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EUROCONTROL

Challenges of Growth 2013

Summary Report

SUMMARY

This report summarises the fourth Challenges of Growth study, which aims to deliver the best-achievable information to support long-term planning decisions for aviation in Europe. It brings together the challenges that have been highlighted by a number of technical tasks.

The European market for air transport is becoming more mature, but is far from reaching full maturity except for a few, largely domestic flows. Thus the current downturn in traffic is driven by economics, not by saturation of the air transport market. So when confidence and economic growth return, we expect demand to **start growing again**.

Looking ahead to 2035 or 2050, it is more robust to consider not just a single forecast, but a range of potential scenarios for how air transport in Europe, and the factors influencing it, might develop. This forecast uses **four scenarios** to explore the future of the aviation and the risks that lie ahead:

- **scenario A:** Global Growth. Strong global growth with technology used to mitigate effects of sustainability challenges;
- **scenario C:** Regulated Growth (Most-Likely). Moderate growth regulated to reconcile demand with sustainability issues;
- **scenario C':** Happy Localism. Like *C*, but with a fragile Europe increasingly, and contentedly, looking inwards.
- **scenario D:** Fragmenting World. A World of increasing tensions and reduced globalisation;

Each scenario has different input assumptions: economic growth, fuel prices, load factors, hub-and-spoke versus point-to-point etc. This leads to different volumes of traffic and **different underlying patterns of growth**: long- versus short-haul, rates of up-gauging of aircraft etc.

The economic and traffic downturn since 2008 has reduced the ability of airports to deliver the expansion plans that they reported then, and indeed reduced the urgency of the plans. But even so a new survey, covering 108 European airports, shows a surprisingly **sharp reduction in expansion plans**: just 17% increase in capacity is planned by 2035 compared to 38% by 2030 reported five years ago.

In all four scenarios, forecast traffic to 2035 grows more slowly than historical rates; the most-likely scenario *C* has 50% more flights in 2035 than in 2012. Some flows and some parts of Europe will see faster growth. But **slower growth** will make it harder to deliver increasing cost-effectiveness for air traffic management.

Forecasting 2050 is not about predicting specific volumes of traffic, but enabling robust planning that can be adapted as the challenges of 2050 come more sharply into focus. After 2035, the scenarios show more significant divergence. The main challenge will be continuing to deliver affordable mobility, when growth elsewhere may pull the focus for investment and increasingly for technology development away from Europe.

Inertia in the climate system means some degree of climate change is inevitable. A growing number of organisations are either taking or considering action to address climate change risk. Those risks are not necessarily urgent but they are most effectively addressed by building **climate resilience** into current infrastructure and operations planning. Many cheap and no-regrets measures such as staff training have already been identified. Early action is the key to building resilience at the lowest cost. Therefore, the time to act is now.

Beyond the scope of the four forecast scenarios there are other challenges and risks which should be taken into account in a long-term plan. These include environmental **sustainability** and the potential for a number of **external shocks** influencing demand or supply over the long-term including: regulation, taxes, fuel price or tourism trends.

The current, extended traffic downturn and weaker growth in the future should have given an eight-year head start on meeting the airport capacity challenge highlighted in 2008. At the 2030 milestone, now five years closer, it is true that there is less unaccommodated demand. But looking out by the same interval, 22 years, we find the same level of unaccommodated demand; half of the **head start has been lost**. In the most-likely scenario *C*, **1.9 million flights cannot be accommodated** (12% of total demand) by 2035 within the plans that airports have reported. That is equivalent to an estimated 120 million passengers unable to make their there-and-back trip. Turkey and the UK have the most unaccommodated demand.

Drawing on evidence for how industry already responds to lack of capacity, we modelled seven ways to mitigate the challenges. A combination of them reduces unaccommodated demand by 42% in 2035. That would enable up to 800,000 flights that otherwise

would not be able to operate in scenario *C*; perhaps 50 million passengers able to make their there-and-back journey. These models of mitigation do not fully capture the political, financial, environmental and other implementation difficulties, so they have a built-in optimism. Even then, none of them meets half of the unaccommodated demand. So, new infrastructure will inevitably need to be part of the **bridge over the airport capacity gap**. In reality, we would expect the industry to use each of the seven methods, and resort to building new runways and other infrastructure, just as it has in the past. All of these have costs as well as benefits.

For *Challenges of Growth* 2013, we have made the first estimates of the delay impact of airport congestion on future **network performance** by simulating two busy Summer months. In scenario *C*, by 2035 more than 20 airports are operating at 80% or more of capacity for 6 or more hours per day, compared to just three in Summer 2012. This drives ATFCM airport delay up from around 1 minute/flight in 2012 to 5-6 minutes in 2035, taking it from a minor or intermittent cause to a permanent, major contributor of delay.

The financial crisis has put the financial challenge of adapting to slower growth into sharper focus, compared to the 2008 study. So in summary, the five principal challenges for European aviation in 2035 and beyond are slightly different to those from 2008:

- The continuing difficulty of delivering **airport capacity** when, where and at the price it is needed. In the most likely scenario, the capacity gap is equivalent to 9 fully-used runways, but impossibly spread around the 21 cities that lack airport capacity.
- The difficulty of delivering the required level of performance on a **congested network**, when airport delay increases on an average busy day by a factor of 5 or 6 to become a frequent, major contributor to overall delay.
- Keeping the industry financially viable in an era of **slower growth**, with the potential for investor fatigue at the lack of return on investment in some portions of the industry, and more interesting investment opportunities away from Europe, where aviation will be growing more quickly.
- Even with slower growth, emissions from aviation are likely to increase. Therefore for growth to be **sustainable**, more needs to be done for example to develop competitively-priced low-carbon fuels.
- Building **resilience to climate change**. Current evidence points to the climate changing in the coming years in ways which will threaten aviation infrastructure, challenge day-to-day operations and shift patterns of demand within Europe. A growing number of organisations are making resilience to climate change a routine part of their business or operational planning. However, more needs to be done to build local and network climate resilience. Some of the solutions are relatively low-cost (training and procedures), or happy side-effects of other investment. An early start should save money in the long run.

This report, and the seven detailed technical reports which it summarises, are available at www.eurocontrol.int/articles/challenges-growth.

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1. INTRODUCTION

The *Challenges of Growth* series of studies aims to deliver the best-achievable information to support long-term planning decisions for aviation in Europe. EUROCONTROL has completed three studies, in 2001, 2004 and 2008 (Ref. 1, 2, 3). This report provides an overview of the fourth study, *Challenges of Growth 2013* (CG13), which addresses the following question:

What are the challenges of growth for commercial aviation in Europe between now and both 2035 and 2050?

This report is complemented by a number of more detailed, technical reports covering individual tasks:

- First we looked at how the traffic was developing, compared to the previous 20-year forecast (Ref. 4).
- To establish the scope of the study, and begin to structure the forecast scenarios, we reviewed a wide range of issues within and external to air transport (Ref. 5).
- Having completed an in-depth review of environmental issues in 2008, this time we focused on the resilience of the network to climate change (Ref. 6)
- The traffic forecasts to 2035 and 2050 are reported in Ref. 7 and Ref. 8 respectively.
- We looked in detail at the impact of network congestion on delays (Ref 9).
- And finally we modelled how to mitigate the airport capacity challenges (Ref. 10)

2. LOOKING AHEAD

2.1 The return of growth. Grounds for optimism?

The European market for air transport is getting more mature, but is far from reaching maturity except for a few, largely domestic flows. Thus the current downturn in traffic is driven by economics, not by saturation of the air transport market. So when confidence and economic growth return, we expect demand to start growing again.

The number of flights in European airspace peaked in 2008. With another year of decline forecast for 2013 and the peak not expected to be passed until 2016, discussion of Challenges of *Growth* might appear rather optimistic.

Is the European market mature? Both Boeing and AAE forecasts (Ref. 11, 12, 13) may be read as suggesting that this is the case. However, we need to distinguish carefully between 'being mature' and 'becoming mature'. Given the depth and duration of the current economic downturn, the fact that there are a number of traffic zones[1] which have not passed their 2006 or 2007 peak is not surprising, but is that telling us something about economics or about demand for air transport?

It is clear that some areas have plenty of scope for growth – especially in the East. So, are there parts of the European market that are mature? Undoubtedly, some internal[2] flows show signs of maturity. Figure 1 shows, for example, that all four of the Scandinavian traffic zones peaked more than 10 years ago, for traffic within each individual zone. The underlying reason for this is that internal traffic is being replaced by improving road and rail connections. Over longer distances, the situation is less clear.

We define and measure maturity by analysing how demand for air transport changes as the size of the economy (measured in GDP) changes. If an increase in GDP produces no increase in demand for air transport, then the market is indeed "mature". There is evidence for this in Figure 1, for internal markets and in some countries, since GDP has increased but traffic has not. The details are discussed in Ref. 5.

If an increase in GDP produces a smaller increase in demand for air transport than it used to, then the market is becoming mature. There is certainly evidence for this in the data, and it is built into our forecasting models. For this study, we have recalibrated the relationships between GDP and demand based (called 'elasticities') on the most recent data. We did not find maturity; the current traffic downturn is driven by economics, not saturation of European air transport. So when business and consumer confidence finally return, when economies finally start growing again – which the economic forecasters say is within the next 18 months – then demand for air transport should also start to grow.

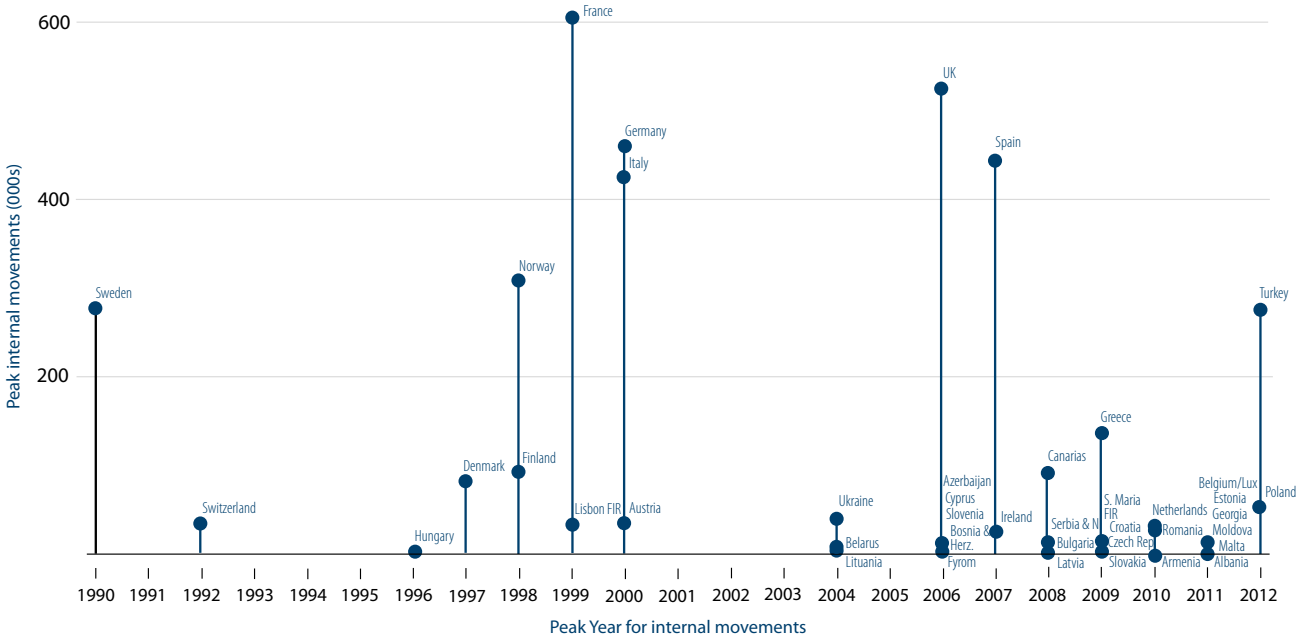

Figure 1. Some traffic zones passed their peak *internal* flight movements in the 1990s.

