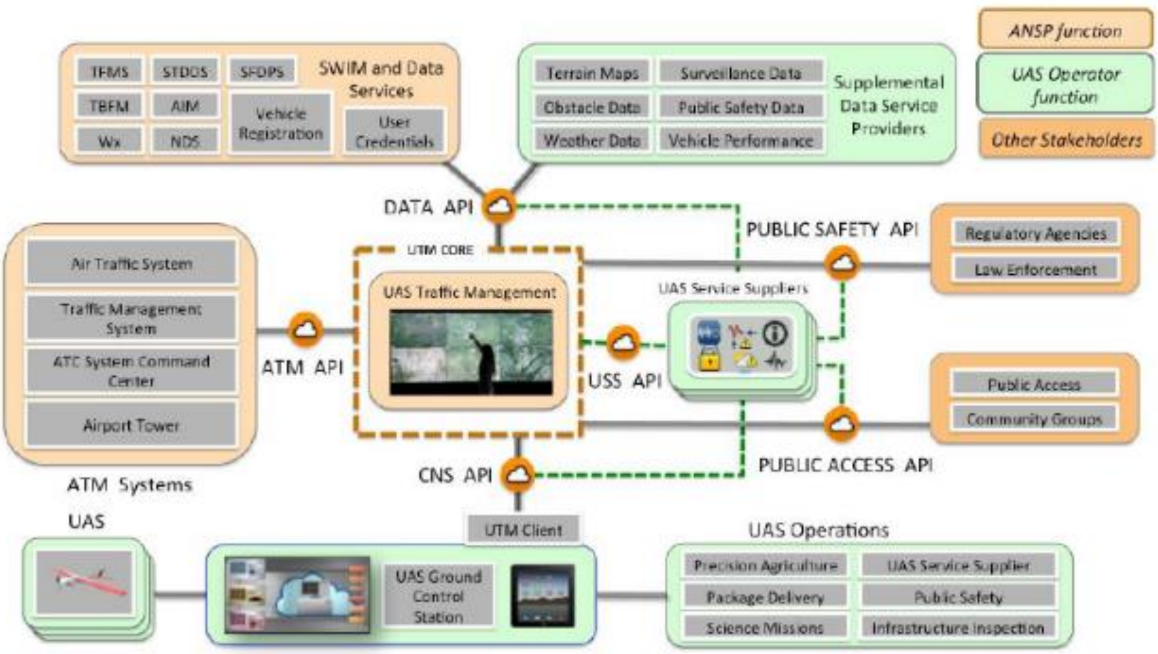


Figure 2.68. Complete UTM architecture (NASA UTM)

The second key to reducing the travel duration would be the improvement of the current processes carrying out at the airports or even the design of a new system regarding both passengers and luggage processes. These processes are, concerning the passengers: check-in, security control, passport control and customs; concerning the luggage: security control, management and customs.

Nowadays, airlines advise their passengers to get to the airport with enough time to boarding. For example, Iberia set the following limit hours to check-in:

Distance	Time Limit
Short and mid-haul	45 minutes
Long-haul	60 minutes

Apart from this time limit set by the airlines, the passengers have to bear in mind the time spent from the start of their journey to the airport and also the time spent in going through the processes at the airport, thereby passengers usually start their journey at least 2 hours before the estimated time of departure. In the last few years, some developments have been done in order to reduce the time elapsed going through these processes: online check-in, new baggage screening devices as RAPISCAN RTT™ 110 or new procedures which are being developed within Smart Security, a joint project between IATA (International Air Transport Association) and ACI (Airports Council International). The following solutions, some of which are now permanently installed and operational in airports, have been or are being tested: Innovative use and integration of advanced and new security technology and passenger processing systems, use of biometrics and data for passenger differentiation, adaptable risk-based screening capabilities, dynamic lane screening, efficient resource allocation, seamless integration of security processes into the passenger journey from curb to boarding and process efficiencies.

Reference state in 2010

Since the beginning of the liberalization of air transport in Europe (1993), many projects related to the facts stated above have been carrying out. At the outset, as the growth of passengers was increasing steadily over time, the first step was to expand both airside and landside, consisting of building new runways and more terminals. For example, in 1990 Amsterdam Airport Schiphol exceeded the 16-million-passenger mark and further expansion thus became essential, since that moment a new control tower was built in 1991, thus the opening of Terminal West in 1993 which meant an increase of the Terminal capacity to a total of 32 million passengers a year. Since that, several expansions were made until the opening of runway 18R-36L in 2003.

The same case as Schiphol was Madrid-Barajas Airport (Figure 2.69) which had only 2 crossed runways until 1998 when new runway 18R-36L was built. Additionally, the expansion continued during the following years with the opening of 2 new runways (18L-36R and 14L-32R), 2 new terminals (T4 and T4S) and new connections with the city centre by underground and train.

Figure 2.69. Madrid-Barajas Airport in 1998 and 2008, respectively

Once the infrastructures were developed, the next aim in the outline was to improve the processes carried out at the airports. Regarding these processes, many projects were set in order to develop them.

For example, the ASSET project (Aeronautic Study on Seamless Transport) defined the problem in 2008 as the insufficient punctuality in air transport was the high variance in off-block times (Figure 2.70). This is related to the fact that off-block time is mainly driven by the duration of landside airport processes which contain passenger processes, baggage handling processes and aircraft turnaround processes.

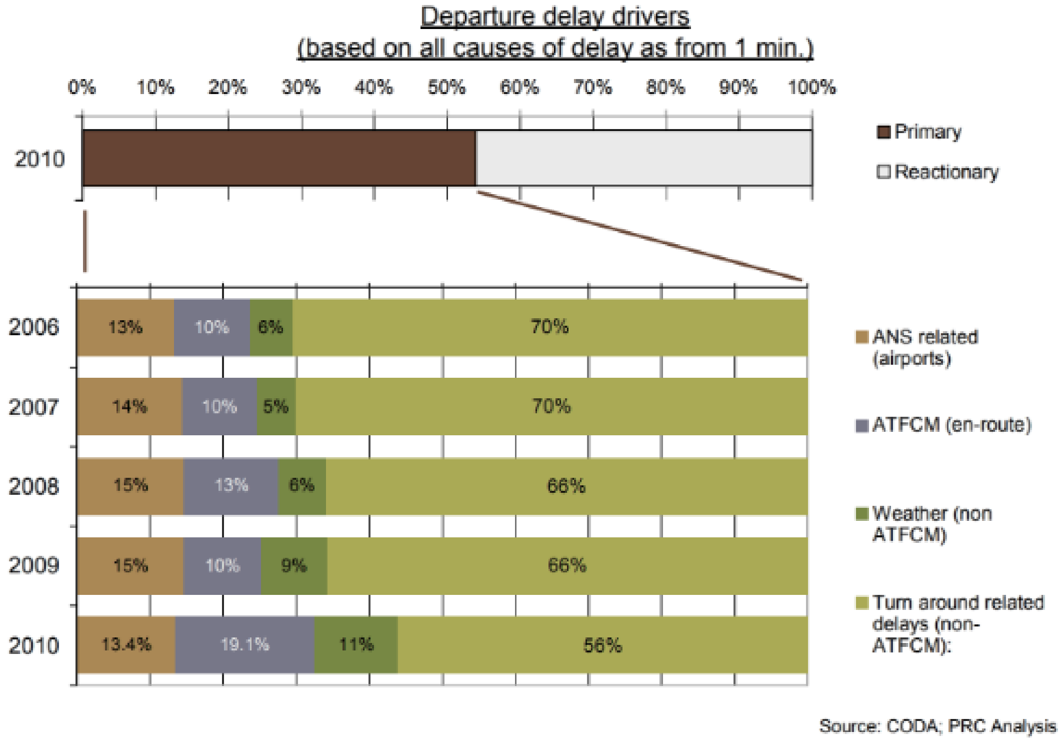


Figure 2.70. Drivers of departure delays (2007-2010) (Eurocontrol PRR 2010)

As can be noticed, the turnaround related processes have been the main factor that has induced delays in the air transport operation over the years. In order to decrease these percentages, researches in this field have been essential: new procedures, new devices to screen both passenger and luggage and so on. However, this cluster of processes still constrains the throughput of air transport operations nowadays and it will be studied in the next part.

Progress up-to-now

Nowadays, all the different processes at airports still remain as essential in air transport operations. For example, in a 2015 global passenger survey by IATA, 90% of respondents indicated that they prefer to check-in and reserve their seats before arriving at the airport, and nearly 50% prefer to use self-bag drop service (Figure 2.71) for their check-in luggage. Thus, it is essential to develop new systems and concepts related to this matter and since 2010 several improvements have been done.

Figure 2.71. Self-bag drop at Hong Kong Airport. Source: Introducing advanced technologies and new facilities in the airport experience, Hong Kong Airport

As an example, Hong Kong Airport has developed some new procedures and systems than allow passengers to have a better experience in a seamless environment:

- Enabled home-printed bag tags due to completed trials for Radio-Frequency Identification (RFID).
- Greater check-in convenience due to the launching of self-bag drop system, reducing baggage processing time from 2-3 minutes to about 1 minute. In this manner, it is expected that 120 self-bags drop counters will be in operation by the end of 2017.
- Enhanced passenger traceability and security due to the installation of a Positive Boarding System at all departure security checkpoints to capture boarding pass data of each passenger. This data is used to improve airside security and operational efficiency, and airlines' on-time throughput.
- Began rolling out iBeacon technology to provide passengers with terminal directions, walking times to gates, lounge access and boarding alerts via their mobile devices.
- Faster baggage delivery due to a team deployed to monitor real-time baggage arrival flows and set up rescue tractor team to help operators maintain service levels during temporary shortfalls in manpower.
- Smoother immigration service at arrivals implementing real-time arrival passenger forecast, enabling the Immigration Department to deploy resources more efficiently against real-time demand.

On the other hand, another project has been carried out by Aruba (Figure 2.72), The Netherlands, Aruba International Airport, KLM, VISION-BOX™ and Schiphol Group called Happy Flow. This project consists of a streamlined sequence of user-centric self-service touchpoints, from check-in to boarding the aircraft. At all passenger touch-points, the passenger's face image is the identification token so that passengers are only required to show their passport once, at check-in, when they also enrol their biometric data. At that moment, a virtual Passenger Data Envelope is created, containing passenger biometric and biographic information. After check-in, the passenger goes through baggage drop off, pass border control and board the aircraft without being asked to show any travel document: user-centric self-service Passenger TouchPoints (Self-service Baggage Drop stations, Automated Border Control eGates and self-boarding Gates) identify each passenger's face and match it to the passengers' database, only allowing authorized passengers to move on.

The most important thing is that the process at each Passenger TouchPoint only takes a few seconds, so queues are smaller if exist.

