Challenges of Growth 2008

Summary Report

EUROCONTROL

Executive Summary

Challenges of Growth 2008 is the third in a series of studies (published in 2001, 2004 and now 2008) that aim to provide decision-makers with up-to-date assessments of the challenges presented by the increasing demand for air transport.

This year has seen an upheaval in air transport and in the economy more widely. 2009 also shows every sign of being a difficult year. However, this is no time to lose sight of the long-term challenges and goals, because the challenges ahead continue to require decisions and actions today.

Good decisions require good data. To provide that data, Challenges of Growth 2008 considers three modes of growth: growing economies, growing demand for transport, and growing numbers of flights. These three modes are likely to remain linked for the foreseeable future presenting long-term challenges relating to growth which need long-term solutions.

Four scenarios are used to describe possible levels of future demand in a new, long-term forecast of European air traffic:

- *Global Growth* has a strong economic growth scenario in which use of technology partially mitigates environmental challenges. Strong growth makes this the **most-challenging** scenario.
- *Business as Usual* is a moderate growth scenario with little change from current trends.
- *Regulation & Growth* also exhibits moderate growth, but includes growing environmental challenges that bring accelerated responses by Industry and regulators. This is seen as the **most-likely** scenario of the four.
- *Fragmenting World* features increasing tensions between regions, with consequent reductions in long-haul trade and travel.

This report focuses on the most-likely scenario: *Regulation & Growth*.

In *Challenges of Growth 2008* airport 'capacity' is assessed using the results of a new study that surveyed the current plans of 138 European airports. This survey shows a **planned 41% increase in airport capacity** between 2007 and 2030, including new airports, 29 new runways and new air- and ground-side infrastructures.

As in earlier studies, *en route* air traffic capacity does not constrain growth in this forecast, although in some cases the 'airport' constraint is really in the airspace immediately above the airport and is included. Instead the results of the forecast can be taken as indicating the capacity gain that the Single European Sky and SESAR (its research programme for a future integrated European air traffic management system) will need to deliver *en route*. The separate benefits of SESAR at airports are considered as a mitigation action (for example see section 3.2).

Within the available capacity, the forecast is that **by 2030 there will be between 1.7 and 2.2 times the number of flights in Europe seen in 2007**, with 1.8 the most-likely forecast[1]. This growth includes significant variations, for example: strong growth in Eastern Europe in percentage terms and limited growth in domestic traffic for many of the currently busier Member States.

[1] Forecasts are given for the ESRA region, see Annex C for definition, and for IFR (Instrument Flight Rules) Flights.

Executive Summary

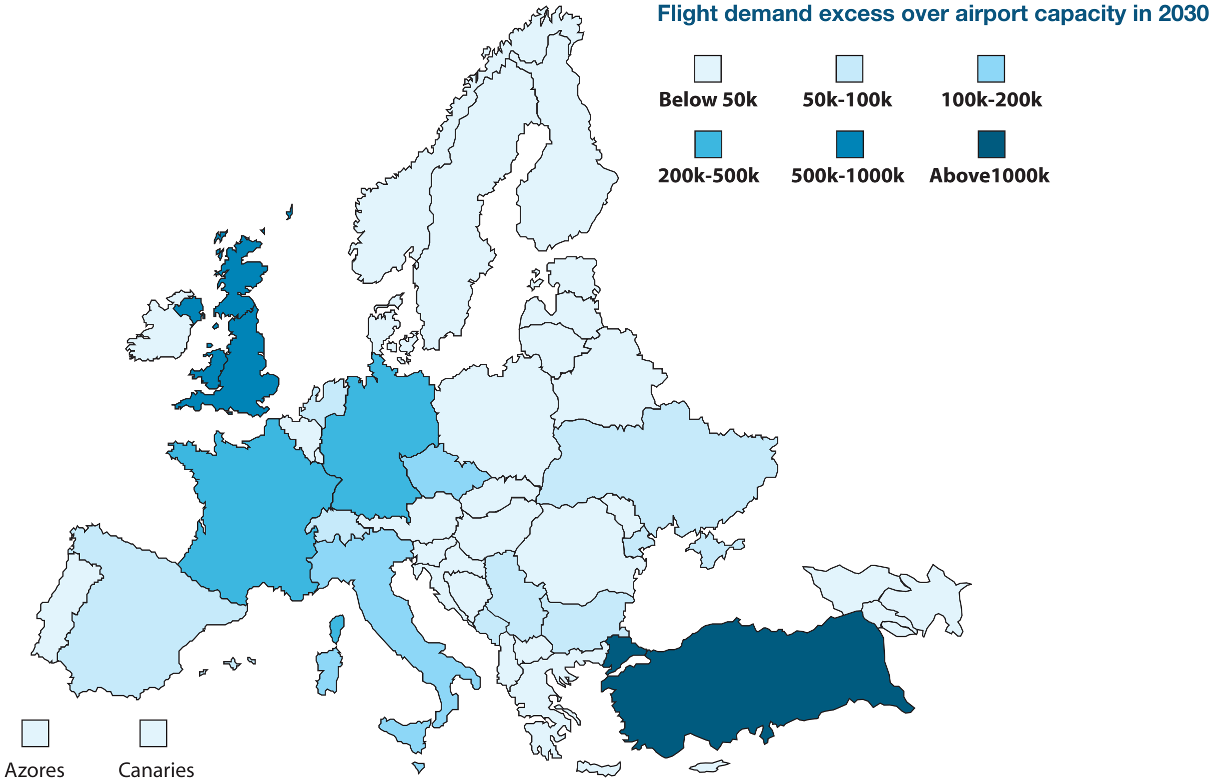

Figure 1. Summary of the excess of demand over airport capacity in the most-likely, Regulation & Growth scenario