1 "Traffic zone" is typically a State, but depends on how the airspace is organised, so that Portugal, for example splits into Lisbon FIR and Santa Maria FIR.

2 "Internal" means within the TZ. It is not quite the same as "Domestic" which must be by an aircraft operator from the State.

2.2 Four scenarios capture just four possible futures

Looking ahead to 2035 or 2050, it is more robust to consider not just a single forecast, but a range of potential scenarios for how air transport in Europe, and the factors influencing it, might develop. This forecast uses four scenarios to explore the future of the aviation and the risks that lie ahead: scenario A: Global Growth, scenario C: Regulated Growth (Most-Likely), scenario C': Happy Localism, and scenario D: Fragmenting World. Each scenario has different input assumptions: economic growth, fuel prices, load factors, hub-and-spoke versus point-to-point etc. This leads to different volumes of traffic and different underlying patterns of growth: long- versus short-haul, rates of up-gauging of aircraft etc.

Looking ahead 20 or 40 years, the World may change in many ways and it is impossible to predict all of the factors, events, decisions and actions that will shape it. Our understanding of global system dependencies and dynamics can never be perfect and, perhaps even more importantly, it is limited by our current experience and knowledge. To overcome this difficulty for the forecast, we developed various scenarios, depending on factors like the economy, fuel prices etc. Based on these scenarios, the forecasts explore various possible ways in which air traffic might evolve in the future.

In contrast to the 7-year forecast which develops a central forecast as a base scenario and an interval around with bounds referred to as high and low scenarios, the scenarios for 2035 and 2050 are individual, qualitatively-different representations selected from amongst many possible futures. Rather than creating a forecast range that is likely to cover the number of future flights, they each follow a specific path of events and developments that corresponds to the forecast traffic. What the 2035 forecast, and even more so the 2050 forecast, aims at is not providing the exact future traffic counts but more the understanding of the factors that will shape future air traffic and the risks that lie ahead. None of the scenarios will actually become true in 2035 or 2050. In reality, the future number of flights will be the result of the effective realisation of the various factors and will be nearer to some of the scenarios than some others. Nevertheless, these scenarios provide context to help organizations consider the implications of future events (e.g what events might lead to high/low traffic growth), and help them prepare for change and uncertainty.

The development of air transport in Europe is driven by a series of interrelated factors, many of which are external to aviation and indeed external to Europe. Key drivers include:

- **Demographics**: globally there is high uncertainty about population to 2050, with UN projections diverging rapidly after 2035;
- The global **economy**: the European Union is projected to represent 17% of the world economy in 2050, cf. 29% in 2010;
- For the 2030-2035 aircraft fleet, most of the **aircraft technology** is already for sale. Beyond 2035, technology advances will have a sharper impact on global aviation markets, and may for example sharply cut energy consumption, thus reducing environmental impact and dependence on oil products. Some of these advances are likely to come from outside Europe, with Asia moving up traditionally European value chains.

We differentiate the scenarios by whether Europe has an 'inward' or an 'outward' perspective at a global level (a primarily political question), and whether Europe adapts (as measured by the economic effect). Figure 2 illustrates this. They do not represent all possible outcomes, and are not necessarily equally probable or exclusive – indeed actual events will probably comprise a combination of factors from different scenarios.

For the last 20-year forecast (LTF10) published in December 2010 we used four scenarios, largely based on previous long-term forecasts. Scenarios *A: Global Growth*, *C: Regulated Growth* and *D: Fragmenting* World drew on the work done for CONSAVE (Ref. 14), ACARE (Ref. 15) and the IPCC (Ref. 16) although they had been updated to reflect the views on likely future developments in aviation. We also developed a specific scenario, "scenario *E: Resource Limits*" to address the possibility of reaching the peak in oil production.

For these new forecasts (LTF13 and the 2050 forecast), we revisited these four scenarios and, after discussion with the STATFOR User Group (SUG) and the WG 1 of the Airport Observatory, decided to drop scenario *E*. Not that the risk of peak oil has gone away, but it was felt that modelling it again was not necessarily the highest priority. Instead discussions during the scenario workshop led to the conclusion that we needed to envisage a scenario in which Europe would look increasingly inwards whilst maintaining the momentum of economic growth. Thus, a new scenario "scenario *C': Happy Localism*" has been introduced. The

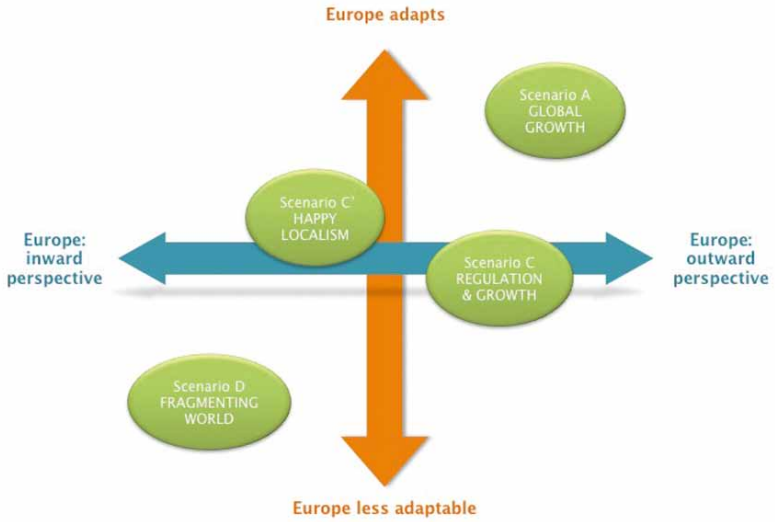

Figure 2. The four scenarios capture adaptability and inward- versus outward-looking perspective.

latter has been basically defined around the scenario *C* with the idea that fragile Europe would "better" manage to adapt economically, technologically and politically by keeping a contented, inwards perspective. In other words "Small is beautiful". It is named *C'* to highlight this connection to scenario *C* (and to avoid confusion with a different scenario *B* in an earlier forecast).

In summary, we look at the following four scenarios for the future of the aviation in Europe. The details are in Annex A and in Ref. 7 and 8.

- **Scenario A:** *Global Growth (Technological Growth)*: Strong economic growth in an increasingly globalised World, with technology used successfully to mitigate the effects of sustainability challenges such as the environment or resource availability.
- **Scenario C:** *Regulated Growth*: Moderate economic growth, with regulation reconciling the environmental, social and economic demands to address the growing global sustainability concerns. This scenario has been constructed as the 'most-likely' of the four, most closely following the current trends.
- **Scenario C':** *Happy Localism:* this scenario is introduced to investigate an alternative path for the future. With European economies being more and more fragile, increasing pressure on costs, stricter environmental constraints, air travel in Europe would adapt to new global environment but taking an inwards perspective. There would be less globalization, more trade inside EU (e.g. Turkey joining Europe is important in this scenario); also slow growth of leisure travel to outside Europe, however certainly more inside EU; more point-to-point traffic within Europe. It does not mean that Europe does not grow or does not adapt to new technologies and innovation but its main focus is "local". Although this scenario is mostly based on scenario *C* (as its name indicates), it also inherits some aspects of other scenarios like higher fuel prices or low business aviation traffic of scenario *D*.
- **Scenario D:** *Fragmenting World*: A World of increasing tensions between regions, with more security threats, higher fuel prices, reduced trade and transport integration and knock-on effects of weaker economies.

The general 'storylines' above are further elaborated and translated into quantitative terms to serve as input assumptions to the forecast model. Since the 20-year forecast starts from the end of the 7-year forecast, the scenario factors are described from 2019 onwards. A full listing of the factors is in Annex A. Some of the more important factors to 2035 are as follows (section 2.5 carries on with the discussion for 2050):

Economic growth The base GDP forecast has been prepared by Oxford Economics Ltd. (January 2013 update). The forecast economic growth for 2019-2035 in the EU27 averages 1.6% per annum and is directly used in scenario *C*: Regulated Growth. It is 0.2 percentage points higher in scenario *A*, 0.5 points lower in scenario *D* and 0.2 points lower in scenario *C'*. In the most-likely scenario, the GDP growth trend has been cut by around 0.5 points compared to what was expected in the previous 20-year forecast.

Elasticities describe the relationships between GDP growth and growth in passenger demand, as discussed in the previous section. Following the exploration of market maturity in Task 3 of Challenges of Growth (Ref. 5) these have been fully recalibrated for this forecast. The study reviewed the elasticities for all region pairs and also examined the specific characteristics of domestic flows in the forecast in order to express the less rapid growth of the domestic markets.

Oil prices steadily grow in scenarios *A* and C reaching around $145 per barrel (in 2010$) by 2035. Uncertainty about the stability of oil production in scenarios C' and D results in speculation, high price volatility and high prices. In the model, this is captured by persistently high oil prices starting at around $105/barrel in 2019 climbing to around $200/barrel in 2035. Due to higher refining margins in scenarios *C'* and *D* (than in scenarios *A* or *C*), the kerosene prices increase somewhat faster and therefore have somewhat stronger effect on fares when these costs are passed onto passengers.

Environmental regulation even if the EU Emission Trading Scheme (EU ETS) for aviation is partly on hold, work continues at ICAO to develop global, market-based measures. The 20-year forecast needs to reflect the costs of emissions for airlines in the period 2019-2035. We assume that some framework is in place in which 100% of CO_2 emissions are paid for. This could be by auctioning of emissions permits, by taxation or some other means. The forecast is not sensitive to the actual mechanism by which these costs are incurred. Scenario *D* sees the strongest regulation with highest CO_2 costs (around €107/tonne CO_2 in 2035). Scenarios *C* and *C'* are more successful at adapting to the global long-term sustainability issues and so have lower costs (around €66/tonne CO_2 in 2035). In scenario *A* the technology has successfully moved towards less carbon-intensive energy sources and therefore has the lowest CO2 costs (around €42/tonne CO_2 in 2035). The method assumes that these additional costs of airlines are fully passed onto passengers via an increase in fares.

Network structure of the airlines, i.e. concentration of traffic into hubs or use of more point-to-point operations, has an effect on the total number of flights and their regional distribution. This forecast assumes a growing importance of Middle-East hubs (namely Dubai, Abu Dhabi and Doha) for connecting traffic to and from the Middle-East, Asia/Pacific and Southern Africa, resulting in slow growth of transferring passengers at European hubs on these flows. This assumption is used in all but scenario *D* (possible instability in the Middle-East). In scenarios *A* and *C*, Istanbul airport plays also a key role with higher hubbing rates (to a lesser extent compared to previous Middle-East airports) for connecting traffic to/from Asia/Pacific and Southern Africa. This additional emphasis on Turkey is however not kept in scenario *C'* where Europe is seen as a region increasingly flown over by long-haul international flights.

2.3 Airports plan less capacity growth

The economic and traffic downturn since 2008 has reduced the ability of airports to deliver the expansion plans that they reported then, and indeed reduced the urgency of the plans. But even so a new survey, covering 108 European airports, shows a surprisingly sharp reduction in expansion plans: just 17% increase in capacity is planned by 2035 compared to 38% by 2030 reported five years ago.

Challenges of Growth 2013 is based on a fully-refreshed set of airport capacity figures covering some 108 airports. The EUROCONTROL Airport unit exploited and expanded its process for collecting data directly from key airport stakeholders. The scope included airport capacity, significant events and works planned as well as efficiency enhancement initiatives. This homogeneous source of data was compiled between October 2012 and January 2013. Where information for some key airports was not available, additional data received from STATFOR User Group members (especially the navigation service providers) helped complete the sample.

As a result, from an initial target list of 122 we have capacity data from 108 airports. Of the busiest 50 airports in Europe, we have future capacity data from 46. Although it is a small proportion of the 2,000 airports included in the forecast, the 108 are involved in the lion's share of flights: 83% of all European flights in 2012, 8.1 million flights in total, either departed from or arrived at one of these airports.