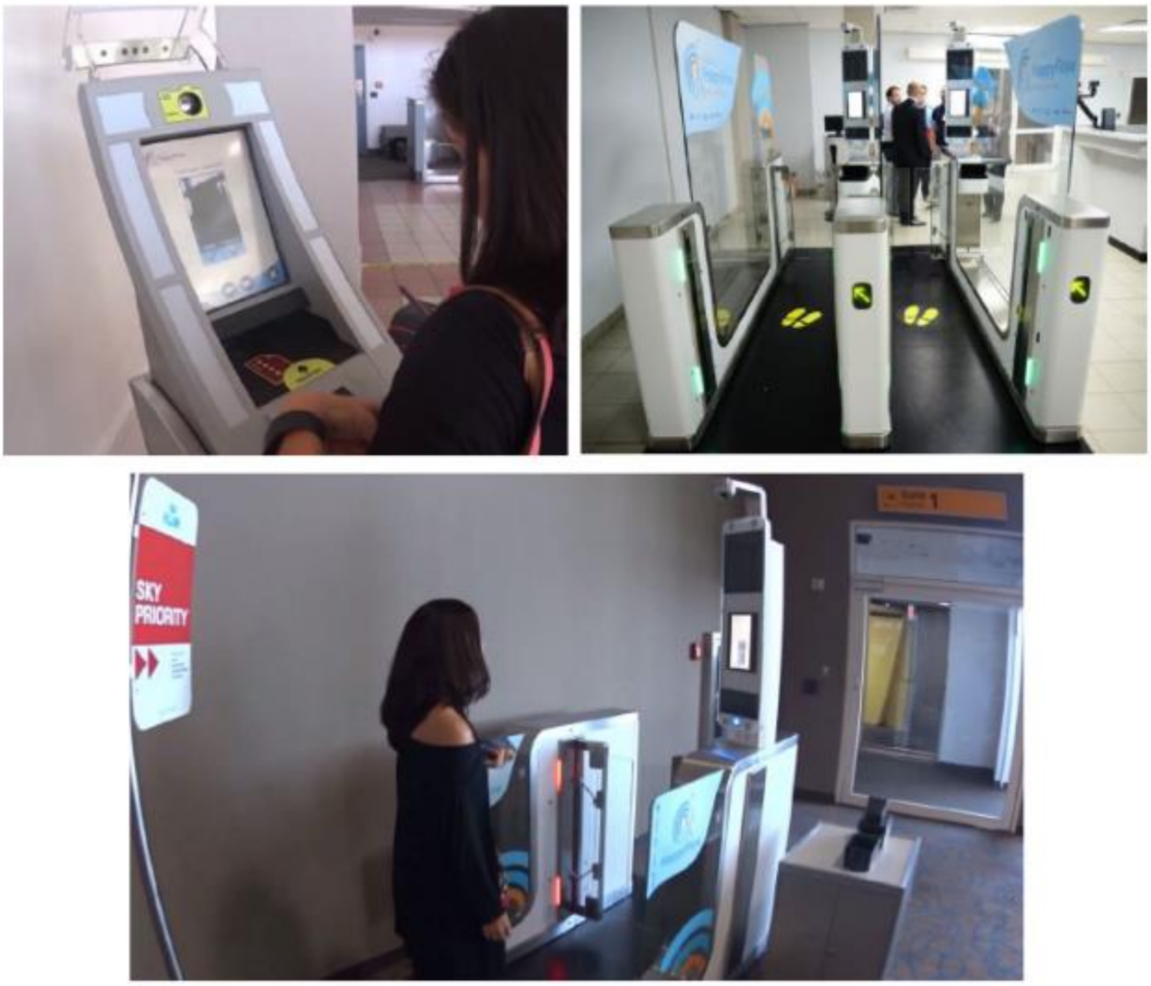


Figure 2.72. Different processes in Aruba Happy Flow

Predictions up-to-2025

Following the development outline carried out during the past few years, it is expected that current systems regarding passenger and baggage processes continue to develop and, in addition, this development is expected to be implemented to the entire airport network around the world.

On the one hand, new screening machines will be operating in the next years. These devices present a technology capable of detecting suspicious baggage more accurately at the primary level 1 in order to fulfil EU Regulation No. 1087/2011, which modifies EU Regulation No. 185/2010. This Regulation establishes detailed measures to enforce the basic and common regulations of air security related to Explosive Detection Systems (EDS). In this manner, the minimum detection levels required are set within the Standard 3 framework which regulates and certifies them. This Standard is defined by ECAC (European Civil Aviation Conference) and these minimum levels required can only be reached using Computed Tomography (CT) technology, whereas previous Standard 2 levels are based on simpler dual X-ray equipment (horizontal and vertical) that allow getting two simultaneous images that make staff be able to detect explosives. The main features required in each Standard are the following:

ECAC Standard 1: Dual Energy X-ray and single operator image; set the baseline data for Probability of Detection and False Alarm Rate. Standard 1 has been in use since January 2002 and was made mandatory for all airports in 2007.

ECAC Standard 2: Dual Energy X-ray, dual operator images; specifies that for the X-ray unit the Probability of Detection must be higher than Standard 1 and the False Alarm Rate must be lower than Standard 1; image quality parameters, resolution, wire detection, steel penetration, organic/non-organic discrimination.

ECAC Standard 3: Dual Energy X-ray + Computed Tomography (CT) technology, single operator image; specifies that for the X-ray unit the Probability of Detection must be higher than Standard 2 and the False Alarm Rate must be lower than Standard 2; image quality parameters, resolution, wire detection, steel penetration, organic/non-organic discrimination (very close to US TSA standards for BHS).

EU Regulation No. 1087/2011 states that, since September 1st, 2014, all new automatic inspection equipment installed in Europe shall be based on Computed Tomography (CT) according to ECAC Standard 3.

Regarding old inspection equipment already installed at the airports, both according to Standard 1 and Standard 2, the deadline to replace them is September 1st, 2022 (Figure 2.73), hence it is expected that current inspection equipment is upgraded during the following years.

Figure 2.73. ECAC Standards timeline. Source: Assessing the impact of ECAC3 on baggage handling systems, BEUMER Group

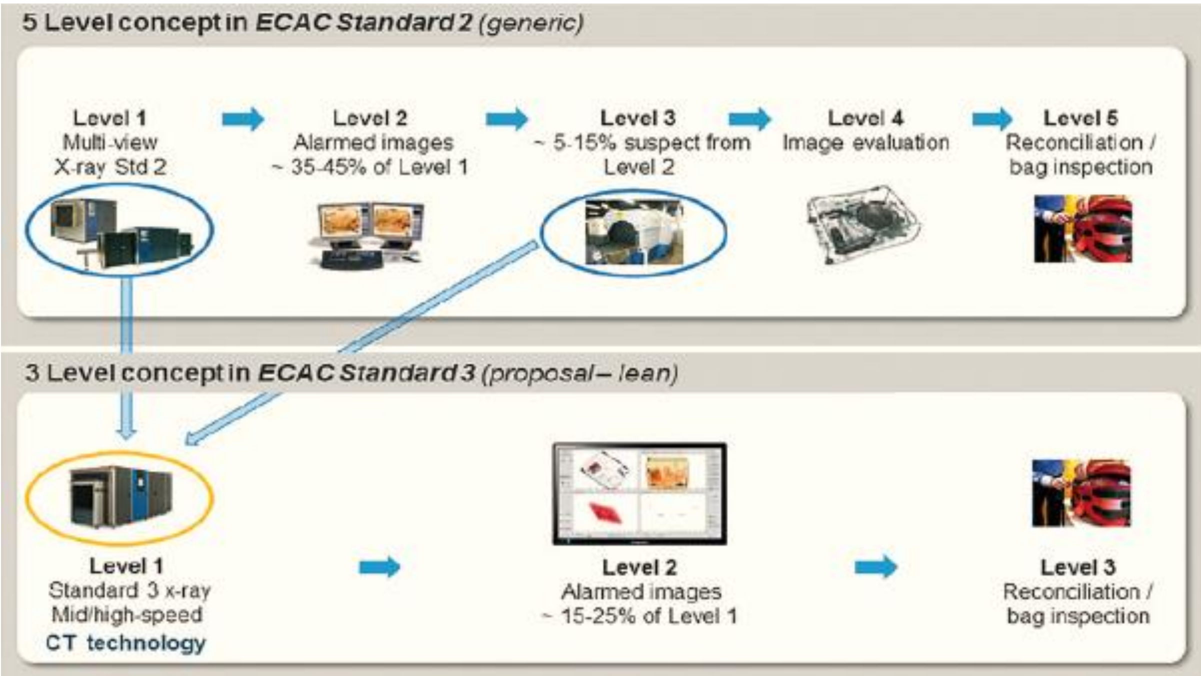


Figure 2.74. Comparison of ECAC Standard 2 system with a proposed ECAC Standard 3 system. Comparison of ECAC Standard 2 system with a proposed ECAC Standard 3 system

The idea of screening bags at different levels (Figure 2.74) is to be able to screen and approve the majority of the bags as fast as possible. Bags that fail the screening process are diverted from the main flow and moved to another screening level where further, slower manual investigation is undertaken. The in-line multi-level screening approach set out in ECAC Standard 3 is designed to be able to screen the baggage in-line, faster and more cost-efficiently.

The main changes specified by ECAC Standard 3 result in an increase in security standards and an increase in system availability and throughput. The modern CT machine can process up to 1500 bags per hour, which is the same as a traditional dual-energy X-ray machine. However, the traditional X-ray machine only cleared approximately 70% of all bags, restricting its approval capacity to around 1050 bags per hour. The CT technology-based machines clear approximately 80% of all bags giving it an approval capacity of around 1200 bags per hour, effectively giving it a higher handling rate.

On the other hand, systems related to passenger processes will continue to be developed during the following years. In this manner, biometrics will be essential to make the passenger journey through airports faster and more seamlessly as much as this technology has made our personal lives easier through fingerprints (logging in to our phones), voice (Siri, Cortana) and facial recognition (logging in to Windows 10 or iPhone X with our faces).

Some of these new technologies are being trialled within Europe and the rest of the world.

For example, the US Customs and Border Protection (CBP) launched the Automated Passport Control (APC) program consisting of providing an automated process through CBP's Primary Inspection area. Travellers use self-service kiosks to respond to CBP inspection related questions and submit biographic information. Since 2015, when firstly Orlando International Airport upgraded them, the APC kiosks (Figure 2.75) include facial recognition for arriving passengers. This allows the kiosks to authenticate identity by matching people's face to the biometrics record in their e-passport. These kiosks have helped to reduce lines by as much as 40%. During the last few years, this technology has been successfully implemented in most of the airports across the United States.

Figure 2.75. Passengers using APC kiosks at Miami Airport

As another example, Finnair invited 1000 of its frequent flyers to participate in a face recognition test at Helsinki airport in order to improve the airline's understanding of the applicability of face recognition technology and the impact it has on the customer experience.

This test consisted of using an Android app to send three selfies and upload Finnair loyalty card information to the test system. Then, it was used a check-in desk with face recognition technology. As customers approached the check-in desk and were recognized, service agents were provided with the name of the passenger and their flight information and could address them in a personalized way.

Evolutionary progress up-to-2050

The expected progress between 2025 and 2050 is a continued development and implementation of current systems that are currently being tested. These new technologies explained above such as biometric recognition or computed tomography will take up the whole air traffic industry.

However, the continued growth of air traffic during the next decades will lead to the saturation in the different processes related to aircraft operation. It is expected that the current number of passengers will be more than double in the next 20 years which will set the pace in the research and development rush.

Related to that, current air traffic capacities will not be able to accommodate this growth of passengers. The increase of the number of passengers will mean an increase of delays in the different processes involving aircraft operation from passenger handling to ATM operation going through baggage handling if no measures are taken. These processes could experience even more delays than they have already experienced in the past.

Therefore, the growth of passenger numbers could be considered as a driver for the increase in delays. In this manner, it is likely that the processes become bottlenecks, causing a limitation in the growth of air traffic during the following decades. This would be the case in which demand exceeds offer and it would be frightful for the development of the air traffic industry.

Proper measures should be taken to predict and solve these bottlenecks before they become real, hence research and development will be essential for the aviation industry. In that case, the European Union should provide institutions, companies and other stakeholders with the tools needed for successful development.

Possible or predictable breakthroughs

The following breakthroughs could be expected:

- Full implementation of technologies currently being tested (biometric recognition, computed technology and so on). These new technologies could be implemented within airport-collaborative decision making (A-CDM) framework which has been developed and implemented in European airports during the last few years. Nowadays A-CDM is implemented in 26 airports across Europe, including: Barcelona, Berlin Schönefeld, Brussels, Copenhagen, Düsseldorf, Frankfurt, Geneva, Hamburg, Helsinki, London Gatwick, London Heathrow, Lyon, Madrid, Milan Malpensa, Milan Linate, Munich, Paris CDG, Paris Orly, Oslo, Palma de Mallorca, Prague, Rome Fiumicino, Stockholm Arlanda, Stuttgart, Venice and Zurich. The addition of passenger and baggage data to the A-CDM network could mean that airport operators, airlines and other stakeholders had the right information at the right moment, and it would allow facilitating a more seamless and secure operation through the airport.
- Construction of new runways and terminals at constrained airports, or even new airports.
- Development of both aircraft and ground systems allowing lower separation minima.
- New aircraft designs and manufacturing reducing wake turbulence and, thereby, reducing wake separation.
- New research about innovative technologies in order to accommodate the growth of traffic.