In the 2008 report we remarked that one of the challenges would be "*delivering* the plans already reported by airports" (Ref. 3, p3). Since then, delivering on plans has indeed been severely challenged by three linked factors:

- The banking crisis has sharply limited access to funding. ACI-Europe reports a 29% increase in capital costs for European airports in just two years, between 2009 and 2011 (Ref. 17).

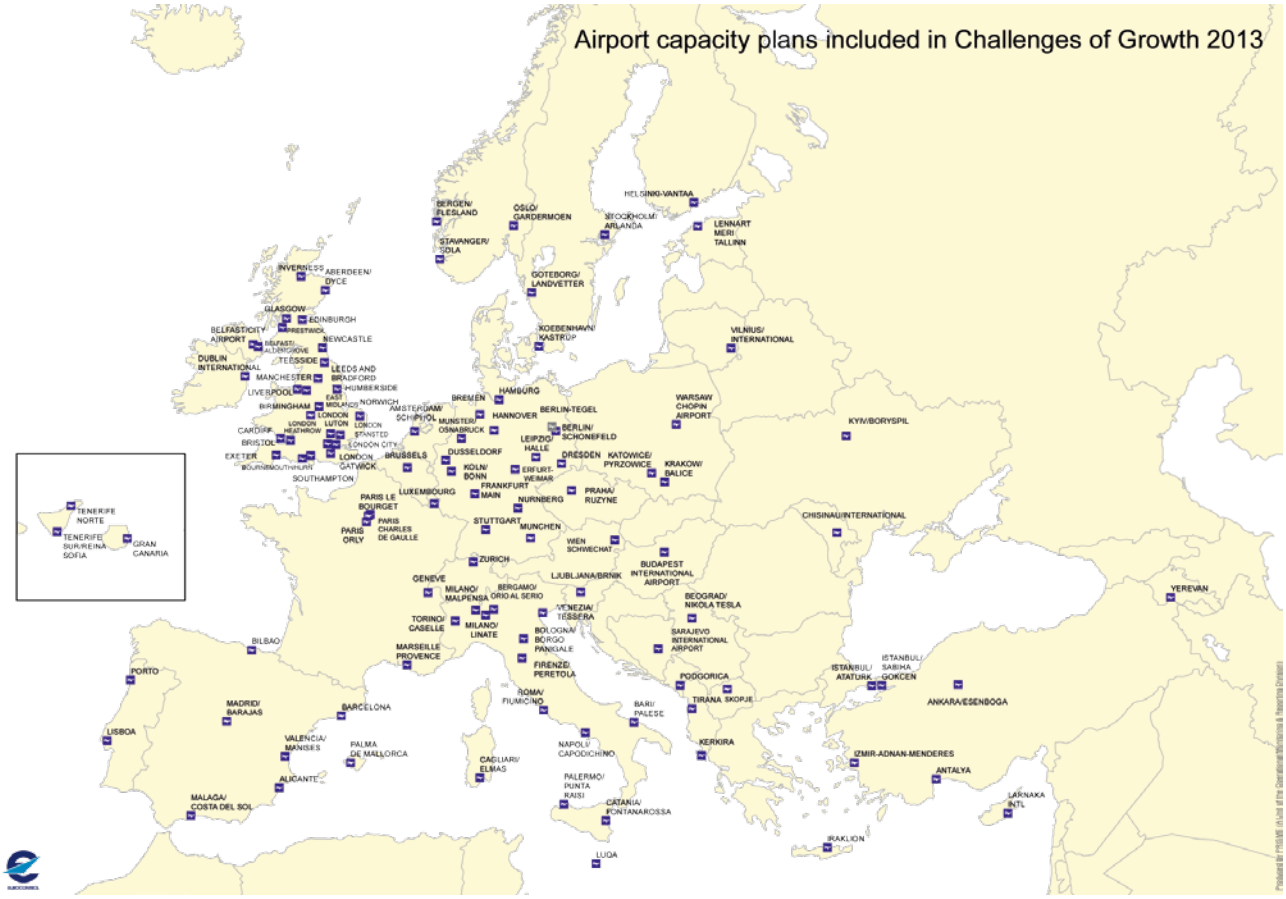

Figure 3. Capacity data for 108 airports. Flight data for ~2000 airports.

- The economic downturn means fewer flights and hence lower revenue at airports, thus reduced ability to finance future expansion plans.
- The decline in traffic experienced in 2009-2012 and into 2013 has lifted the pressure on capacity at many airports, giving the system some extra years to react and adapt. With a slower than expected recovery of growth and a return to previous 2008 record flight-counts now delayed to 2016, the immediate sense of urgency for airport congestion has diminished (Ref. 18, p21).

As a result, total capacity is now planned to increase by just 17% between 2012 and 2035. This is significantly lower than the 38% increase between 2008 and 2030 reported by airports for *Challenges of Growth 2008*. 48 airports now report no plans to increase capacity. In 2008, 27 airports reported plans to add runways. This time, the 17% increase includes just 4 new runways, with a further three likely, but for which new capacity figures were not available. Out of the 13 airports which contributed most to the capacity growth in 2010 long-term forecast, 12 have cut back their expansion plans substantially.

Challenge:
Plan, finance and deliver airport capacity.

As with earlier studies, CG13 does not look at *en route* capacity constraints. The results of the study will point to the required *en route* capacity, so to include *en route* constraints would risk circular arguments. Nevertheless, ensuring that airport, TMA and *en route* capacity are consistent with each other in a cost-effective manner will not be a trivial task.

2.4 European traffic growth to 2035 will be slower

In all four scenarios, traffic to 2035 grows more slowly than historical rates. Some flows and some parts of Europe will see faster growth. But slower growth will make it harder to deliver increasing cost-effectiveness for ATM.

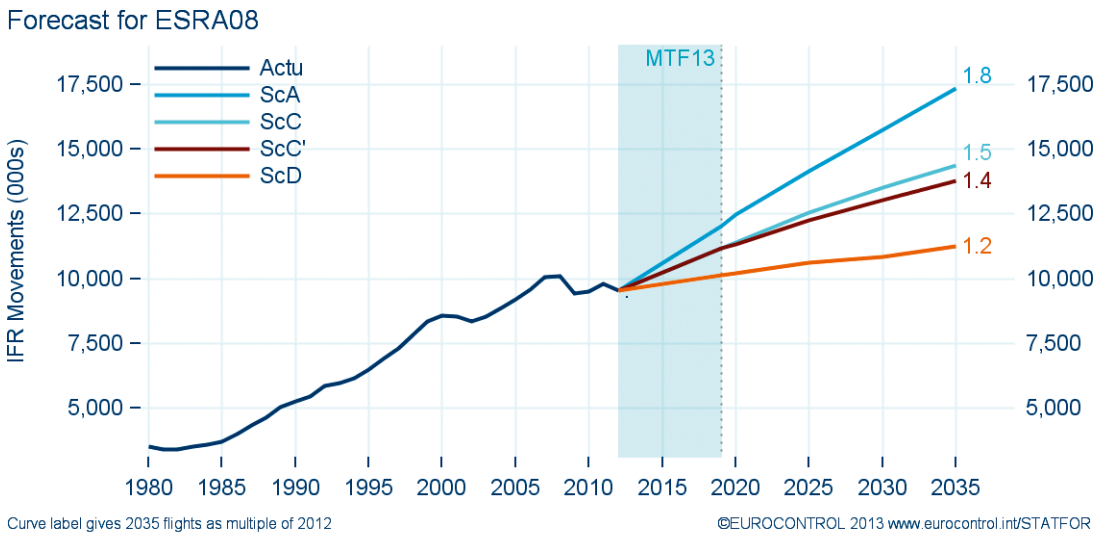

Figure 4. In 2035, the most-likely scenario has 1.5 times more flights than in 2012, but other scenarios show significantly different growth patterns.

	IFR Mvts (million) 2035	Traffic Multiple 2035/2012	Ave Annual Growth 2035/2012	Extra flights/day (thousands)
A: Global Growth	17.3	1.8	2.6%	21
C: Regulated Growth	14.4	1.5	1.8%	13
C': Happy Localism	13.8	1.4	1.6%	12
D: Fragmenting World	11.2	1.2	0.7%	5

Figure 5. Summary of the key traffic values expected in the 4 scenarios for Europe by 2035.

Each scenario paints a picture of a different future, with different pattern of traffic growth. Details are in the 2035 forecast report (Ref. 7). In this summary, we focus on the ESRA08 region (see Figure 6) which covers most of Europe. The results are shown in Figure 4 and Figure 5 and are:

- Scenario *A*, starting from the high-growth scenario of the 7-year forecast presents the most challenging traffic situation for Europe supported by quite strong economic growth, slower fuel price growth, and a wide range of open skies agreement (compared to other scenarios). There will be 17.3 million flights in 2035 in Europe, corresponding to 1.8 times the 2012 traffic levels. The average annual growth of 2.6% is the highest of the four scenarios. However, relatively rapid growth rates (around 3.5%) during the first 8 years will then slow down to around 2%. This deceleration is explained by increasing market maturity and especially capacity constraints at airports.

- In the 'most-likely' scenario (scenario *C*) of the LTF13, there will be 14.4 million flights in Europe in 2035, 1.5 times the 2012 volume (Figure 4). That is an average of 1.8% increase per year, around half the historic rate from the 1960s to the peak of 2008. Traffic growth will slow down from 2025 as markets mature, economic growth decelerates and as the capacity limits at airports increasingly become an issue.
- Scenario *C'* follows almost the same pattern in growth as scenario *C*, partly because it starts at the same point. However the traffic growth develops less rapidly in scenario *C'* from 2020 as a result of slower economic growth, higher fuel prices and higher load factors (compared to scenario *C*). The growth rates slacken from 2025, resulting in a difference of 0.6 million fewer movements in scenario *C'* compared to scenario *C* in 2035.
- Scenario *D* starts from the low-growth 7-year forecast, in which Europe has struggled for much of the decade to get back into growth. This weak growth is compounded by high oil prices, fragile economic growth, no population migration, no free trade agreements with extra European partners, high price of travel etc an accumulation of factors that lowers the demand not only for international flights but also for intra-European ones. This scenario has just 11.2 million flights for Europe in 2035, an annual growth rate of 0.7%.

Figure 6. Average annual growth on main flows from Europe, 2035 versus 2012 ('most-likely' scenario).

Growth will not be uniform across Europe; it will be faster in some regions and on some flows than others. In the 'most-likely' scenario *C*[3], growth is stronger in Eastern Europe. Eastern Europe markets are relatively less mature, so their economies develop faster to catch up with Western Europe. We see more potential for air traffic growth especially as the population expands quickly as well. For example, in 2010, the yearly flight departures per 1000 capita[4] were 9 for Germany and 3 for Turkey. By 2035, Germany is expected to increase to 13 while Turkey will reach 9, the per capita departures Germany had in 2010 (Turkish population will grow by 16 million in 2035).

In absolute terms, Germany and France are expected to remain the busiest States, with more than 4 million flights each in their respective airspace. UK and Turkey will follow with around 3 million flights each to handle in their airspace in 2035.

Flights within ESRA08 ("intra-European flights") currently account for slightly less than 80% of the total traffic, arrivals and departures for around 20% and the share of overflights is negligible. A general trend observed in this forecast is the decline of the share of intra-European flights. One of the reasons for that is the less rapid growth of the domestic markets, mainly in North West and Mediterranean Europe. In the most-likely scenario (scenario *C*), the share of the internal flights will decrease by 10 p.p to 70%. Traffic flying over European airspace will grow at fastest (4.4%/year) though it will still only represent 2% of the total traffic. More details are in the 2035 forecast report (Ref. 7).

Challenge:
Improve ATM cost-efficiency in a market that is growing slowly.

Plans to improve the efficiency of air traffic management in future depend on both: new technology and having the resources to fund this; and on 'doing more with the same, or less', reducing cost per flight by keeping costs stable as traffic grows. The European market will continue to expand, but economic growth is expected to be slower, and the traffic growth driven by that will be slower still. So funding for new technology will be harder to come by, and reducing costs per flight will need more reductions in costs, not just holding costs constant. There are other ways to reduce costs, such as centralised services, but slower growth will make hitting the target more difficult.