Identification of gaps

As well as Goal 1, tasks related to Goal 4 are not new in Europe. One of the key projects that have been carried out is Airport-Collaborative Decision Making (A-CDM) (Figure 2.76). Its implementation is focused on enhancing the operational efficiency of airports and improving their integration into the Air Traffic Management Network (ATMN) while maintaining or improving safety levels. These objectives are achievable by increasing the information sharing between the local ANSP, airport operator, aircraft operators, ground handlers, the Network Manager and other airport service providers; and also, by improving the cooperation between these partners to enhance the predictability of events and optimize the utilization of resources, therefore, increase the efficiency of the overall system.

Figure 2.76. A-CDM common objectives. Source: Airport CDM Implementation Manual. Eurocontrol, ACI, IATA

Airport-Collaborative Decision Making has been developed since 2004 and it was supposed to be fully operating in 2016. However, it is expected a 2-year delay until it is completely deployed, as can be seen in the following Figure 2.77:

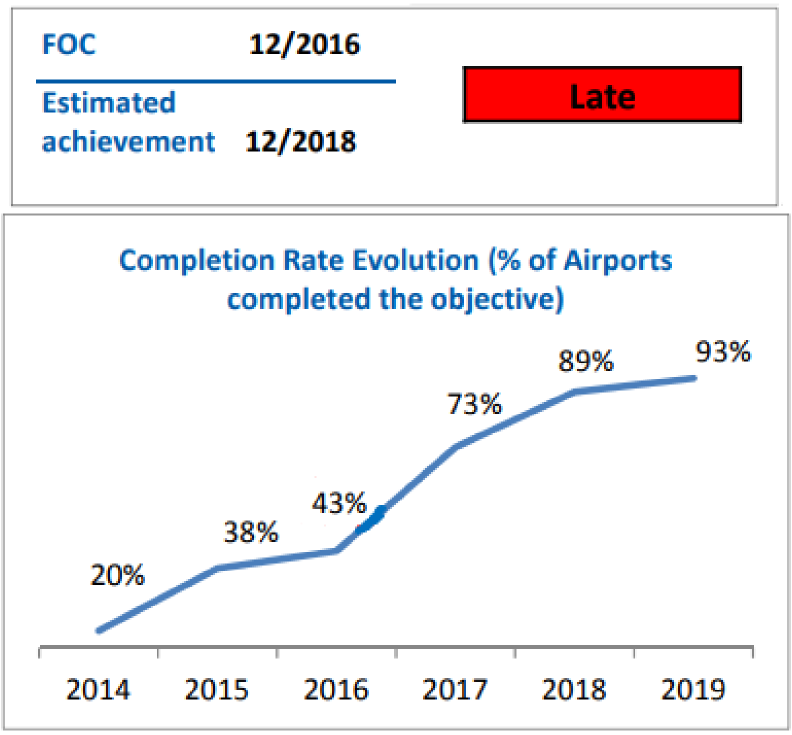


Figure 2.77. A-CDM implementation progress. Source: ATM Master Plan monitoring, Eurocontrol

It is the same case as Goal 1, referring to that delays in projects' implementation means more spending and inconvenient and it could affect other upcoming projects if they directly depend on the previous one. The fact that future projects will be focused on seeing the airport as a whole, in such a way that most of the services (regarding aircraft, passengers and baggage) will be integrated into the same network, could take more time than expected as they have to work as a mechanism with multiple pieces, each one necessary for the rest.

In this context, stakeholders will face the integration of technologies currently being developed and also new technologies that will be developed in the future into the airport network in order to achieve both a more seamless experience for the passenger and also an improved throughput, allowing to reduce the time dedicated to each process.

Moreover, future integrated technologies such as biometric recognition will face other issues related to privacy constraints. Travellers' privacy is key to the implementation of advanced IT systems for facilitating airport's processes and, as future projects aimed at speeding up airport processes, specific attention must be paid that systems and equipment do not store data but rather streamline procedures until the ultimate boarding phase without infringing passengers' privacy.

The harmonization of security features and the integration of biometric identifiers is an important step towards the use of new elements in the perspective of future developments at European level, which render the travel document more secure and establish a more reliable link between the holder and the passport and the travel document as an important contribution to ensuring that it is protected against fraudulent use.

Summarizing, future projects related to seamless passenger operation could be constraint by privacy policies, hence stakeholders should work together with governments in order to set the proper regulatory framework that allows the full implementation of these new technologies.

KEY TOPIC T2.6 – OVERALL GROUND PLUS AIR TRAVEL TIME

Introduction

Europe is one of the densely populated continents on Earth. The European Union, a political and economic union of 28 Member States has an area of 4,475,757 sq km with over 513 million inhabitants in 2019 (Eurostat). Geographically, it is almost 4.200 km height and 5.600 km wide. These dimensions define the framework of the market related to the European transportation.

Air transportation is considered to be the most efficient means of transport and therefore has a dominating position at long distances. It is also significant at short or medium distances, but upon various factors influencing the passengers' mode selection criteria, it competes with rail and car transport.

Air transport and flight movement

In 2018, the total number of passengers travelling by air in the European Union could be established at 1106 million, an increase of 6.0 % compared to 2017. The intra-EU share in total transport could be established at 46 %. It was the main destination ahead of extra-EU transport (37 %) and domestic passenger transport (16 %). International intra-EU traffic at country level, as set out in the Table 2.13, shows that for 2018, the top ten country-to-country flows, in general, remained stable compared with 2017 (Eurostat).

Rank	Country pairs		2017		2018	
			Passengers carried (in 1000)	Share in total intra-EU (%)	Passengers carried (in 1000)	Share in total intra-EU (%)
1	United Kingdom	Spain	45 392	9.6	44 036	8.9
2	Spain	Germany	28 534	6.0	29 579	6.0
3	United Kingdom	Italy	15 106	3.2	15 819	3.2
4	United Kingdom	Germany	14 608	3.1	15 092	3.0
5	Italy	Spain	13 982	3.0	15 262	3.1
6	Italy	Germany	14 062	3.0	14 389	2.9
7	France	Spain	13 658	2.9	14 582	2.9
8	United Kingdom	France	13 478	2.8	13 466	2.7
9	United Kingdom	Ireland	12 856	2.7	13 017	2.6
10	Italy	France	11 431	2.4	11 912	2.4

Table 2.13. Intra-EU traffic at country level: top-10 country pairs represent almost 40 % of 2018 intra-EU traffic (Eurostat)

At European level (ECAC area), the traffic forecast for 2020 was in line with 2019 with a growth of 2.3% and European flight growth is expected to remain stable at around 1.9% per year over the 2021-2025 period. The 2008 peak of 10.2 million was almost reached in 2016. The forecast is for 12.5 million IFR flight movements in Europe in 2025, 13% more than in 2018 (EUROCONTROL, 2019).

ECAC

	Total Traffic										
Scenario	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
1. High Scenario					11.157.868	11.590.583	12.007.006	12.382.935	12.712.017	13.060.367	13.371.992
2. Base Scenario	9.922.845	10.196.799	10.603.566	11.001.807	11.117.821	11.372.565	11.591.866	11.851.906	12.063.947	12.298.399	12.469.520
3. Low Scenario					11.070.817	11.124.166	11.136.252	11.217.891	11.288.578	11.367.384	11.375.875

Table 2.14. Summary of flight forecast for Europe (ECAC). Total traffic. (Eurocontrol)

ECAC

	Growth										
Scenario	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
1. High Scenario					1,4%	3,9%	3,6%	3,1%	2,7%	2,7%	2,4%
2. Base Scenario	1,6%	2,8%	4,0%	3,8%	1,1%	2,3%	1,9%	2,2%	1,8%	1,9%	1,4%
3. Low Scenario					0,6%	0,5%	0,1%	0,7%	0,6%	0,7%	0,1%

Table 2.15. Summary of flight forecast for Europe (ECAC). Growth. (Eurocontrol)

European airports

A characteristic feature of the European air transport service market is the co-existence of several large centres performing trans-continental links and a dense net of local links between the majority of small cities and tourist resorts. According to a research report published in 2006, Europe has about 2570 airports and landing fields [Brusow, 2007], from which 2100 is used by IFR movements [EUROCONTROL, 2007].

More particularly, out of the 2570 identified locations, Europe has 1270 airports and 1300 landing fields. The geographical distribution of airports across Europe is presented in the Figure 2.78:

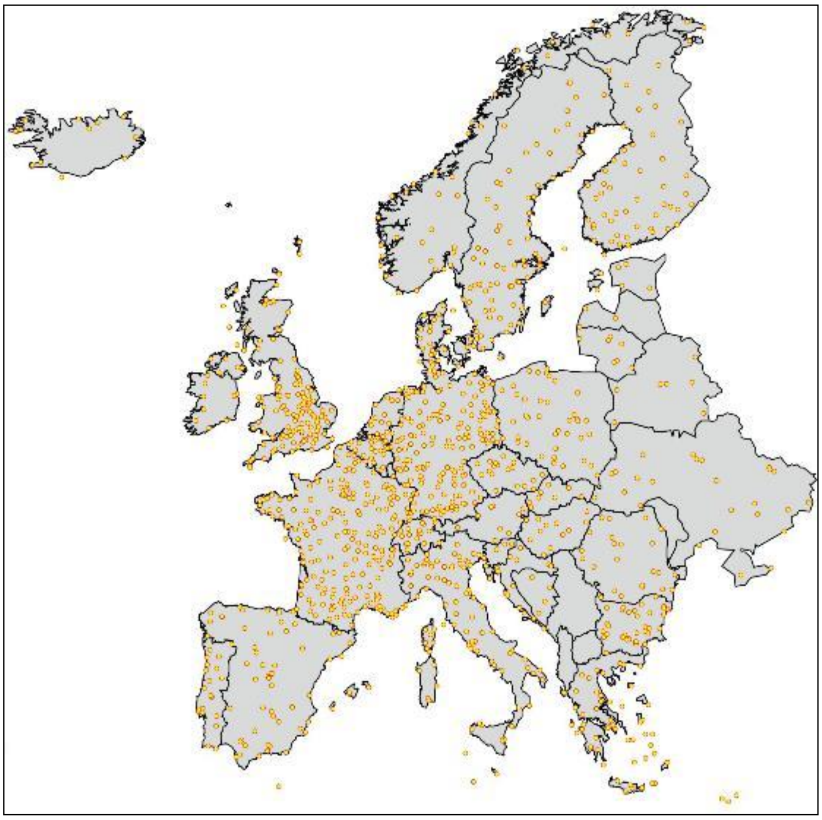


Figure 2.78. All European airports location (Brusow et al., 2007)

Regarding airports, the top airports in the EU-28, most busy – ranked by the total passengers per year in 2018 – is shown in the Table 2.16. Accordingly, there is a geographical concentration at the region London-Amsterdam-Munich-Milan. In addition, just the top 25 IFR airports generate 50% of all passenger movement [Eurostat].