2.5 A first look at 2050

Forecasting 2050 is not about predicting specific volumes of traffic, but enabling robust planning that can be adapted as the challenges of 2050 come more sharply into focus. After 2035, the scenarios show more significant divergence. The main challenge within Europe will be continuing to deliver mobility, when growth in demand, and increasingly technology developments are coming from elsewhere.

When confronted with today's challenges, with short-term financial pressures, or even with the challenges of 2035, 2050 may seem like too far away to need to plan for. However, decisions we make today - for policy, infrastructure, concepts and technology - can strongly improve or reduce our ability to respond as the challenges of 2050 come more sharply into focus.

For this update of *Challenges of Growth*, we have prepared the first EUROCONTROL forecast of IFR flight movements in Europe up to 2050 (Ref. 8). This forecast focuses on developments after 2035; traffic evolution between now and 2035 is discussed in the 7- and 20-year forecasts (Ref. 7,18).

The 2050 forecast does not aim at providing the exact future traffic counts, but focuses rather on understanding the factors that will influence the future of air traffic and the challenges that lie ahead. The range of likely outcomes presented in the scenarios should contribute to planning and managing risk, and help cope with uncertainty and the potential impact of changes in underlying assumptions.

The 2050 forecast uses the same four scenarios to explore European air traffic as the 2035 forecast (section 2.2). They set the political and economic environment of Europe, providing the context to consider a range of plausible futures for 2050. At this horizon, the inputs are increasingly driven by scenario assumptions, and less by historical data or available forecasts of external values, although population and economic forecasts are still available to 2050. The scenarios produce different levels and flows of traffic and follow different paths of growth according to their storylines and mix of characteristics factored into the forecast:

- The most 'visionary' scenario, A (Global Growth), is characterised by strong economic growth in an increasingly globalised World, with technology used successfully to mitigate the effects of sustainability

[3] Similar patterns can be observed in the other LTF13 scenarios, yet with some variation at State and flow levels.
[4] Comparison made for States with roughly same population sizes in 2010: Turkey had 73 million inhabitants and Germany had 82 million inhabitants in 2010 (source: United Nations).

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 the 2012 volume.

- Scenario *C* (Regulation & Growth) represents an extension to the existing environment we are in today. It is characterised by moderate economic growth, with regulation reconciling the environmental, social and economic demands to address the growing global sustainability concerns. It exhibits a medium level of growth with 18.6 million IFR movements in Europe by 2050 – twice the 2012 volume.
- Scenario *C'* (Happy Localism) is characterised by the European economies focusing on local exchanges, with nevertheless some adaptation to new technologies but with more environmental consciousness. It exhibits a comparable level of growth to scenario *C*, with 17.7 million IFR movements by 2050 – 1.9 times the 2012 volume, but exhibits relatively stronger European regional flows.
- The forecast for scenario *D* (Fragmenting World) exhibits the lowest growth; resulting in 10.5 million IFR movements – only 10% more than in 2012, and it exhibits a 6% decline in traffic between 2035 and 2050. This scenario is characterised by a World of increasing tensions between regions, fragmentation of Europe, with more security threats, reduced trade and transport integration and knock-on effects of weaker economies. Much of the growth in traffic comes from outside of Europe.

At the 2050 horizon, we do not identify a 'most likely' scenario since there is so much scope in 37 years for divergence from anything that could be described as 'business as usual'.

There are a number of key trends that are evident across all scenarios, to a greater or lesser extent. In all the scenarios, the major growth will come through international arrival/departures, with internal flights declining as a percentage of the total forecast. This is a consequence of Europe's declining relative role in the world economy by 2050 in all scenarios. ESRA North-West (NW) (see Figure 18 in the Glossary) remains the European region with the highest total IFR movements in 2050, but it will exhibit a decline in the relative proportion of traffic in Europe. ESRA NW – North Atlantic drops out of the top 10 flows (by number of flights) in all scenarios, with flows from ESRA East and ESRA Mediterranean to Other Europe displacing it. The significant growth (as a fraction of 2012 traffic) comes from ESRA East and ESRA Mediterranean flows, particularly international flows to North Africa and Asia/Pacific, and to Other Europe (which in traffic terms is mostly Russia).

The use of scenarios in developing new strategies and assessing existing strategies is particularly aimed at policy makers and business planners. Scenarios should provoke thought – how could we manage if there was 2.7 times today's air traffic (as for scenario A which exhibits the highest growth) – and in what economic

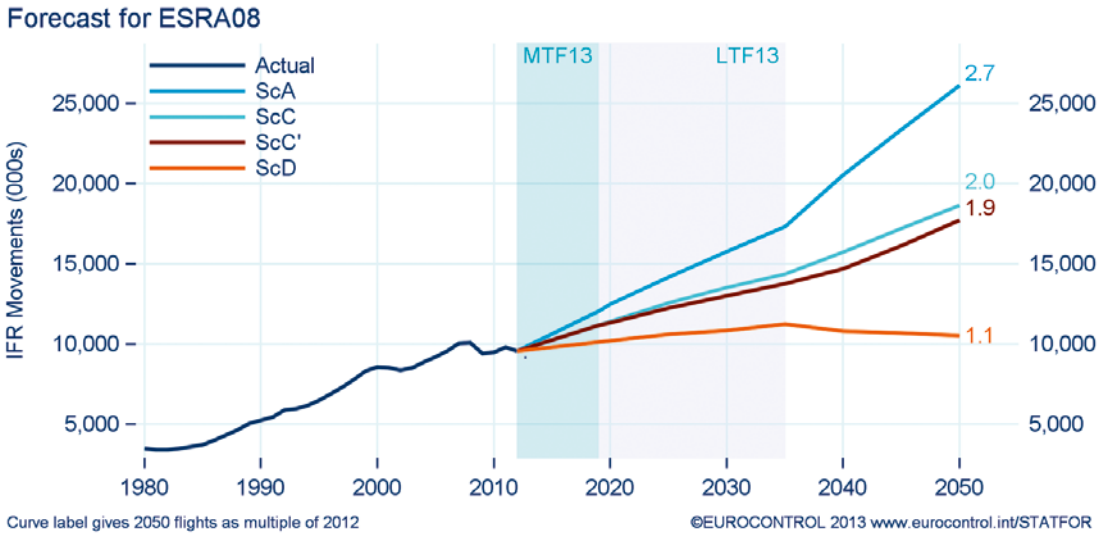

Figure 7. Summary of the forecast to 2050

and technological state would we be to manage with such growth? What would be disruptive to the current assumptions? Should governments support plans for extending capacity? What are the 'early warning signs' that tell us which scenario is beginning to unfold?

In our analysis the 'y axis' in the scenario diagram (Figure 2), economic and technical adaptability is the most critical for stimulating aviation growth in Europe, even if the growth forecasted is still moderate compared to the second half of the twentieth century. However, the political orientation of Europe should not be discounted. In a world where Europe will become a declining player on a global scale, the easiest route to higher traffic growth is for Europe to maintain an outward focus.

There are some things that policies and business plans can influence, and others on which policy and planning professionals need to keep a watching brief (for example the global economic and political situation, demographics). Some of the big challenges will be linked to decoupling aviation resource use from economic growth by using less oil fuel products and reducing environmental impact, and yet in an environment where economies continue to grow.

Challenge:

Continue to deliver affordable mobility, when faster-growing regions are more attractive for investment.

As the highest economic and population growth shifts to Africa and Asia, the demand for air transport in these regions will expand substantially over the coming decades. This could be exploited, since Europe should remain an attractive destination. But it also risks making Europe a less attractive place for aviation investment, reducing our ability to stay at the forefront of technology, and losing the economic advantage that this brings. Furthermore, in the higher traffic growth scenarios it is clear that airport capacity will continue to substantially limit growth; on our projections here, this will be particularly in ESRA Mediterranean, and it will be necessary for policy planners to decide if, and how, to invest to accommodate demand.

2.6 Resilience to climate change is of increasing concern

Inertia in the climate system means some degree of climate change is inevitable. A growing number of organisations are either taking or considering action to address climate change risk. Those risks are not necessarily urgent but they are most effectively addressed by building resilience into current infrastructure and operations planning. Many cheap and "no-regrets" measures such as staff training have already been identified. Early action is the key to building resilience at the lowest cost. Therefore, the time to act is now.

Challenges of Growth 2008 identified the impacts of climate change as a potential operational and financial risk to European aviation. *Challenges of Growth* 2013 (CG13) followed up by consulting industry to determine to what extent they consider adaptation actions are necessary to address those risks, and what actions are being implemented or planned. The resilience report (Ref. 6) presents the results of that consultation. It also reviews climate change risks out to 2050, by which time the impacts are expected to be widely felt.

Due to inertia in the climate system some degree of climate change is now inevitable. *Challenges of Growth* 2008 identified the risks this might entail for European aviation and there is now broad agreement on the qualitative issues that will be faced. However, impacts will vary across Europe's climate zones and there remain uncertainties as to their extent, severity and timing. Moreover, looking beyond the current challenging economic climate, the aviation sector will need to build climate resilience whilst dealing with growth in demand. Some of the regions where the highest rates of growth are expected are also areas which may experience the most severe impacts of climate change.

- In general, Europe should prepare for higher temperatures and an increase in precipitation. An exception is Southern Europe where precipitation will decrease. Increased summer heat and humidity in the Mediterranean Basin may influence the amount and location of demand as traditional destinations could become uncomfortably hot during the traditional summer season. This would lead to both a temporal and geographical shift in demand. Increased temperatures would also reduce aircraft climb performance which in turn would affect the

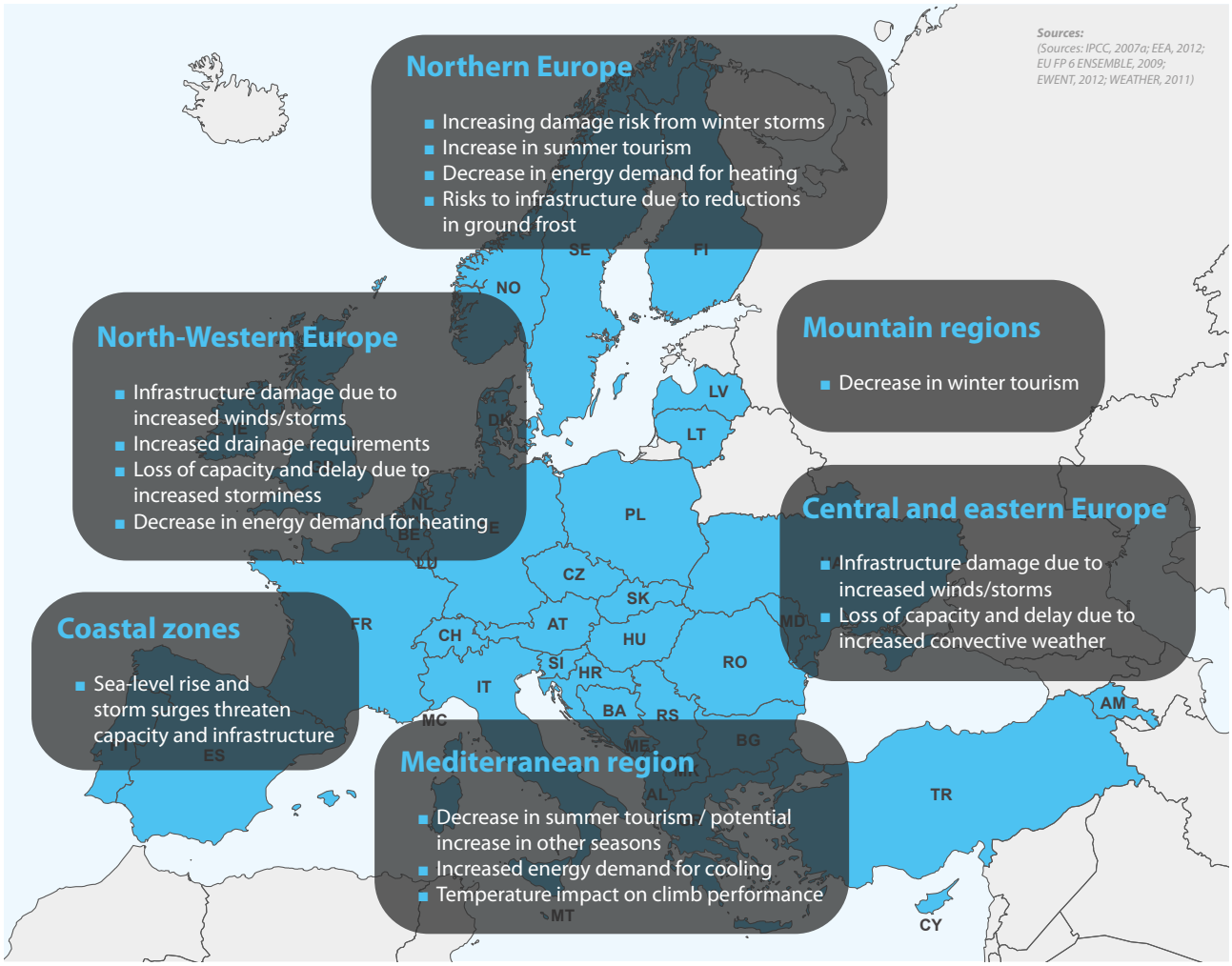

Figure 8. Potential vulnerabilities to, or opportunities from, climate change.

distribution of local noise. Heavy precipitation events will reduce airport throughput and challenge an aerodrome's surface drainage capacity.