Rank	Country	Airport	Total air transport (in 1000 passengers)	of which			Growth of total air transport 2017-2018 (%)	Total number of passenger flights (in 1000)	Growth of total number of flights 2017-2018 (%)
				National air transport	International intra-EU-28 air transport	International extra-EU-28 air transport			
1	UK	LONDON/HEATHROW	80 100	4 793	27 730	47 577	2.7	477	1.2
2	FR	PARIS/CHARLES DE GAULLE	72 196	6 472	28 257	37 468	4.0	451	1.0
3	NL	AMSTERDAM/SCHIPHOL	70 979	1	42 151	28 828	3.7	487	1.1
4	DE	FRANKFURT/MAIN	69 386	7 601	30 684	31 102	7.8	483	8.0
5	ES	MADRID/BARAJAS	56 478	15 952	24 769	15 758	8.6	380	6.2
6	ES	BARCELONA/EL PRAT	49 594	13 427	27 190	8 978	6.0	318	3.9
7	DE	MÜNCHEN	46 206	9 662	22 951	13 593	3.8	394	2.2
8	UK	LONDON/GATWICK	46 081	3 729	28 633	13 719	1.2	283	0.1
9	IT	ROMA/FIUMICINO	42 894	11 464	18 056	13 374	5.0	308	4.3
10	FR	PARIS/ORLY	33 115	14 125	11 354	7 636	3.4	229	0.0
11	IE	DUBLIN	31 225	98	25 257	5 870	6.4	218	5.0
12	DK	KØBENHAVN/KASTRUP	30 192	1 836	19 746	8 609	3.7	254	2.6
13	ES	PALMA DE MALLORCA	29 069	7 012	20 833	1 224	4.0	207	6.8
14	PT	LISBOA	29 046	3 633	17 887	7 526	8.9	216	9.2
15	UK	MANCHESTER	28 256	2 552	17 778	7 926	1.7	193	-0.9
16	UK	LONDON/STANSTED	27 995	1 945	23 964	2 086	8.1	176	8.6
17	AT	WIEN/SCHWECHAT	27 025	581	17 546	8 897	11.1	234	7.6
18	SE	STOCKHOLM/ARLANDA	26 841	5 285	15 221	6 335	1.0	231	-1.6
19	BE	BRUSSELS/NATIONAL	25 637	3	17 174	8 461	3.5	208	-1.6
20	DE	DÜSSELDORF	24 256	4 184	12 530	7 542	-1.4	209	-1.4
21	IT	MILANO/MALPENSA	24 148	4 017	12 327	7 804	9.6	178	8.8
22	EL	ATHINAI/ELEFTHERIOS VENIZELOS	24 130	7 736	11 278	5 116	11.1	205	11.4
23	DE	BERLIN/TEGEL	21 991	8 112	9 958	3 921	7.5	180	8.0
24	FI	HELSINKI/VANTAA	20 990	2 976	12 510	5 505	10.6	181	9.0
25	ES	MALAGA/COSTA DEL SOL	18 927	2 738	14 680	1 510	1.9	130	3.9
26	PL	WARSZAWA/CHOPINA	17 772	1 749	10 213	5 810	12.8	172	7.2
27	DE	HAMBURG	17 198	5 161	8 551	3 487	-2.2	139	-3.7
28	CZ	PRAHA/RUZYNE	16 810	29	11 536	5 245	9.4	139	5.7
29	UK	LONDON/LUTON	16 767	1 197	13 685	1 884	4.9	105	0.5
30	HU	BUDAPEST/LISZT FERENC INTERNAT	14 801	0	11 226	3 575	13.6	102	12.6
34	RO	BUCURESTI/HENRI COANDA	13 819	1 379	10 145	2 295	7.9	114	5.6
55	CY	LARNAKA	8 057	0	4 979	3 078	4.3	58	3.4
60	LV	RIGA	7 037	11	4 984	2 043	15.8	78	13.0
61	BG	SOFIA	6 932	309	5 621	1 002	7.0	52	4.8
63	MT	LUQA	6 806	0	6 179	627	13.3	47	14.5
83	LT	VILNIUS	4 920	0	3 538	1 382	30.9	42	20.1
91	LU	LUXEMBOURG	3 988	0	3 599	389	12.2	55	8.1
96	HR	ZAGREB/PLESO	3 322	499	1 877	946	7.8	38	4.5
106	EE	LENNART MERI TALLINN	2 996	28	2 330	638	13.7	40	8.3
125	SK	BRATISLAVA/M.R.STEFANIK	2 273	13	1 606	654	17.9	29	86.6
139	SI	LJUBLJANA/BRNIK	1 811	0*	1 111	700	7.6	25	3.8

Table 2.16. Top airports in the EU-28 in terms of total passengers carried in 2018

Distance between city pairs

For European airports/landing fields, the distribution of the distance between the airport pairs is shown in the Figure 2.79. As visible, the most frequent distance is related to approximately 1000 km, while there are only a few potential links above 3000 km.

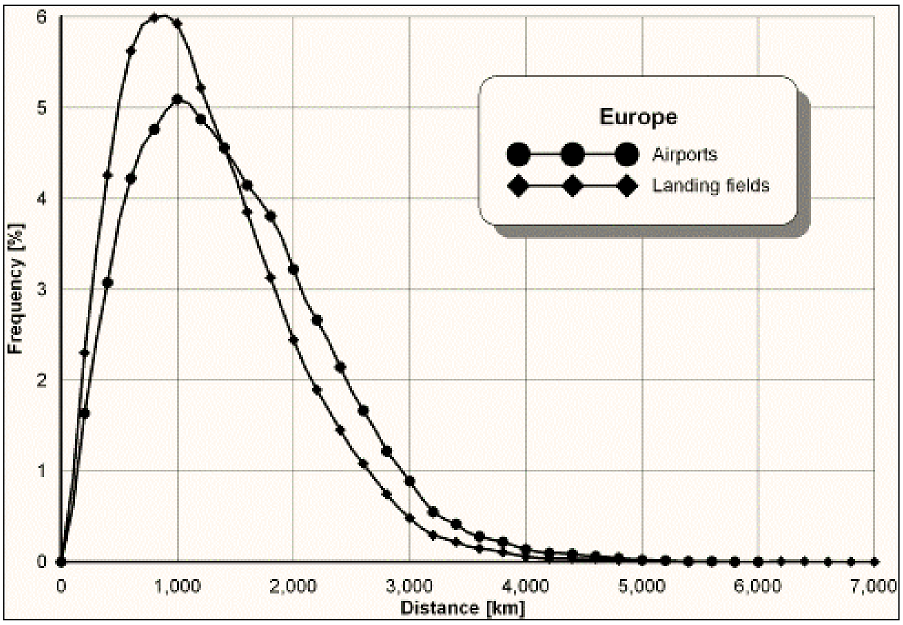


Figure 2.79. Distribution of the European airport pairs distances (Brusow et al.,2007)

Taking into account short distances between the European cities, transportation on the territory of Europe is performed mainly over short and medium distances, with the domination of the former. The European transport market is, therefore, the area of competition between road, rail and air transport.

Travel time from the city centre to airports

Seeing the facts above, it is clear Europe has a significant number of airports. On the other hand, to assess the efficiency of the air transportation system, and more particularly once considering the door-to-door time, it is also important to know, how far these airports are located from the European city centres. To answer this question, the Figure 2.80 presents the distribution of the distance between the European city centres (with a population of over 50 thousand inhabitants) to the nearest airport. As the Figure 2.80 indicates, it is clear that for almost 80% of the European cities, the nearest airport is situated at 20 km. Such a short distance reflects that the general accessibility of the European airports is high.

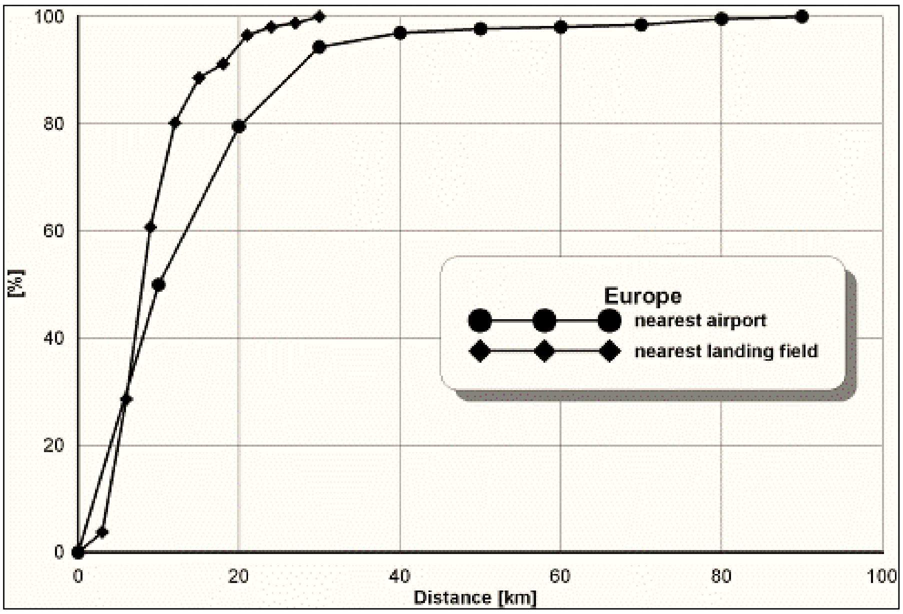


Figure 2.80. Cumulative distribution function of the city distance to the nearest airport (Brusow et al., 2007)

This fact is also reflected by looking at the top 10 airports in Europe, in terms of IFR flights (EUROCONTROL, 2007). London has the most airfields nearby: 46 within 100 km. Barcelona has the fewest, only 4. As shown in the Table 2.17, the typical distance of these airports from the city centres (weighted by the number of flights) is ranging between 14 and 24 km.

City	Number of Airfields within 100km of City Centre	Distance from City Centre (weighted average) km	Total Departures (k)
Amsterdam	31	16.2	244
Barcelona	4	19.3	185
Copenhagen	21	16.3	155
Frankfurt	33	13.8	258
London	46	33.9	603
Madrid	8	13.8	233
Munich	28	32.5	224
Paris	28	20.8	441
Rome	9	21.1	196
Vienna	13	23.5	145

Table 2.17. Airports and airfields of the 10 busiest European cities (Eurocontrol)

The DATASET2050 shows information about what the "doors" (e.g. houses, hotels, offices) are and how much time it takes to go from the "door" to the airport "kerb" (and vice-versa). The results for specific areas/airports are presented in the Tables 2.18 – 2.20:

The UK CAA has analysed this topic in detail, with some 30 specific modes of transport available to respondents, for 11 English airports (5 London and 6 provincial). Although the cost of obtaining these complete data is beyond the available budget for this project, the publicly-available summary report (CAA, 2014) provides the following:

	Gatwick	**Heathrow**	**London City**	**Luton**	**Stansted**	**Birmingham**	**Doncaster**	**East Midlands**	**Leeds Bradford**	**Liverpool**	**Manchester**
Private %	58.3	58.6	52.9	70.9	48.5	76.5	90.8	92.4	88.5	79.3	83.5
Public %	41.4	41.1	46.3	28.8	49.6	22.7	9.0	7.4	11.3	20.4	16.2
Other %	0.2	0.3	0.8	0.3	1.9	0.9	0.2	0.3	0.1	0.3	0.2
Terminating passengers (000's)	34,994	46,991	3,533	10,186	18,855	8,976	714	4,374	2,879	3,752	20,830

Table 2.18. Surface access modes to UK airports (DATASET2050)

The French DGAC has also studied surface access in their 2014-2015 airport passenger survey (DGAC, 2015), covering 15 airports. Unfortunately, these data have been aggregated over all 15 airports. The result of 33,655 responses by non-transfer passengers to the question of how people arrived at the airport is given below:

Transport	Usage	
Kiss-and-Fly	28%	43% Dropped off at kerb by another person
Taxi	17%	
Personal car	14%	15% in car parked at airport car park
With another passenger (in their personal car)	1%	
Hire car	4%	
Hotel or other Shuttle	4%	
Local public transport	28%	
Intercity train	5%	
Other	2%	

Table 2.19. French airport surface access modes (DATASET2050)

The German Airports Group (ADV) also performs passenger surveys. The latest "Airport Travel Survey 2015" (ADV, 2015) includes summary data on the modes of transport used by (all) passengers to access one of the 22 airports in the study:

Transport	Usage
Private car (including kiss-and-fly)	44%
Taxi	21%
Metro/U-Bahn	16%
Bus (including coach)	8%
Rail	6%
Rental Car and Other	5%

Table 2.20. Surface access mode share for 22 German airports (DATASET2050)

The Table 2.21 gives the mean and standard deviation (StD) speeds in km/h for both driving and public transport travel modes and for the chosen airport.

Mode	Driving		Public transport	
Airport	**Mean**	**StD**	**Mean**	**StD**
AMS	73.27	19.44	32.62	17.13
BCN	55.21	23.71	21.99	8.86
BRU	68.83	22.69	30.81	14.89
CDG	71.39	19.02	27.54	11.45
CPH	63.63	23.91	29.27	17.03
DUB	57.51	22.37	21.93	10.05
DUS	75.23	20.81	31.55	17.97
FCO	62.02	20.23	31.68	15.49
FRA	73.08	22.18	38.06	21.68
LGW	65.34	18.58	31.64	16.03
LHR	61.71	23.10	28.29	15.35
LIS	70.28	25.34	15.13	10.29
MAD	73.98	19.63	19.04	7.95
MAN	61.65	20.05	26.86	14.12
MUC	74.25	18.52	30.55	16.95
ORY	65.63	23.36	19.13	9.56
OSL	63.04	13.44	26.89	13.73
PMI	47.98	16.27	14.95	4.92
STN	65.26	19.88	29.35	16.68
TXL	64.98	25.43	25.53	14.22
VIE	73.77	19.32	29.73	14.17
ZRH	66.00	19.26	32.91	13.93
Total	**66.67**	**21.86**	**28.16**	**15.61**

Table 2.21. Driving and public transport speeds (km/h) by airport (DATASET2050)

The Table 2.22 provides an overview of the airport accessibility by rail of the 30 largest airports in Europe, measured by total passengers in 2008. The geographical scope is the European Economic Area and Switzerland.

Rank	Airport	Country	Passengers in millions (2008)	Long-distance trains - no. of daily services	Short-distance trains - no. of daily services	Short-distance rail journey time to city train station	Short-distance train fare - single ticket to city train station	Underground/ Metro access	Underground/ Metro journey time to city train station	Underground/ Metro fare - single ticket to city train station
1	London Heathrow	United Kingdom	67.1	-	73	00:23	20.38 €	x	00:40	5.56 €
2	Paris Charles de Gaulle	France	60.9	62	142	00:29	8.50 €	-	-	-
3	Frankfurt	Germany	53.5	167	214	00:10	3.80 €	-	-	-
4	Madrid	Spain	50.8	-	-	-	-	x	00:22	2.00 €
5	Amsterdam	Netherlands	47.4	377	294	00:16	3.70 €	-	-	-
6	Rome Fiumicino	Italy	35.1	-	101	00:31	14.00 €	-	-	-
7	Munich	Germany	34.5	-	116	00:40	9.60 €	-	-	-
8	London Gatwick	United Kingdom	34.2	-	80	00:30	18.77 €	-	-	-
9	Barcelona	Spain	30.2	-	37	00:19	3.00 €	opening 2012	-	-
10	Paris Orly	France	26.2	-	Indirect connection to the RER regional train system by an automated people mover					
11	Dublin	Ireland	23.5	-	-	-	-	planned	-	-
12	Palma de Mallorca	Spain	22.8	-	-	-	-	-	-	-
13	London Stansted	United Kingdom	22.4	-	76	00:46	24.45 €	-	-	-
14	Zurich	Switzerland	22.0	116	185	00:11	4.68 €	-	-	-
15	Copenhagen	Denmark	21.5	40	182	00:13	4.63 €	-		
16	Manchester	United Kingdom	21.4	-	171	00:16	4.69 €	-	-	-
17	Vienna	Austria	19.7	-	126	00:16 / 00:31	3.60 € / 10.00 €	-	-	-
18	Oslo	Norway	19.3	32	156	00:19 / 00:26	13.92 € / 21.51 €	-	-	-
19	Milan Malpensa	Italy	19.2	-	39	00:36	11.00 €	-	-	-
20	Brussels	Belgium	18.5	2	114	00:20	5.10 €	-	-	-
21	Stockholm Arlanda	Sweden	18.2	-	76	00:20	29.46 €	-	-	-
22	Düsseldorf	Germany	18.2	45	332	00:06	2.30 €	-	-	-
23	Athens	Greece	16.4	-	17	00:50	6.00 €	x	00:42	6.00 €
24	Berlin Tegel	Germany	14.5	-	-	-	-	-	-	-
25	Lisbon	Portugal	13.6	-	-	-	-	opening 2011	-	-
26	Helsinki	Finland	13.4	-	opening 2014	-	-	-	-	-
27	Hamburg	Germany	12.8	-	110	00:25	2.75 €	-	-	-
28	Malaga	Spain	12.8	-	70	00:12	1.25 €	-	-	-
29	Prague	Czech Republic	12.6	-	-	-	-	opening 2014	-	-
30	Geneva	Switzerland	11.4	31	58	00:07	2.26 €	-	-	-

All values in €. Non-€ currencies were converted into € with the exchange rate of 29th June 2010.

Table 2.22. Airport accessibility by rail for the 30 largest airports in the European Economic Area + Switzerland (DLR, 2010)

In the case of most of the 30 largest airports in Europe, passengers have a choice between different public transport service providers for access between the centres of the respective cities and the airports. Currently, 23 out of the 30 largest airports in the European Economic Area (including Switzerland) have direct rail access at or in the vicinity of the passenger terminal. A number of rail access projects are currently being planned or under construction.

An airport should cover the area of economic transport value (a city, a place of people concentration, tourist areas) in order to attract a certain group of passengers. In the territory of Europe concerning numerous airports, a strong competition between the airports develops in order to gain passengers, new carriers and new air links. The zone of competition between the airports is covering the gravitation area of the neighbouring airports, called catchment areas. The value of the catchment area of an airport – the area where passengers start their air travel from a certain airport or the point where they reach their destination – is determined mainly by the time factor of getting to the airport. The value of the gravitation area which influences the potential increase in the number of passengers, raising its competitive position depends also on other factors, such as the convenience of the connections with land transport.

Taking a simplified assumption that the value of catchment areas is influenced mainly by the time factor, while the travel time is the function of distance, the gravitation areas were determined for four European airport categories, including small, medium, large and very large. As Figure 2.81 indicates, while generally, the European airports could easily access, very large and large airports could attract passengers even from several hundreds of kilometres.

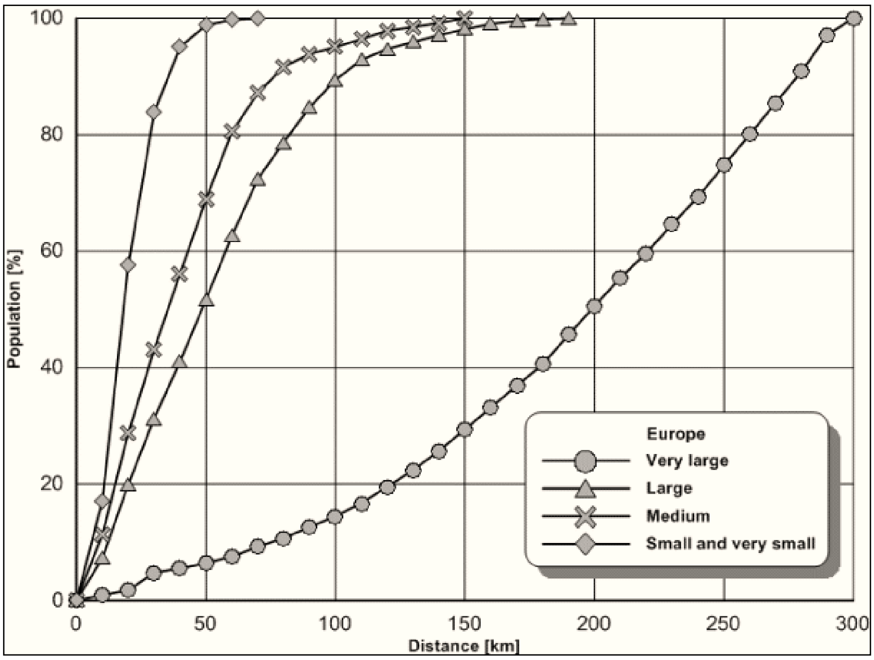


Figure 2.81. Cumulative distribution function of the population within catchment's areas of airports and landing facilities (Brusow et al., 2007)

For each airport, it can be identified in the catchment area. In principle, all the potential passengers from that area (inhabitants, tourists, business travellers, etc.) would use that airport when taking a flight. Catchment areas can be simply defined based on the distance to the airport. The distance (to be strict: time-based distance) is measured in terms of travel time spent in the door-to-kerb process, which ultimately depends on the mode of transport chosen. Catchment areas for Budapest airport are presented in the Figure 2.82:

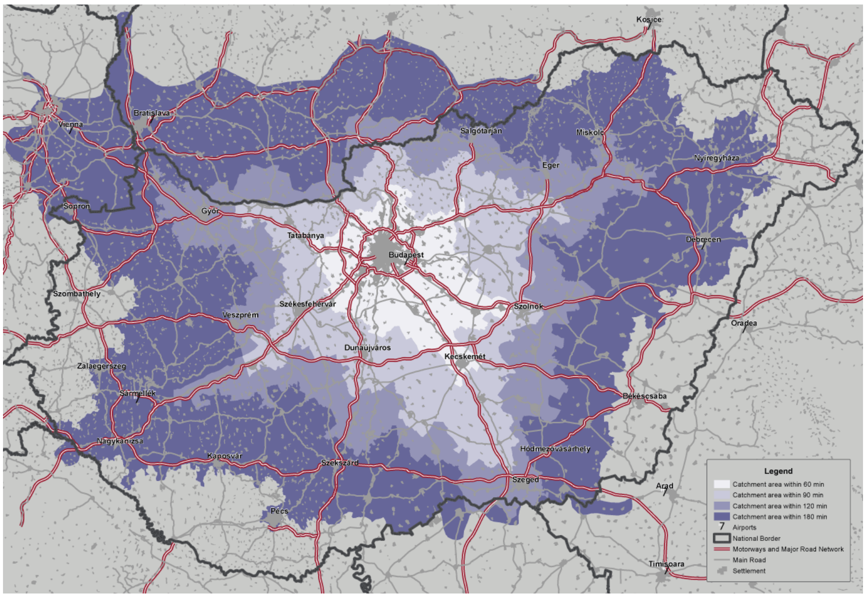


Figure 2.82. Budapest 60, 90, 120, and 180 minutes' drive time

Delays distribution

A flight delay is when an airline flight takes off and/or lands later than its scheduled time. Usually, the flight is considered to be delayed when it is 15 minutes later than its scheduled time. EUROCONTROL's Central Office for Delay Analysis (CODA) collects operational data from airlines operating IFR flights in Europe. Delay monitoring and analysis is an important aspect of the airlines' operational and financial success. The cost of delay is estimated at €82 per minute of delay for delays in excess of 15 minutes (EUROCONTROL, 2010).

The cost of delay is calculated separately for strategic delays (those accounted for in advance) and tactical delays (those incurred on the day of operations and not accounted for in advance). Tactical delay costs are given for 5, 15, 30, 60, 90, 120, 180, 240 and 300 minutes. These are scaled up to the network level because on the day of operations, original delays caused by one aircraft ('primary' delays) cause 'knock-on' effects in the rest of the network (known as 'secondary' or 'reactionary'.