- Snowfall will generally decrease throughout Europe although there may be heavy snow events in new areas and an increase in more-challenging wet snow conditions. Snow in locations where it is not usually experienced has the biggest effect on airport operations due to relative lack of preparedness. Overall, more snow clearing and de-icing equipment may be required. A balance always needs to be struck between the financial costs and an adequate level of preparedness, but climate change may shift the balance.
- The strongest storms are expected to become larger and more powerful. Convective weather can impact flight predictability and punctuality whilst having implications for flying pre-determined 4D trajectories. An increase in larger and more intense convective systems may affect multiple hub airports in a region.
- Changes in prevailing wind direction are also expected, leading to an increase in crosswinds. Associated changes in procedure may have an environmental impact whilst capacity will be reduced at airports with no crosswind runway.

A central part of the 2013 study was a stakeholder consultation to determine whether the industry now considers that measures to increase climate resilience are required, and what actions they are taking. It was carried out in two parts: an online survey and a follow-up workshop. The survey was sent to operational stakeholders, industry associations and civil aviation associations. Over three quarters of respondents acknowledged that they expect to need to take action to adapt to the potential impacts of climate change, indicating a heightened level of awareness compared to feedback in 2008.

A growing number of actors within the aviation industry are already taking comprehensive steps to assess potential vulnerability to climate change and put in place appropriate adaptation plans and resilience measures. For example, the Network Manager has been working in partnership with operational stakeholders to build this resilience and enhance network operations; we have been working with ANSPs, airports and airlines to re-enforce the operational management of adverse weather conditions, both en-route and at airports.

Thus, the survey indicates a clear shift compared to the limited number of organisations active in this area four years ago. However, many organisations have yet to consider this issue.

Challenge:

Make resilience to climate change a routine part of operational and business planning.

The workshop was attended by stakeholder organisations representing airport operators, air navigation service providers, industry associations, the academic community and European policy makers. Participants concluded that there is a growing need for climate change risk assessment and planning for adaptation measures. Cost-benefit analyses will be required to determine what level of impact to be prepared to cope with. However, some of the cheapest and potentially most effective ways identified to build resilience are staff training, sharing of best practices, experiences and solutions, and the implementation of processes which facilitate collaborative responses to climate change challenges. In particular, the development of realistic and objective operational responses should be considered whilst "No-regrets" or "win-win' measures which are intended to address issues such as capacity but which also contribute to building long-term climate resilience, can be cost and resource efficient solutions. Therefore, although the impacts of climate change will vary according to geographical location and type of organisation, many solutions are either already being implemented, or at least have been identified and may include any of the following:

- Climate change risk assessments for individual organisations and the European network;
- Identification and implementation of specific local and network-wide resilience measures, particularly no-regrets measures;
- Identification and implementation of measures such as training which can be cost-effective when implemented at both a local and pan-European scale;
- Increased collaboration with meteorology services to better exploit advanced forecasting techniques.

2.7 Other challenges and risks

Beyond the scope of the four forecast scenarios there are other challenges and risks which should be taken into account in a long-term plan. These include environmental sustainability and the potential for a number of external shocks influencing demand or supply over the long-term including: regulation, taxes, fuel price or tourism trends.

Four forecast scenarios can not present the whole picture of future challenges and risks for air transport in Europe. Here we discuss briefly two groups of issues which are an essential part of any long-term plan.
Sustainability: The environmental impacts of aviation are both global (e.g. CO_2 emissions from burning fuel) and local (e.g. noise and local air quality impacts). Moreover, there are often difficult trade-offs to be made between the various impacts. The Challenges of Growth 2008 Environment technical report presented a comprehensive overview of aviation's environmental challenges and the main issues have not changed significantly since its publication (Ref. 19).

Aviation industry stakeholders have long been working to reduce these environmental impacts, with notable results. Current average aircraft noise levels are around 20dB lower than 40 years ago and within Europe average emissions of the greenhouse gas carbon dioxide (CO_2) per passenger kilometre (pkm) have fallen from over 160g CO_2/pkm in 1995 to under 120g CO_2/pkm in 2010, although such improvements have been largely offset by traffic growth (see Ref. 20, 21).

Meanwhile, locally, there is a danger that technological improvements that reduce noise or improve local air quality will be offset by a trend towards increased public resistance. Moreover, new or more stringent measures aimed at abating noise or improving local air quality may impose an environmental limit to capacity. Together these will be a growing constraint to airport expansion.

Operational and technological improvements, and challenging political targets, will undoubtedly continue

to reduce the relative environmental impact of aviation. However, even at the modest levels of growth forecast in scenario *C* (most-likely), without an unforeseen step change, improvements in aircraft technology are unlikely to outstrip growth in the medium-term. Consequently, the overall environmental impact of aviation is likely to continue to increase, even if considerably mitigated.

Challenge:
Achieving sustainable growth.

External shocks: Aviation has shown time and again that it is sensitive to external shocks, which can push demand up or down, for a brief period or for the long term. Some of these are already captured in the four forecast scenarios, such as accession of new states to the EU or a continuing increase in the oil price.

Amongst those that go beyond the scenarios and have a particularly long-term potential are:

- **Regulation:** Over the past 20 years, deregulation has been a strong force for growth of aviation in Europe; for example, the three packages of EU market deregulation 1988-1993, the deregulation linked to the accession of 10 new member states in 2004, or a number of cases of reductions in visa restrictions. Beyond the scenario storylines, we could envisage further deregulation, although in the current climate a resurgence of regulation might seem more likely. This could affect traffic in either direction but on balance, this seems predominantly a downside risk, ie. threatening a reduction in traffic.
- **Taxation:** Sitting neatly between "regulation" and "fuel price" is the question of taxation. In recent years, European governments have been quick to add taxes to aviation, and in some cases to remove them again. Constrained budgets or "environmental concerns" (particularly if there is no deal on emissions trading) could both act as triggers for taxation which simply ends up increasing the price of travel. This is a downside risk.
- **Fuel price:** All four forecast scenarios include the assumption that fuel prices will continue to rise. Beyond the scenarios, we can imagine two different fuel price shocks: a "peak oil" situation which sees a sharp and sudden rise in fuel costs, coupled with an economic downturn (the 20 year forecast published in 2010 looked at this case, ref. 22); or a downturn in costs if supplies from non-traditional sources increase substantially, or if there is agreement to limit total CO_2 emissions by not recovering all of the oil that is available. With fuel currently at around 35% of airline operating costs, either of these shocks has the capacity to strongly affect the price of aviation (although they would be linked to economic changes which would also influence demand). The scenarios capture most of the upside risk here so, perhaps surprisingly, this could be considered as a downside risk.
- **Tourism Trends:** Each forecast scenario assumes some change in the pattern of tourism demand, following the scenario storyline. But more significant changes would also be possible. For example, as Figure 8 illustrates, climate change could lead to significant changes in tourism demand even within Europe, linked to reductions in winter snow, or to increasing summer temperatures in the main tourist resorts of the Mediterranean. This is a downside risk for some regions of Europe, and an upside risk to others.

3. MEASURING AND MITIGATING THE CHALLENGES

3.1 The airport capacity challenge is as strong as ever

The current, extended traffic downturn and weaker growth in the future should have given a 7 to 8 year head start on meeting the airport capacity challenge highlighted in 2008. At the 2030 milestone, now five years closer, it is true that there is less unaccommodated demand. But looking out by the same interval, 22 years, we find the same level of unaccommodated demand; half of the head start has been lost. In the most-likely scenario C, 1.9 million flights cannot be accommodated (12% of total demand) by 2035 within the plans that airports have reported; that is an estimated 120 million passengers unable to make their there-and-back trip. Turkey and the UK have the most unaccommodated demand.

This study is based on plans reported by airports for capacity growth. Section 2.3 described how these plans have been scaled back as traffic declined and finance became more difficult to obtain. Overall airports report 17% growth, or about 0.8% per year. As we approach the 2035 horizon, information on airport plans becomes scarce. For the 2050 forecast, therefore, the best we could do was to extrapolate that rate of growth, 0.8%/year, region-wide.

The estimated impact of capacity limits on the total number of flights on the network are shown in Figure 9. More detail is provided in the 2035 and 2050 forecast reports (Ref. 7 and 8).

- In the fastest growing scenario *A: Global Growth*, around 4.4 million flights will be lost due to airport capacity shortfall in 2035, corresponding to 20% of the unconstrained demand. The corresponding congestion levels are also delayed compared to CG08, but as then, once the limits are reached, the congestion spreads and the number of unaccommodated flights grow quickly almost doubling between 2030 and 2035, and doubling again to 2050.
- In the most-likely scenario *C: Regulated Growth*, around 1.9 million flights will be lost, approximately 12% of demand in 2035. We estimate this is around 120 million passengers unable to make their there-and-back trip[5]. This is less than in CG08 in terms of flights, but more in percentage terms, mainly because of overall lower forecast traffic now. The unaccommodated demand of 2.3 million flights previously expected to be lost in 2030 in CG08 will now happen five years later. By 2050, unaccommodated demand reaches 19%.
- Scenario *D* and *C'*, as a result of slower traffic growth rates, have lower demand at airports compared to the other scenarios, and rates of unaccommodated demand are consequently smaller. Nevertheless, we see a doubling between 2035 and 2050, as for scenario *A*.

In 2008, we wrote that "the economic turbulence of 2008 and the difficulties of operating in 2009 might buy a few years extra to respond" (Ref. 3, p28). In fact, the extent of the crisis surpassed the expectations of most. The recent drop in traffic has given not just 'a few', but around eight extra years to react, and weaker economic growth in future means that forecast traffic growth is also weaker, in theory reducing the scale of the capacity challenge.

Appendix *B* provides a like-for-like comparison with previous *Challenges* studies, showing the level of unaccommodated demand reducing at 2025 and 2030 milestones. That is to be expected, as those milestones get closer; and it represents perhaps a 4-year advance compared to the 2008 situation (scenario *C*). However, the rest of the potential head start from the downturn and slower growth has been lost, and we see the same level of unaccommodated demand (12%) 22 years from now, as we saw in 2008 at the same interval.

	Unaccommodated IFR Flights (million)	Unaccommodated demand (%)	
	2035	2035	2050
A: Global Growth	4.4	20%	36%
C: Regulated Growth	1.9	12%	19%
C': Happy Localism	1.0	7%	15%
D: Fragmenting World	0.2	2%	5%

Figure 9. In the most-likely scenario, almost 2 million flights will be lost to airport capacity constraints by 2035. The rate of unaccommodated demand then approximately doubles to 2050.
Unit: reduction in IFR Departures when airport constraints are taken into account

[5] For these high-level results, we convert flights into passengers using a forecast of approximately 125 passengers/flight in 2035, up from around 100 in 2012.

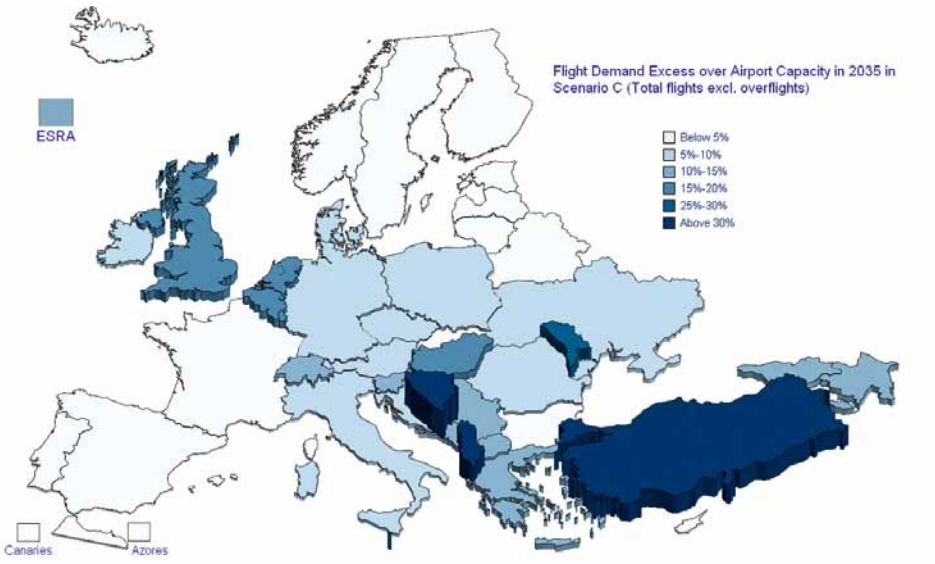

Figure 10: Unaccommodated demand by local airports

The mismatch between capacity and demand is not the same across Europe. There are 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. 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 the scenario *C* (Figure 10). In terms of flights, rather than percentages, it is Turkey and the UK that are most affected.

3.2 Airport congestion will bring delays to the network

For Challenges of Growth 2013, we have made the first estimates of the delay impact of airport congestion on future network performance, by simulating two busy Summer months. In scenario C, by 2035 more than 20 airports are operating at 80% or more of capacity for 6 or more hours per day, compared to 3 airports in 2012. This drives ATFCM airport delay up from around 1 minute/flight in 2012 to 5-6 minutes in 2035, taking it from a minor or intermittent to a permanent, major contributor of delay.

So far, we have discussed the lack of airport capacity as causing unaccommodated demand, but even after this unaccommodated demand is removed, there is a second important effect of operating near capacity: delay. The relationship between capacity, delay and the number of flights involves two trade-offs:

- **Strategic:** In theory, an airport can to some extent trade off unaccommodated demand against delay at a strategic level (eg for a whole schedule season). It reduces delays by keeping free some slots out of its maximum capacity to act as contingency, but this increases unaccommodated demand. In practice, commercial pressures will push the number of contingency slots to near zero.
- **Tactical:** On the day of operations, airlines will respond to delays by making some cancellations. Their policy may even vary during the day, eg favouring on-time performance early on, then switching to connectivity later (to get passengers to their destinations, even if delayed).

In CG08, we were able to quantify the number of airports that would be congested, and deduce that this would cause difficulties in the form of delay, but we were not in a position to quantify the delay. For *Challenges of Growth* 2013, we have been able to make the first steps towards quantifying the impact of airport congestion on network performance in terms of delay. This work is reported in detail in Ref. 9.

When we analysed August and September 2012, there were just 6 airports that were "congested" in the sense of operating at 80% or more of their capacity for more than 3 hours per day. In scenario *C*, this climbed to more than 30 airports in 2035. Even for the stricter condition of operating at 80% or more of capacity for 6 hours/day, there were more than 20 airports congested in 2035. Normally, a small hiccough (late bags, missing passenger etc) might cause departure delay that is caught-up en route. With this future level of congestion, it becomes difficult to accommodate

minor deviations from plan, and delays begin to accumulate rapidly.

Delays are classified as primary (delays to this flight) and reactionary (knock-on delays incurred by this aircraft on previous flights). It is through reactionary delay that problems at one airport propagate through the network. In 2012, airport-related primary delays were only 0.9 minutes out of an average of 5.7 minutes of primary delay per flight and of 10 minutes/flight total including reactionary (Ref. 23). Airport-related delay is made up of air traffic flow and capacity management (ATFCM) regulations at airports responding to capacity shortfalls, and of other airport causes (ramp congestion, runway closures etc). So on average airports are a relatively minor cause of delay, and on only a few days in the year are a more major cause. It is airline-related causes that remain the biggest proportion of primary delays overall (typically 50%).

For this study we have adapted our tools, originally focused on ATFCM delays and nearer-term capacity planning, and which simulate the algorithm used by the Network Manager to respond to constraints. The key changes were to model how reactionary delays propagate from flight to flight during the day; and to calibrate the model using data on delays from all causes, provided by airlines to EUROCONTROL/CODA (Ref. 23). The analysis is based on modelling and comparing two Summer months in the 2012 baseline year, and in 2035. For 2035, traffic was grown using scenario *C* (most-likely) in this study.

Congestion in the network affects day-to-day delays, but it also influences our ability to respond to an unusual event. So, in addition to these busy months in 2035, we also modelled the effects of two 'disturbances': a 'security' scenario in which on this day Heathrow capacity falls to zero for two hours due to a security issue, recovering back to full capacity by hour 4; we also modelled a 'weather' disturbance that is more geographically widespread (Ref. 9).

The new modelling is focused on ATFCM (airport) delay, and reactionary delay. At a highly-congested airport, running near its capacity limit, it might be expected that other classes of delay would be liable to increase, such as airline or government (security, immigration). These have not been modelled for this study. Secondly, we assume that delays in en route airspace do not increase. This is consistent with the assumption of each Challenges study that en route is not the constraint – it may be challenging to deliver the capacity there, but not insuperably so. Consequently, the results here are likely to be a low estimate, and for this reason we do not report on the share of airport delay in the face of the network congestion of 2035.

Figure 11 shows the growing delay challenge at airports, for these Summer months. Figure 12 compares current-day and future delay profiles for ATFCM (airport) and reactionary delay. The delay per flight is 1.12/mins in the simulation of August and September 2012 (lower line), slightly higher than the whole year 0.9 mentioned earlier. This jumps to 5.6 minutes/flight in the 2035 case, with delays mounting very quickly once the first rotation starts, around 0600 UTC. In the scenario with a security problem, average delays jump to 9.1 minutes/flight, propagating rapidly from one airport with temporary difficulties to produce widespread delays across the network. In terms of average delay per delayed flight, the multiplication of delay is not quite as high, but still significant. The effect is diluted because such a high proportion of flights are delayed. In practice, we would expect cancellations to have the effect of limiting reactionary delays, although they were not explicitly modelled for this study.

In current-day operations it is very rare to see days with 5 minutes/flight across the network of airport delay. When it does occur, it is for widespread weather problems: low-visibility procedures in Winter, thunderstorms in Summer. A number of future improvements to concepts and technology aim to improve network performance by improving predictability of flights. A high level of airport delay could threaten such improvements in predictability.

The 50% increase in traffic (scenario *C*, see Figure 5) is partly responsible for ATFCM delay minutes at airports increasing by a factor of 5 or 6. But the critical factor is the number of airports operating near capacity.

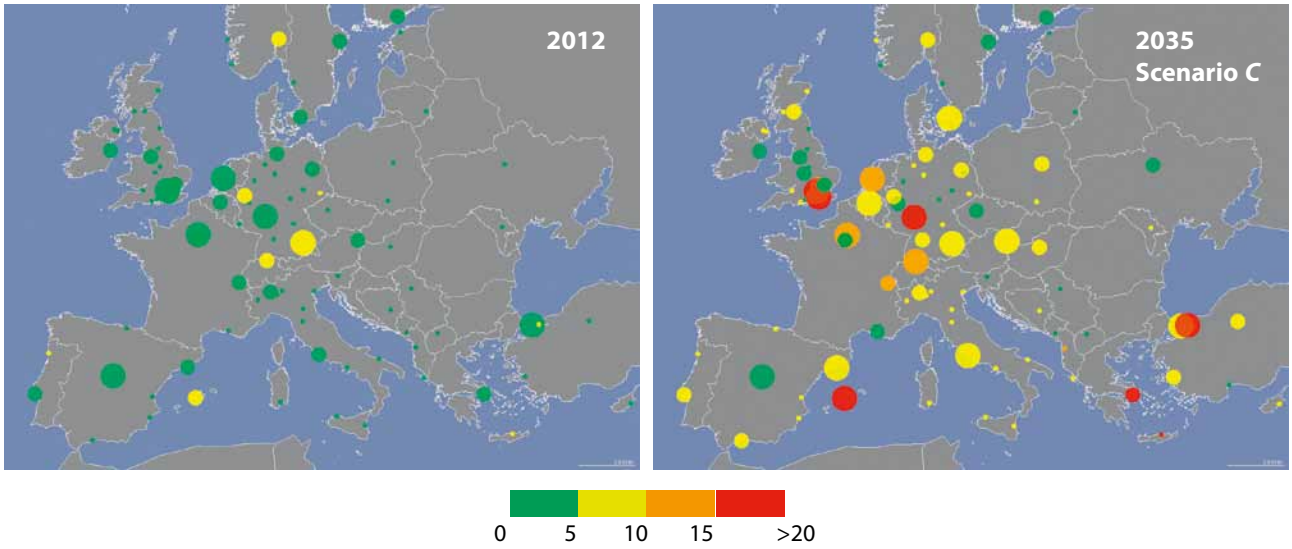

Figure 11. Increasing number of airports with Summer delay (in minutes/flight).

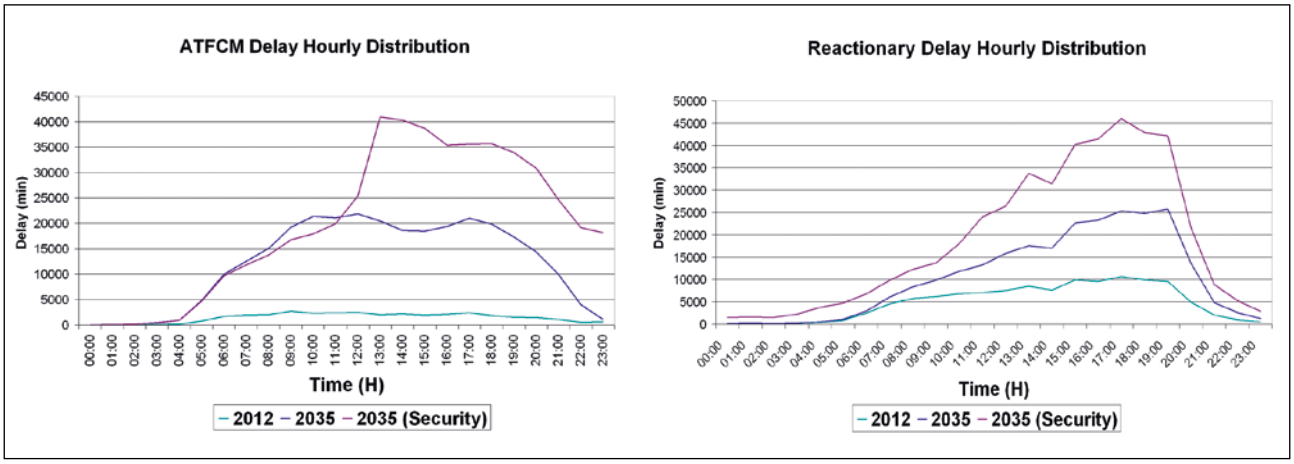

Figure 12. Growing reactionary and ATFCM (Airport) delay.