The largest single group of delay reasons by total generated delay minutes are delays caused by airline operational processes. They account for approximately 50% of the primary delays. This group is followed by airport and en route delays which account for almost one-third of all delays. Weather delays may vary by season.

Past situation

In Europe, in 2008, 15.2% of flights departed 5 minutes or more before their planned time and 60% of flights departed within 5 minutes of the planned time. Of all delayed flights on departure 21.4% were delayed by more than 15 minutes. On the other hand, 21.6% of flights arrived > 15 minutes after the STA (scheduled date and time of arrival). In 2008, the Average Delay per Movement was 12.6 minutes, a decrease of 2.1% in 2007. In 2008, the reactionary/primary delay ratio was 0.83. This means that for each minute of primary delay there was 0.83 minute of reactionary delay. In 2003 the ratio was 0.23. This evolution indicates a loss in delay recovery for airlines.

The share of Airport, Weather, Security and Miscellaneous delays are presented on the Figure 2.83 ATFCM (Air Traffic Flow and Capacity Management) en Route delays increased by 3% in 2008 compared to 2007 and represents 13% of all primary departure delays.

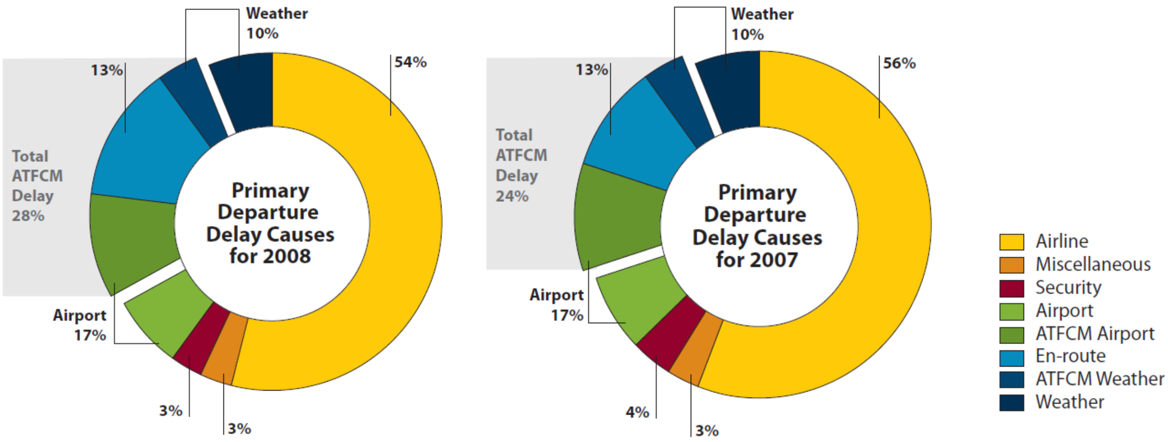


Figure 2.83. Primary departure delay causes 2008 vs 2007 (Eurocontrol)

Current situation

In 2016, the average departure delay per flight ranged from a low of 8 minutes per flight in February to a peak of 16 minutes per flight in July. This translated to an annual average all-cause departure delay of 11.3 minutes per flight, an increase of 0.9 minutes per flight, alongside an increase in daily flights of 2.8% in ECAC. Reactionary (knock-on) delay increased contributing 5.1 minutes to the 11.3 minutes average delay per flight, a 45% share of delay minutes meaning for every 1 minute of primary delay there were 50 seconds of reactionary delay generated. The range of reactionary delay during the year was wider than airline delay, with a range of 4 minutes being observed from the lows in February of 3.5 minutes per flight and the high in June of 7.5 minutes per flight, a month which also saw a peak in en route ATFM delay (EUROCONTROL, 2017).

In 2016, delays due to airline operations remained the main cause of primary delay, contributing 3.1 minutes to the average delay per flight. Compared to reactionary delay which doubled during the summer month's airline delays remain relatively stable with the 2016 monthly average ranging between 2.5 to 3.5 minutes per flight. The airline reported en route ATFCM delays increased to 0.8 minutes per flight. Airport operations delay including ATFCM, remained at 1.2 minutes per flight and together was the second-highest cause in the share of primary delay. Yearly airline arrival punctuality decreased, with 81% of flights arriving within 15 minutes or earlier than their scheduled arrival time (STA) compared to 82% in 2015 (EUROCONTROL, 2017).

Analysis of the delay reasons in 2016 in comparison to 2015, shows that reactionary delays contributed the most to the average with 5.1 minutes per flight (Figure 2.84). Airline-related delays increased slightly by 0.1 minutes per flight. ATFCM en route delay had the third-highest contribution with 0.8 minutes per flight increasing by 0.3 minutes per flight compared to 2015. Total ATFM delay reported by airlines delay increased to 1.7 minutes per flight with en route restrictions mainly contributing to the overall increase, Airline and airport delays remained stable, with weather delays slightly increasing in 2016 (EUROCONTROL, 2017).

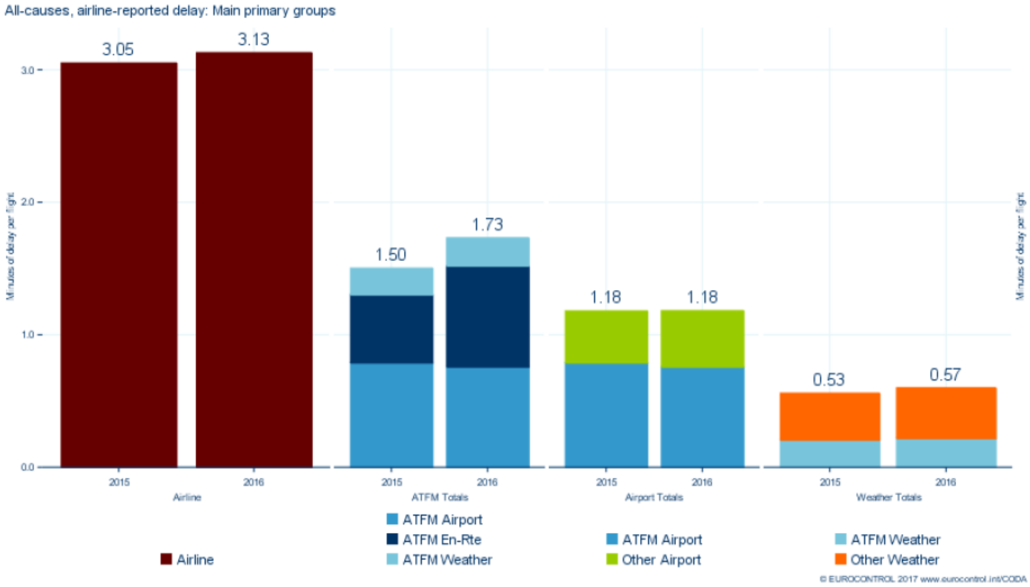


Figure 2.84. Primary Delay Causes 2015 vs. 2016 (Eurocontrol)

Delays from all-causes for Q3 2017 illustrates poorer punctuality than that of Q3 2016 with 76% of flights arriving on time compared to 79% in Q3 2016 (Figure 2.85). This translated to a quarterly average all-cause departure delay of 15.1 minutes per flight, an increase of 2.6 minutes per flight on Q3 2016. A strong increase in daily flights of 4.8% in ECAC for the quarter is a common underlying factor in the main reported causes (EUROCONTROL, 2017):

- Reactionary (knock-on) delay increased by 19% contributing 6.8 minutes to the 15.1 minute average delay per flight, a 45% share of delay minutes.
- Delays due to airline operations remained the main cause of primary delay, contributing 3.8 minutes to the average delay per flight, a slight increase.
- Airlines reported that en route ATFM delays increased by 0.7 minutes per flight to 1.7 minutes per flight, following industrial action in France during September. There were also ATC capacity and en route weather issues affecting Karlsruhe and Maastricht UACs throughout the quarter.
- Airport operations delay including ATFM increased to 1.7 minutes per flight and was the second-highest cause in the share of primary delay behind airline causes.

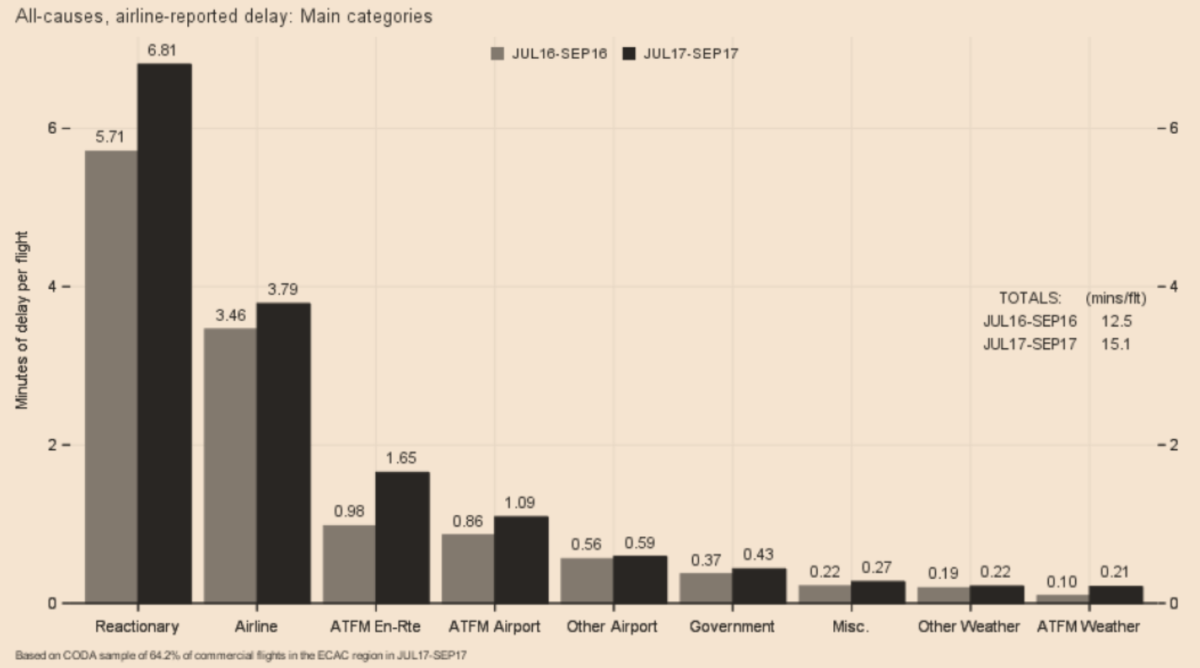


Figure 2.85. Breakdown of the Average Delay per Delay Q3 2016 vs. Q3 2017 (Eurocontrol)

KEY TOPIC T2.7 – FACTORS IN OVERALL AIR TRAVEL TIME

The projected uptick in world passenger traffic challenges the stakeholders involved to optimize the current aviation system and find new solutions being able to cope with the promoted goals of international regulators such as Flightpath 2050 and ACARE. Targets are four hours door-to-door for 90 % of travellers, a 40 % reduction of turn-around times by 2050, and the arrival and departure of each aircraft should be accomplished within one minute of the scheduled time. Especially large airports are located far from the city centre, resulting in long airport access times for passengers combined with buffer times for uncertainties of durations for airport processes like security checks or even unpredictability of airport access times. Therefore, **key enablers to reduce overall travel times are a reduction in airport access times, higher predictability of times accessing the airport and process times inside the terminal**.

"DATASET2050 (DATA driven approach for a Seamless Efficient Travelling in 2050) is a Coordination and Support Action (CSA) funded by European Commission under H2020-Call MG.1.7-2014: Support to European Aviation Research and Innovation Policy; The CSA - sometimes simply referred as "project" - is coordinated by Innaxis, with EUROCONTROL, University of Westminster and Bauhaus Luftfahrt as partners. DATASET2050 was launched during December 2014 and will last 36 months, ending December 2017.