3.3 Some of the challenges can be mitigated, at a price

Drawing on evidence for how industry already responds to lack of airport capacity, we modelled seven ways to mitigate the challenges. A combination of them reduces unaccommodated demand by 42% in 2035. That would enable up to 800,000 flights that otherwise would not be able to operate; perhaps 50 million passengers able to make their journey. These mitigation methods do not fully capture the political, financial, environmental and other implementation difficulties. Even with this built-in optimism, none of them meets half of the unaccommodated demand. So, new infrastructure will inevitably need to be part of the bridge over the capacity gap. In reality, we would expect the industry to use each of the seven methods, and resort to building new runways, just as it has in the past. All of these have costs as well as benefits.

Lack of airport capacity is not a new phenomenon. This means that there is plenty of evidence for how the air transport industry responds to lack of capacity. Some of those responses are already built into the forecasting model, but there are limits to what can be included in just four forecast scenarios.

It is the role of the mitigation task (Ref. 10) to look beyond the confines of the forecast scenarios, and consider how the industry might mitigate the capacity challenges, learning from the views of the industry in the process.

In the 2008 mitigation study, there was a robust consultation with stakeholders. We continue to draw lessons from that consultation, since the comments still appear to us to be valid and relevant. In a nutshell, the main area of debate comes down to a question of who, when an airport is congested, decides how to respond: airline, airport or regulator?

For *Challenges of Growth* 2013, we analysed seven different ways to mitigate the effects of airport constraints and two combinations of these individual methods. We assessed their effectiveness in terms of the percentage reduction in unaccommodated demand, which in the most-likely scenario reaches 1.9 million flights in 2035 (see section 3.1). Six mitigations are reported here. A seventh, based on clustering the airports of a city, was more theoretical in nature. It is described in the mitigation report (Ref. 10).

- **Larger Aircraft:** Aircraft operators are limited in the short-and medium-term by their fleet decisions as to the size of aircraft they can use. Nevertheless the average size of aircraft has been increasing. We explore the effects of accelerating this increase on congested airport pairs, taking the size of aircraft operated by other airlines as a benchmark. The potential gain is a 15% reduction in unaccommodated demand in total, with less improvement in the Mediterranean region than in the rest of Europe (See Figure 14. Figure 18 in the glossary shows the regions), implying that aircraft are not so much smaller than the benchmark in the Mediterranean.
- **Additional High-Speed Train (HST):** We hypothesise a what-if? HST network almost twice as large as the one that is actually planned for 2035. This would be challenging to finance, but would reduce unaccommodated demand by 11%. The effect is evenly spread across Europe.
- **Local Alternatives:** Particularly in North-West Europe there is no shortage of runways around major cities. They are not necessarily the right runways in the right place at the right price; hub operators in particular need to bring flights together, usually needing capacity to operate waves of arrivals and departures and to mix feeder flights with long-haul. Nevertheless, faced with capacity constraints aircraft operators tend to grow their business where capacity is available. In this mitigation we have modelled this tendency. The result is a 21% reduction in unaccommodated demand, in the most-likely scenario.
- **Consensus benchmark capacity for smaller airports:** Half of single-runway airports reported future capacities under 150,000 movements per year. These low values seem to be driven more by current traffic than by fundamental limits to capacity. As a mitigation what-if, we set the capacity of single-runway airports to a minimum of 200,000 (taking the upper quartile reported by airports as a benchmark), and similarly 330,000 for two-runway airports. However, the challenge of airport capacity is mostly not at these smaller airports, so the effect of this mitigation is to reduce unaccommodated demand only by 10%.
- **SESAR:** Airport and TMA capacity improvements identified by SESAR would increase total capacity of the 108 reporting airports by 11%, over and above what airports themselves reported to *Challenges of Growth*. In the most-likely scenario *C*, the effect of this additional capacity is to reduce unaccommodated demand by 19%. There are significant gains in the North-West region, slightly less in the East and little effect in the Mediterranean.

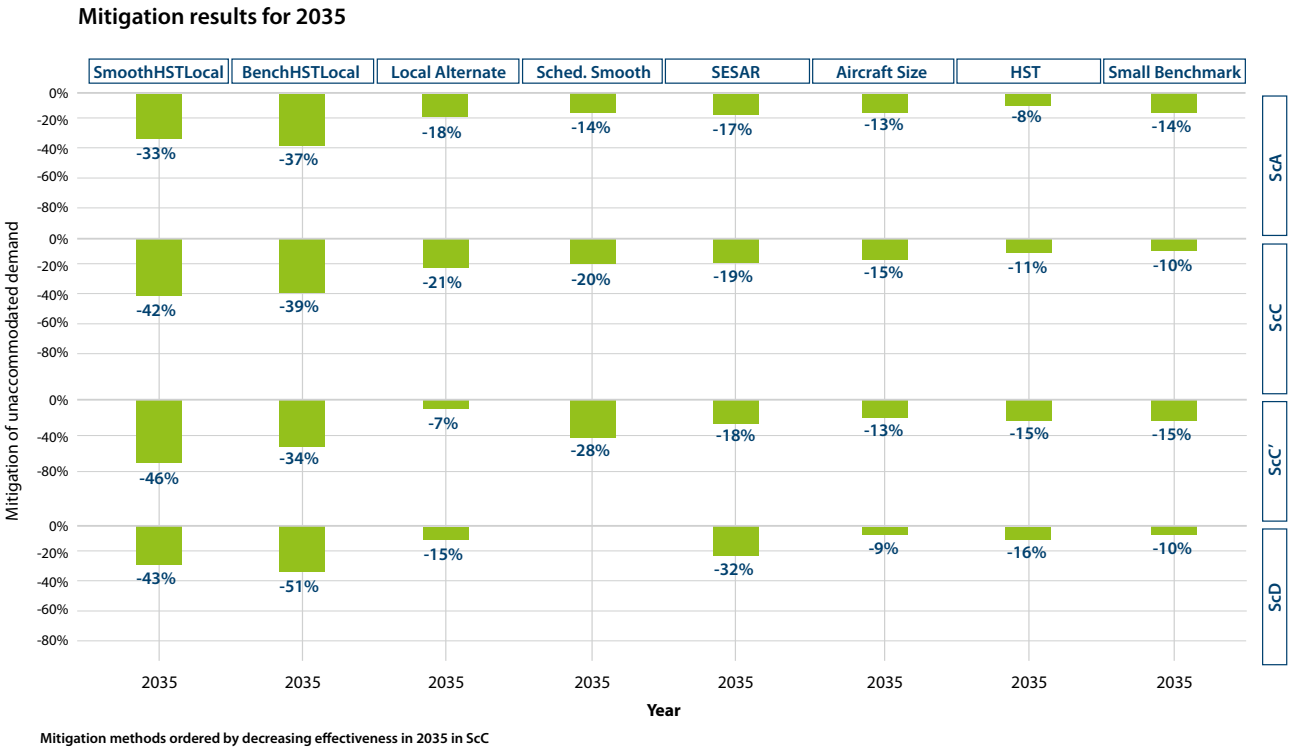

Figure 13. Summary of mitigation benefits. (ordered left-to-right)

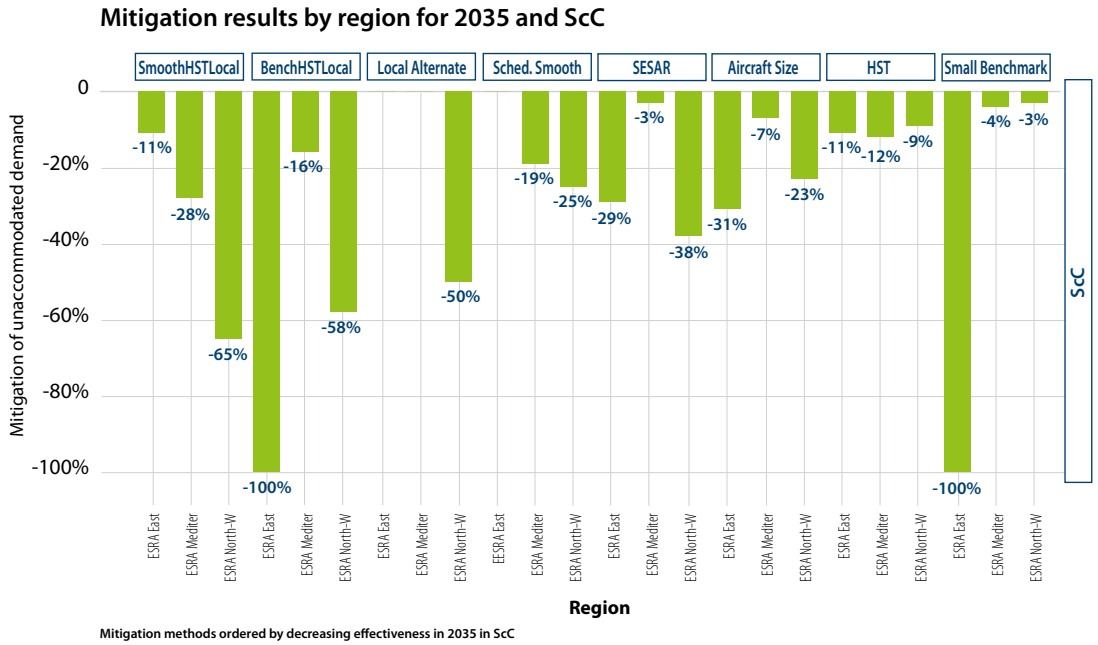

Figure 14. Summary of mitigation benefits. (ordered left-to-right)

- **Schedule smoothing:** At congested airports the quieter hours gradually fill up, even if airlines find that yields are worse for off-peak hours (off-peak in the day, week or year). At a busy airport, traffic demand thus gradually tends towards using as much of each hour's available capacity during the year as Heathrow or Frankfurt use of their own respective capacities. We estimate the additional capacity that this brings and use this to model 'schedule smoothing' as a mitigation. Although this is applicable only to a very limited set of airports, the effect is to reduce unaccommodated demand by 20% in the most-likely scenario *C*.

The mitigation options are complementary in that they represent opportunities for different stakeholders to invest to reduce unaccommodated demand. We have explored that complementarity by analyzing two combinations: HST and local alternatives together with each of smaller airport benchmark and schedule smoothing. Gains from different types of mitigation can not simply be added up into combinations: for the HST, local alternative and schedule smoothing mitigations, their joint effect was a 42% reduction in unaccommodated demand, 10 percentage points lower than the sum of their individual effects.

So, the best solution analysed here, a combination of mitigations, reduces unaccommodated demand by 42% in 2035. That enables up to 800,000 flights that otherwise would not be able to operate; that is perhaps 50 million passengers able to make their there-and-back journey.

Mitigation allows us to look beyond the constraints of the four forecasting scenarios to what could be done to address the capacity gap at airports. Each of the mitigations explored is based on what the industry has already done when capacity is short. While passengers and shippers will gain from additional connectivity, there are also costs that mean none of the mitigations is likely to be achieved in full.

The mitigation methods do not fully model the implementation difficulties, which include political, financial and environmental obstacles. In this sense, they are optimistic, but even with this built-in optimism, none of them meets even half of the unaccommodated demand. So, new infrastructure including new runways will inevitably need to be part of the bridge over the capacity gap. Numerically, airport plans are at least nine runways short, but there is a lack of capacity in Scenario *C* at 24 airports around 21 cities, so those nine runways would need to be impossibly spread. There are evident difficulties in achieving infrastructure growth in Europe, at the locations where the capacity is needed. Even in regions where expansion is currently possible, the difficulty will increase as the population grows and becomes more prosperous.

Mitigation asks: if we cannot build new infrastructure, what can we do to squeeze more out of what already exists? The methods here are somewhat idealised to allow analysis that is data-driven, airport-specific and yet has a Europe-wide scope. A more detailed answer would have been possible, but that apparent precision would add little certainty. Uncertainty is inescapable in a 2035 forecast. Section 2.7 discusses some of the risks hiding in that uncertainty and Ref. 7 has more.