The project addresses the EU passenger mobility in the context of the door-to-door (D2D) objectives defined in the Flightpath 2050 vision. Specifically, the following is the list of overall objectives, challenges and how these are being faced in the project:

- To provide useful insight into the door-to-door European travel paradigm through a cutting-edge data science approach for the present, 2035 and 2050 transport scenarios.
- Taking a passenger-centric approach, paving the way for a seamless and efficient door-to-door travelling experience.

Through this approach, the focus is to analyse how the European transport supply profile (capacity, connections, business models, regulations, intermodality, processes, and infrastructure) could adapt to the evolution of the demand profile (customers, demographics, passenger expectations, requirements).

- To identify European transport bottlenecks and improvement areas across the different scenarios, through expert application of state-of-art predictive analytics, modelling, statistical analyses, data visualisation, along with an examination of multimodal data.

- These findings will serve as a basis for the development of intermodal transport concepts by identifying possible solutions for current and predicted shortcomings. The insights gained through the project's approach will also highlight research needs for the four-hour door-to-door goal formulated by ACARE.

The performed tasks include:

- Looking at the requirements of the data to feed the DATASET2050 model at all its phases (i.e. door-to-kerb, kerb-to-gate, gate-to-gate, gate-to-kerb and kerb-to-door);
- Conducting an intensive review on what data are available, together with analysing temporal/geographical coverage, granularity, cost etc.;
- Designing and developing a visual tool that enables easy exploration of the datasets
- Developing a data-driven model capable of simulating the door-to-door processes;
- Completing the current demand profile, including the current mobility details (passenger behaviour, demographics, passenger expectations, and requirements).

DATASET2050 aims to have a socio-economic impact in the context of how EU door-to-door "transport" performs and predicting how it will perform in the future. In the long term, DATASET2050's outcome will contribute to fewer disruptions and smoother travel for passengers.

The first progress beyond the state-of-the-art is calculating what the current D2D mobility metrics are. This way, a better holistic passenger-centric view will be accomplished, putting the first milestone in the path of providing D2D quantitative metrics further than the already available qualitative analyses.

In parallel, by using the data-driven model developed in the project, DATASET2050 will try to predict what will be the bottlenecks in future mobility scenarios (2035 and 2050). This prediction will include assessing and analysing how compressible the D2D sub-segments are; what are the potential futuristic scenarios; which will tentatively be the future demand and supply profiles in transport etc.

The DATASET2050 report provides a holistic view of the different, current supply-profile processes involved in European journeys involving at least one air-transport segment. The most important outcome is the amount of valuable data (both qualitative and quantitative) that can be used in modelling, specifically for adequately modelling the current mobility-supply elements. The effort allocated has enabled the discovery and access to difficult-to-reach datasets and to plan how to model the air transport supply profile. Following the DATASET2050 approach, the door-to-door process has been divided into five simpler phases: door-kerb-gate-gate-kerb-door.

The outcomes of the DATASET 2050 report range from the provision of specific data about certain airport processes (e.g. minimum times for different types of flight connection at an airport, the different surface transport options available and their timings) to the scientific research done on how to model the processes (e.g. catchment areas vs an airport feeder approach). The rationale, hypothesis, scope, literature review and some specific case studies that enable an easy understanding of the overall approach are given in the main text sections of the reports whereas the data discovered in quantitative research are presented in tables in the appendices.

According to DLR report regarding the Flightpath 2050 goal 4, the following elements are needed for the assessment of the current state:

- European origin-destination passenger demand data matrix;
- Flight schedules;
- Train schedules (limited to air/rail code sharing);
- Ground access/egress times between NUTS regions and airports;
- Assumptions on process times (MCT, time from airport arrival to flight departure/flight arrival until exit from the airport).

The minimum travel time between regions consists of the following elements:

- travel time from the point of origin to the departure airport
- the processing time required from the arrival of the passenger at the departure airport to the scheduled time of departure (at)
- the flight time from the departure to the arrival airport– in case of a connecting flight, this element also contains the flight time of the first flight segment, the transfer time at the hub and the flight time of the second flight segment
- the processing time required from the scheduled arrival time at the arrival airport to the point in time when the passenger leaves the arrival airport (at);
- travel time from the arrival airport to the destination point.

Using scenarios to test the desired Flightpath2050 4-hour-goal the report concludes by using data from "ETISplus": Modelled origin-destination trip demand from EU project ETISplus and "Population product": Theoretical situation, in which each EU citizen visits each other EU citizen that already today 91.7% of travellers can complete their journeys within 4 hours (with 60 min MCT in air transport). Only 13.1% of trips would be completed within 4 hours if every EU citizen would try to reach each other EU citizen.

The 91.7% value is due to the fact that most trips are over short distances, which can be completed within 4 hours with car/rail modes. But, if a theoretical situation in which every EU citizen should have the opportunity to visit every other EU is aspired, the goal has been achieved only to 13% (60minute MCT) or 22% (45min MCT).

The DLR report concludes that a re-phrase of the Flightpath 2050 goal is required. The proposed version states that "90% of travellers within Europe are able to complete their long-distance journey of over 200km (or 250km or 300km...), door to door, within 4 hours".

2.5. Air Traffic Management (ATM) and Weather

*Flightpath 2050 goal 5: "Flights arrive within 1 minute of the planned arrival time regardless of weather conditions. The transport system is resilient against disruptive events and is capable of automatically and dynamically re-configuring the journey within the network to meet the needs of the traveller if disruption occurs. Special mission flights can be completed in the majority of weather, atmospheric conditions and operational environments".

The basic issue is overall ATM capacity, not only at airports and in terminal areas (goal 1 and section 2.1) but also en route, with spare capacity to cope with special missions, disruptions and weather hazards. The air traffic capacity must be consistent with a very high level of safety, such as the ICAO target level of safety (TLS) of the probability of collision less 5E-9 per hour. The critical parameter is separation between aircraft, in altitude, longitudinally or transversely in all flight conditions including air corridors, crossing, climbing and descending flights and turn manoeuvres. The safe separation limits the capacity available in a given airspace; increases in capacity can be obtained if the same or higher level of safety can be achieved with smaller separation; this requires greater accuracy in navigation and faster detection of position errors either random or due to use of inaccurate data.

The capacity available in each air space sector must be matched to allow the overall flow of traffic along optimal or near-optimal routes that minimize travel time, fuel consumption and emissions and make air transport more convenient, economical and environmentally friendly. The weather effects can be of very different nature: (i) an airport equipped with Instrument Landing System (ILS) should not be affected by visibility conditions; (ii) a windshear warning at an airport will advise the transfer of flights to other locations; (iii) a volcanic eruption causing a large ash cloud may divert air traffic over a large area for a long time. With extreme weather events being not too frequent and adequate weather forecasting and now casting the effects can be minimized to a statistically smaller effect. Special mission flights or ultimately free flight in which each aircraft can choose its own route depending on available capacity, the ability to the ensure safety and the reconfiguration of the airspace. While reconfiguration is common practice within a sector its effect across sector boundaries may require an overall adjustment of the ATM scenario. Improvements in navigation and communication may allow all-weather operations at airports without special equipment and evolution from pre-planned towards free flight.

KEY TOPIC T2.8 – WEATHER EFFECTS ON AIR TRAFFIC

Flight efficiency

Flight efficiency Key Performance Indicators (KPIs) measure the degree to which airspace users are offered the most efficient trajectory on the day of operation. It is reported in Europe by the Central Office for Delay Analysis (CODA) and in the USA by the Department of Transportation. A first estimate of the ATM-related contribution toward overall air transport performance is identified by analysing the reports of the main delays experienced by airlines

Up to now, the pursuit of flight efficiency has been focused on assessing trajectory-based horizontal measures in order to identify opportunities for ATM improvements in the European and US system. More recently, the attention has shifted to address vertical flight profiles and the analysis of fuel-efficient continuous descent operations. The ICAO has identified these aspects as the key steps to improve the "efficiency spectrum", and in particular, fuel-efficiency - costs, environment - emissions that are directly related to fuel consumption. Lower fuel-burnt results in lower emissions, and environmental noise effects. The reduction of descent – related noise is a positive factor for traffic growth and for the environmental pollution. Indeed, these operations will support the ambitious goals set out for the contribution of aviation to the world-wide emissions.

ICAO's has identified 11 Key Performance Areas (KPAs) of interest in understanding overall ATM system performance: Access and Equity, Capacity, Cost Effectiveness, Efficiency, Environmental Sustainability, Flexibility, Global Interoperability, Predictability, Participation, Safety, and Security.

Weather Hazards: Frequency and Severity

In-flight weather hazards (for the purpose of this report, "weather hazards" include weather conditions as icing, strong wind, low visibility, snow, and so on) has become a difficult problem worldwide and this impacts on Air Traffic Management (ATM) systems. For example, icing causes a significant drop in the available airport capacity and may be the cause of accidents.

In the USA the Bureau of Transportation Statistics (BTS) establishes air traffic-related data and statistics (see for example data on weather-dependent delay on the Figure 2.86), whereas in Europe such information (also used for the purpose of market analysis) derives from different sources. For example, Eurostat reports air traffic observed at EU-28 level, while information and data on air traffic at the national level are reported by the national civil aviation authorities or associated statistics agencies. Moreover, both Europe and the USA receive information on delay and operational data for scheduled flights from airlines. These features are used for punctuality indicators of flight.

In many performance analysis indicators and modelling processes concerning atmospheric condition adopted by US Federal Aviation Administration (FAA) periods are categorized in visual or instrument meteorological conditions (VMC/IMC), as indicated by the criteria in the Table 2.23. All major airports are characterized by specific thresholds associated with visual, marginal or instrumental approaches. It is, also, considered as a practical way of comparing weather changes over time. Moreover, VCM/IMC provides a first-order observation of the primary criteria for defining weather.

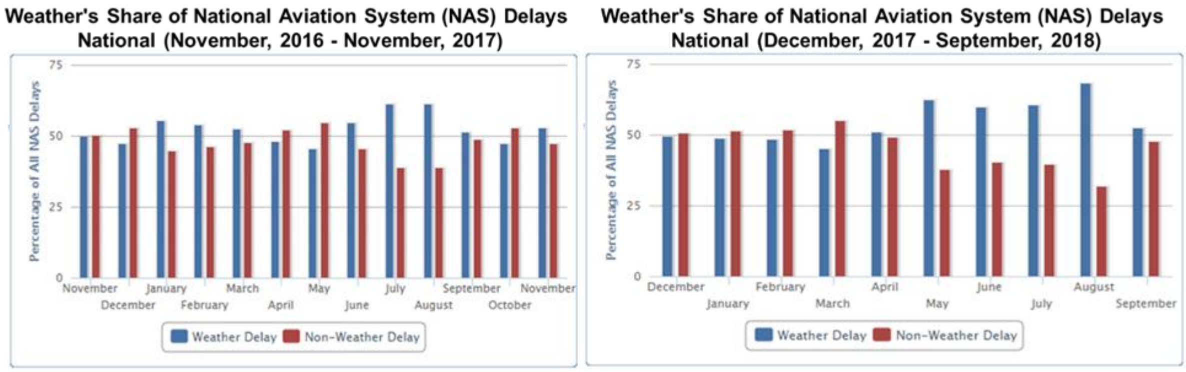


Figure 2.86. US Weather's Share of National Aviation System (NAS) Delays in the period November 2016 – November 2017 (Left) and December 2017 – September 2018 (Right). Source: U.S. DOT Bureau of Transportation Statistics. Airline On-Time Statistics and Delay Causes.

		Visibility (miles)		
		< 3	[3, 5)	≥ 5
Ceiling (feet)	≥ 3,000	Instrument	Marginal	Visual
	[1000, 3000)	Instrument	Marginal	Marginal
	< 1,000	Instrument	Instrument	Instrument

Table 2.23. Ceiling and visibility criteria. Source: Comparison of ATM-related performance: U.S. – Europe, 2015

At US airports, the higher frequency of instrument meteorological conditions (IMC) combined with scheduling closer to visual meteorological conditions (VMC) are key elements to reduce winter delays.

As evident from the Figure 2.84, weather-dependent delays are more relevant during summer. This variability may be related to scheduling (due to increased traffic?) and features like the heterogeneous weather conditions in the different US states. Indeed, the strong jet stream winds in the winter and convective weather in the summer impact overall predictability statistics.

It is important to note that the ATM performance depends on a number of factors and is affected by meteorological conditions, such as visibility, wind, convective weather and so on and can vary significantly by airport equipment (instrument approach system, radar, etc.), runway configurations (wind conditions), and approved rules and procedures. In light of this, a key element of system performance is to the impact on the predictability of ATM, airline, and weather influences.

According to a recent document "2015 Comparison of ATM-related performance: U.S. – Europe", both in the US and Europe, the weather is the predominant element affecting the airport throughput and as a consequence of ATM-related departure restrictions. However, in Europe weather-related constraints represent a smaller share of delays than in the USA. Indeed, Europe has also a notable feature of capacity-related delays that depend on capacity and staffing constraints. The difference between US and European data may derive from the fact, that the US system adopts "homogenous" procedures owing to the single service provider using the same tools and equipment, communication processes and so on. By contrast, at the ATC level, the European system and the provision of air navigation services is still fragmented. Since 2004, the Single European Sky (SES) initiative is aimed at reducing this fragmentation and at improving efficiency and interoperability of the ATM system through the creation of additional capacity. In addition, the susceptibility to weather events at the airport level is largely based on geographic location and traffic density.

At the system level, the weather in Europe is less favourable than the US, but for airport-related delays, the percentage of delayed flights at the gate or on the surface is slightly higher in the US than in Europe. The Figure 2.87 shows the percent of time spent in marginal, visual and instrument flight in Europe and the US in 2013 and in 2015 between 6AM-10PM local time.

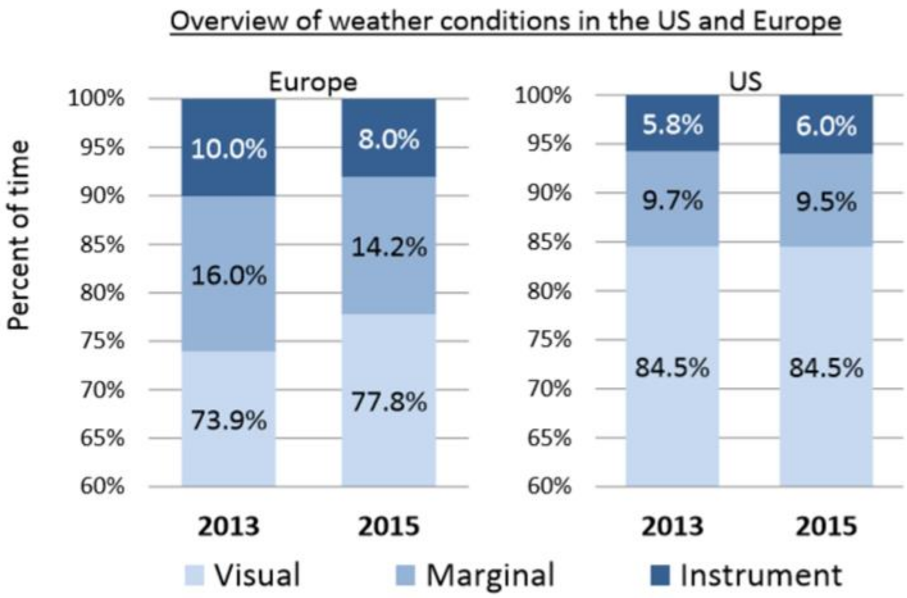


Figure 2.87. Impact of weather conditions on flight operations in the US and Europe. Source: Comparison of ATM-related performance: U.S. – Europe, 2015

Both U.S. and Europe use an effective atmospheric conditions observation system, METAR, also known as Meteorological Terminal Aviation Routine Weather Report or Meteorological Aerodrome Report, to monitor the weather. It contains data on temperature, dew point, wind speed and direction, precipitation, cloud cover and heights, visibility, and barometric pressure. Events such as rain showers, thunderstorms and strong winds, occurring during periods with high visibility and clear skies, are not assessed and ceiling and visibility provide only a preliminary step to measuring weather conditions. However, additional efforts are required to relate weather conditions on airport and air traffic performances and to develop a more comprehensive assessment of weather impact.

Over the period 2010-2015, the improvements on this issue in Europe have occurred mainly because of a notable reduction of ATM-related departure delay, enhancements in taxi-out procedures, and better en route flight efficiency. It is important to point out that in 2010 high delays in Europe have been originated not only by adverse weather but also by Air Traffic Control (ATC) strikes. On the other hand, the performance improvement in the US can be mainly associated with a substantial improvement in taxi-out efficiency. Between 2013 and 2015 the total ATM-related ground delay in the US decreased by 12.7%, while a notable performance deterioration in Europe was attributable to a significant increase in capacity/volume-related delays. However, it is worth noting that also events such as temporary maintenance of runway or dependencies with the traffic flow of nearby airports during good weather may influence the performances.

As it concerns the route and traffic re-orientation under severe weather conditions in the USA, Severe Weather Avoidance Plan (SWAP) routes have been pre-validated and coordinated. SWAP is a formalized program that is developed for areas where weather hazards, like thunderstorms, may produce disruption in air traffic flows. In Europe, EUROCONTROL is responsible for a reference document, named the RAD- Route Availability Document, containing the policies, procedures and description for route and traffic orientation. The compatibility with national procedures ensures each State with regard to the airspace organisation.

As it concerns the apparatuses employed to assist the air operations, especially under severe weather conditions, the (ILS) Instrument Landing System is a lateral and vertical beam aligned with the runway centreline in order to guide aircraft to the runway threshold for landing. To maintain the signal integrity of the Instrument Landing System (ILS) the Low Visibility Procedures (LVPs) require increased spacing between aircraft, which in turn reduces throughput. As illustrated in the Figure 2.88 throughput rates depend on visibility conditions and are reduced significantly when LVPs have to be adopted. The analysis of performance associated with meteorological conditions provides an indication of weather impact on air traffic and put in evidence the airports mostly affected by weather:

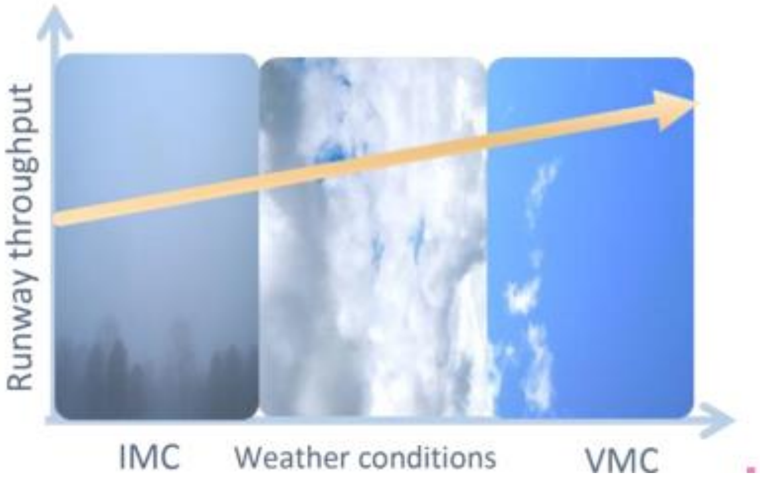


Figure 2.88. Impact of visibility conditions on runway throughput. Source: Comparison of ATM-related performance: U.S. – Europe, 2015

ATFM delay attributed to weather at US and European arrival airports

The Air Traffic Flow Management (ATFM) is established to support Air Traffic Control (ATC) for an optimum flow of traffic. This is a service provided by the appropriate authority to promote the safe, orderly and expeditious flow of air traffic.

In Figure 2.89 the average airport arrival ATFM delay at the system level for the main 34 airports in Europe and the USA between 2008 and 2015 are shown. For Europe, all ATFM delays are included, whereas for the US only delays equal or greater than 15 minutes are included.

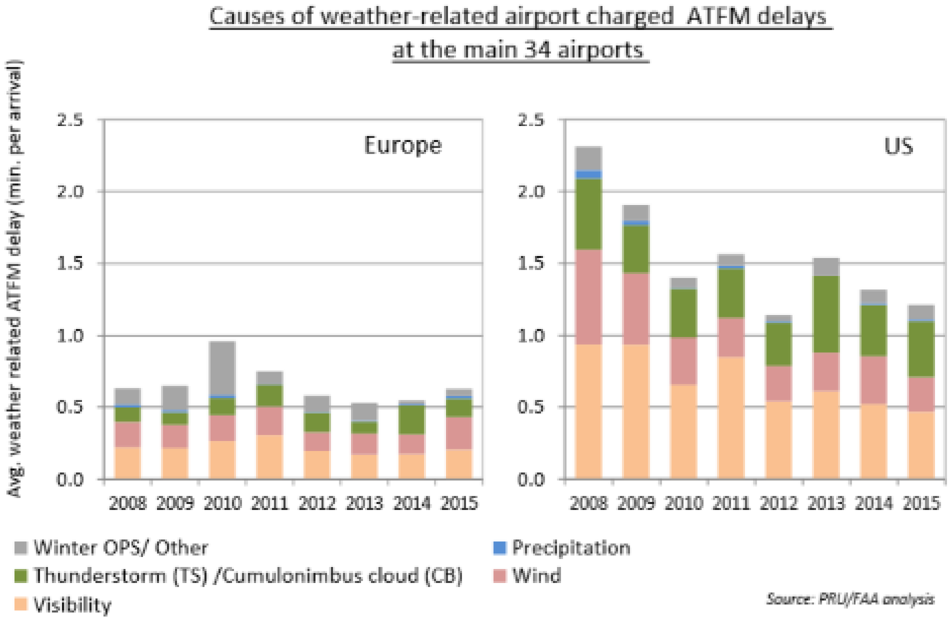


Figure 2.89. Causes of weather-related airport ATFM delays in the period 2008-2015. Source: Comparison of ATM-related performance: U.S. – Europe, 2015

When weather-related restrictions are present, higher ATFM delays per arrival can be observed for the US compared to Europe. Major contributors to the delays in the US are airports with high demand and highly variable capacity. Both in Europe and the US, the main cause of delay is visibility, followed by wind, winter operations and thunderstorms. Overall, in the US between 2013 and 2015 weather-related airport ATFM delays continuously decreased, whereas in Europe they have been characterized by almost the same (lower than in the USA) values.

A high average weather-related airport arrival delay is usually the result of a notable capacity reduction in bad weather combined with a high level of demand.

Briefly, the impact of weather on operations at an airport and as consequence on ATM performance can vary significantly in different airports and depends on a number of factors such as airport and ATM equipment, runway configurations (wind conditions) and approved rules and procedures. Overall, the analysis of meteorological reports suggests that weather conditions at the main 34 airports in Europe are, on average, less favourable than in the US.

Percentage of Airports with ILS

An Instrument Landing System (ILS) in the Airport is fundamental to enhance the reliability of landings in adverse weather conditions and to improve the regularity of service, in particular, during periods of worst weather conditions. According to the European Geostationary Navigation Overlay Service (EGNOS) Bulletin, only the major airports are equipped with ILS. EGNOS is a system developed by European Commission, European Space Agency and EUROCONTROL, consisting of a network of satellites to increase the accuracy and integrity of GPS data for improving existing services or developing a wide range of new services. The accuracy of satellite navigation, while sufficient for en-route flight, is limited to CAT I or CAT II for landing, so that it does not replace ILS CAT III for landing with zero visibility. As an example, Italian Airports with ILS CAT III (year 2013) are 28 out of 39 (7 not having ILS, 4 having localizer) (source ENAV, 2013).

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