In reality we would expect the industry to use each of the seven methods, and also resort to building new runways and other infrastructure, just as it has in the past. So the 'best' combination of three is not a proposal of a best option that should be implemented, but instead an indication of the scale to which unaccommodated demand might be reduced and how.

4. FIVE CHALLENGES

We have identified five principal challenges for European aviation in 2035 and beyond: providing airport capacity, network congestion, adapting to slower growth, resilience to climate change and sustainability. The financial crisis has put the financial challenge of adapting to slower growth into sharper focus, compared to the 2008 study.

In *Challenges of Growth* 2008, we identified five main challenges: airport capacity, sustainability, network congestion, fully exploiting SESAR and responding to climate change (Ref. 3). Five years on, very similar themes have emerged, but the financial crisis has thrown the spotlight onto the difficulty of financing changes to infrastructure and technology which will improve capacity. For that reason, this time we merge the challenge of delivering airport capacity plans with that of delivering the gains from SESAR; from an airport-capacity perspective the latter is just one facet of the former.

Probably the two most striking quantitative results from the 2013 study are:

- a reduction in airports' plans to expand, though the reasons for this are quite understandable (section 2.3);
- the reduction in the future traffic forecast, driven by lower economic growth forecasts, and limited airport capacity (section 2.4).

Lower future growth will present a new challenge. Aviation has shown time and again that it excels in delivering connectivity and mobility, and it can do this with a flexibility that ground transportation finds difficult to match. With time, ground-based modes of transport catch up and can substitute for short-haul trips (section 2.1), nevertheless aviation will still be needed in the future, especially for the medium- and long-haul or to respond to relatively urgent needs (such as connecting the new member states of the EU to the existing members in 2004). But the value-chain in air transport is unbalanced, with some groups of stakeholders routinely making little return on their investment, while others remain consistently profitable. Traffic growth is part of the proposed solution to this imbalance; with cost per flight planned to decrease by holding costs relatively fixed as the number of flights increases. Slow growth now and into the future will increase the need for stakeholders to find more radical ways to adapt their business models. «More of the same» will not be an adequate solution, and a permanent imbalance is not sustainable. So slow growth is a threat to aviation's long-term ability to provide mobility.

In summary, then, the challenges are:

- **Airport Capacity:** As we have seen in the mitigation discussion, this is not so much an issue of lack of capacity overall, rather a lack of capacity where, when and at the price that is needed. In the most-likely scenario *C*, 1.9 million flights (12% of total demand) cannot be accommodated (section 3.1) according to the plans that airports have reported. In the most-likely scenario, the capacity gap is equivalent to 9 fully used runways, but impossibly spread around the 21 cities that lack airport capacity. This lack of capacity will create a challenge in some cases of remaining relevant to the needs of passengers and shippers by reconsidering plans, but the first challenge will be to finance and deliver the airport capacity that is already planned.
- **Network congestion:** It will be a challenge to operate a highly-congested network safely, cost effectively, efficiently and while respecting the environment when airport delay increases on an average busy day by a factor of 5 or 6 (section 3.2) due to lack of scope for responding to everyday operational issues. This would make airport delay a daily, major issue rather than a minor (or intermittent major) cause of delay.
- **Adapt to slower growth:** Continuing to improve cost efficiency will be difficult in a market with slower rates of growth, but without «rebalancing the value chain» ensuring that all stakeholders achieve a reasonable rate of return on their investment, the long-term future of that investment is clearly at risk. Moreover, demand growth and, in the longer term, technology gains will increasingly be outside Europe, so the benefits that Europe derives from being at the forefront of aviation could diminish. There is an increasing potential for investor fatigue at the lack of return on investment in some portions of the industry, and there will be more interesting investment opportunities away from Europe, where aviation will be growing more quickly.
- **Sustainability:** Aviation continues to improve its environmental performance, but the targets that it has set itself are ambitious. Although we are now looking at slower growth than previously forecast, this could still outstrip fuel and operational

efficiency gains. This would leave the industry reliant on offsetting and alternative fuels to meet CO_2 targets; more needs to be done, for example to develop competitively-priced low-carbon fuels. More locally, there is a danger that technological improvements that reduce noise or improve local air quality (LAQ) will be offset by a trend towards increased public resistance; moreover, new or more stringent noise and LAQ measures may impose an environmental limit to capacity. This will be a growing constraint to airport expansion.

- **Climate Resilience:** Climate change is going to happen, and it will threaten infrastructure, impact day-to-day operations and change patterns of demand. We now see a growing number of organisations in European air transport making resilience to climate change a routine part of their business or operational planning. However, more needs to be done to build local and network climate resilience. Some of the solutions are relatively low-cost (training and procedures), or happy side-effects of other investment. An early start should save money in the long run.

5. ACKNOWLEDGEMENTS

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The project was a collaboration between a number of groups in EUROCONTROL: within Directorate of Network Management, the Airport unit provided the airport expertise and led the data collection, STATFOR led the forecasting and mitigation work and PRISME-GIS provided the cartography; in Directorate Single Sky, the Environment unit led the work on climate resilience and contributed the discussion of emissions for the forecasts; in Directorate SESAR and Research, the Network unit developed and ran the methods to evaluate the impact delays on the network, while the Master Plan unit helped with the SESAR benefits; the ATM Policy Bureau participated in the steering and review team; and the Communications unit helped with publication and presentation. Helios and SAMI Consulting developed the 2050 forecast.

ANNEX A SUMMARY OF THE SCENARIOS

Figure 15 summarises the different characteristics of the four scenarios used in both the 2035 and 2050 forecasts. Beyond 2035 there are some additional changes. For these see Ref. 8.

	A: Global Growth	*C: Regulated Growth*	*D: Fragmenting World*	*C': Happy Localism*
2019 traffic growth	High ↗	Base →	Low ↘	Base →
Passenger				
Demographics (Population)	Aging UN Medium-fertility variant	Aging UN Medium-fertility variant	Aging UN Zero-migration variant	Aging UN Medium-fertility variant
Routes and Destinations	Long-haul ↗	No Change →	Long-haul ↘	Long-haul ↘
Open Skies	EU enlargement later +Far & Middle-East	EU enlargement earliest	EU enlargement latest	EU enlargement earliest
High-speed rail (new & improved connections)	54 city-pairs faster implementation	54 city-pairs	42 city-pairs later implementation	54 city-pairs faster implementation
Economic conditions				
GDP growth	Stronger ↗	Moderate →	Weaker ↘↘	Weaker ↘
EU Enlargement	Later	Earliest	Latest	Earliest
Free Trade	Global, faster	Limited, later	None	More limited, even later
Price of travel				
Operating cost	Decreasing ↘↘	Decreasing ↘	No change →	Decreasing ↘
Cost of CO_2	Lowest	Lower	Highest	Lower
Price of oil	Lower	Low	High	High
Other charges	Noise: ↗ Security: ↘	Noise: ↗ Security: →	Noise: → Security: ↗	Noise: ↗ Security: →
Structure				
Network	Middle-East hubs ↗↗ Europe ↘ Turkey ↗	Middle-East hubs ↗↗ Europe and Turkey ↗	No change →	Middle-East hubs ↗↗ Europe and Turkey ↘
Market Structure	Medium ↗↗ Large - Very Large ↗	Medium to Very Large ↗	Large ↗ Very Large ↗	Large ↗ Very Large ↗

Figure 15. Summary characteristics of the scenarios to 2035.

ANNEX B COMPARISON WITH PREVIOUS CHALLENGES STUDIES

To achieve a like-for-like comparison with previous *Challenges* studies, we use the ESRA02 region (Figure 16), since the ESRA08 (shown in Figure 6) was not defined at the time of the previous studies. We are also limited because the 2004 study only reached to 2025, and the 2008 study to 2030. The comparison for the most-likely scenario, and the most challenging scenario is shown in Figure 17.

In terms of demand and accommodated flights, we see clearly the effects of:

- The economic downturn, which has led to around an eight-year delay in traffic growth, meaning that the 2008 peak will not be passed again before 2016. That is the equivalent of 3.5 to 4.5 million flights.
- An economic forecast for future years which is some 0.5 percentage points below the previous values, leading to increasing divergence of the current flight forecast from previous forecasts.

In the most likely scenario *C*, the percentage of unaccommodated demand is little changed in 2025, and lower in 2030. Since we are now five years closer to 2030, such an improvement would be hoped for; for one thing it suggests that the message of *Challenges of Growth* 2008 has been heard. As discussed in the main text, at the 22-year horizon the level of unaccommodated demand has got slightly worse, but at least at a fixed year, the trend in unaccommodated demand is in the right direction, downwards.

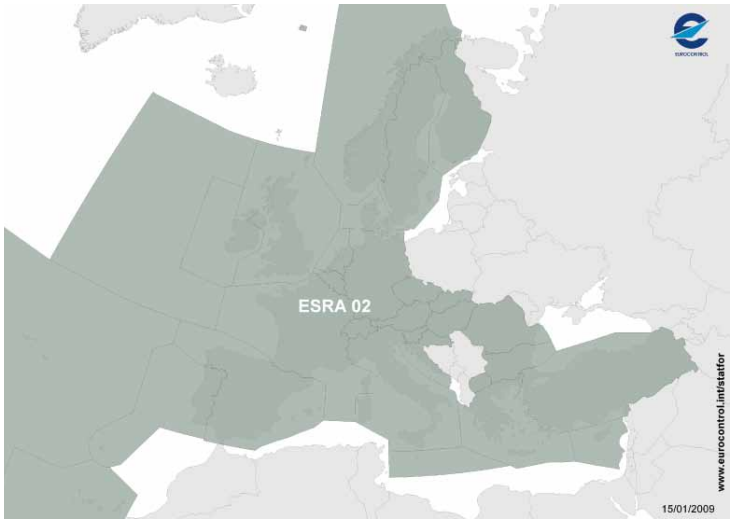

Figure 16. ESRA02 region.

	Sc A: Global Growth			Sc C: Regulated Growth		
	Demand (million)	**Flights (million)**	**Unaccom-modated**	**Demand (million)**	**Flights (million)**	**Unaccom-modated**
2025						
Challenges to Growth 2004	20.9	17.2	18%	16.7	15.1	10%
***Challenges of Growth* 2008**	23.6	19.9	16%	17.6	16.7	5%
***Challenges of Growth* 2013**	15.1	13.9	8%	12.8	12.3	4%
2030						
***Challenges of Growth* 2008**	29.1	22.1	24%	20.4	18.2	11%
***Challenges of Growth* 2013**	17.7	15.4	13%	14.4	13.2	8%

Figure 17. Comparison with previous studies, for the ESRA02 region (Results are different in this annex to the main text, since the region is different.)

ANNEX C GLOSSARY

4D trajectory	Sequence of positions, attitudes and times
AAGR	Académie de l'Air et de l'Espace
ATFCM	air traffic flow and capacity management
ATM	air traffic management
CG08, CG13	*Challenges of Growth* 2008, 2013
CODA	EUROCONTROL Central Office for Delay Analysis
ESRA02	EUROCONTROL Statistical Reference Area (2002)
ESRA, ESRA08	EUROCONTROL Statistical Reference Area (2008)
ESRA NW	ESRA North-West (see Figure 18)
ETS	emission trading scheme
EU	European Union
FIR	flight information region
GDP	gross domestic product
HST	high-speed train
ICAO	International Civil Aviation Organisation
LAQ	local air quality
LTF	long-term forecast (20 years)
pkm	passenger km
ScA	scenario *A* (similarly *C*, *D*, *C'*)
SESAR	Single European Sky ATM Research
STATFOR	Statistics and Forecast Service of EUROCONTROL
SUG	STATFOR User Group
TMA	terminal manoeuvring area or terminal control area
TZ	traffic zone (most often a State)
Unaccommodated demand	the forecast flights that exceed an airport's reported capacity.
UTC	universal time coordinated
WG	Working Group
WPC	SESAR work package C

For 4-letter airport codes, see ICAO Doc 7910.

Figure 18. The ESRA08 region has three sub-regions: North-West, East and Mediterranean.

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