There are five main challenges which result from this growth:

- **Airport capacity**, which in 2030 in the most-likely forecast scenario will lag demand by some 2.3 million IFR flights (or 11%), even if all the current plans can be delivered.
- **Environmental impact**, including difficult trade-offs not just between growth and environmental impact, but between carbon dioxide (CO_2) emissions, noise and local air quality.
- Operating a **congested air traffic network** which, as more parts of it operate at near to capacity, will be very vulnerable to perturbation (e.g. bad weather, delays etc.) and will be less able to recover from these effects.
- Achieving **institutional and social change** so that SESAR can deliver the required air traffic capacity on time.
- The impact of **climate change** that will affect demand for travel, threaten parts of the infrastructure and make operations more difficult.

Particular features of these five challenges include:

- Underlying demand in 2030 is forecast to be between 1.7 and 2.9 times the 2007 traffic level depending on the scenario. In the most-likely scenario, 2030 traffic is 1.8 times greater, but demand is 2.3 million flights higher than that, so **11% of actual demand will not be accommodated** (see Figure 1).
- Although the focus in this summary report is on the most-likely, Regulation & Growth scenario, for planning purposes any risk assessment should also pay attention to the most-challenging scenario in which, for example, 25% of demand would not be accommodated.
- From 2025 to 2030 unaccommodated demand almost doubles, so congestion will accelerate rapidly in this period.
- However, the expected situation has **improved significantly since the 2004 study**: the network in 2025 is now forecasted to be able to accommodate 1.7 million more flights and at a lower level of congestion than forecast four years ago. This improvement derives from both better information about plans, and from the way that airports have responded in recent years to the known challenges by producing plans which are better matched to the expected demand.

- The effects of aviation on the global environment are increasingly in the spotlight. Legislative attention is on CO_2 emissions, but there are increasingly well-understood non-CO_2 effects that contribute to climate change. These include NOx emissions and contrail formation. An **emissions trading scheme is expected to reduce demand by around 1 million departures in 2030**, equivalent to around 5%.
- Locally, environment impacts are also significant, not least due to noise and local air quality issues.
- Air traffic management (ATM) has a limited ability to directly reduce the CO_2 emissions of aviation (10% per flight is seen as an appropriate target by SESAR), but it has a role to play in trade-offs between environmental challenges.
- Rising sea levels, rising temperatures, declining water resources and increasingly frequent extreme weather events could directly affect demand for air transport, and at the same time may **impair the air traffic network infrastructure** (a significant number of airports around Europe are located on coastlines or river floodplains within the tidal limit). This will make air traffic management (ATM) more difficult.
- Action is under way to reduce fragmentation of air traffic management, to enable better response to these challenges. But the institutional and social complexity of the task presents significant risks, particularly in terms of timescale.
- In the most-likely scenario in 2030, **19 airports will be operating at full capacity** eight hours a day, every day of the year, and involving 50% of all flights each day. In the most-challenging scenario, 39 airports would be at full capacity, involving 70% of flights on departure or arrival or both.

The highly-challenged air traffic network does not simply reject unaccommodated demand and continue to operate as efficiently as today. The network is challenged both because more and more segments of the network reach their capacity and because delay-causing events become more likely. As a result, the network will be vulnerable to regular delay and flight cancellations on an unprecedented scale unless there is strong action to manage it.

Methods for mitigating these challenges have also been analysed. Three methods were found to have limited benefits as mitigation actions for the network as a whole: schedule smoothing; accelerated investment in high-speed train infrastructure; and accelerated shift to large aircraft to reduce frequencies.

Two other methods were found to be more effective: use of alternative airports can reduce unaccommodated demand by 25-40% (but this effect is limited due to capacity constraints elsewhere and in the end to the willingness of passengers and shippers to relocate their demand); and investment to bring all airports to the capacity of the best in their class, together with SESAR improvements, could bring gains of 40%. The largest reductions in unaccommodated demand would come from a mix of these methods.

In summary, the link between economic growth and growth in transport demand may weaken, but will remain to some extent. Therefore growth of air transport demand will continue to be a feature of the years to 2030. The slowing of demand growth during the turbulence of 2008 and the likely economic and business difficulties of 2009 may buy a few extra years to respond, but this will not allow the air transport industry to escape the five main challenges in the longer term.

The conclusions of *Challenges of Growth 2008* are:

- Airport plans are now better adapted to demand than they were four years ago.
- There remains a significant airport capacity challenge, not least in *delivering* the plans already reported by airports.
- Air traffic management needs to be ready to manage a highly-congested air traffic network.
- High-speed train networks are of narrow applicability in reducing congestion; other mitigation actions appear more effective in this respect.
- In addition to greenhouse gas emissions, local air quality and noise will remain significant challenges and will be compounded by the requirement to reduce emissions.
- Climate change can change demand, and will also affect infrastructure and operations as the weather changes.

All in all, the European air transport system will have to become more *agile* to respond to the challenges of growth.

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1. Introduction

1.1 Updating the Challenge Assessments

This is the third in a series of studies (previously published in 2001, 2004 and now 2008) aiming to provide decision-makers with more refined and up-to-date assessments of the challenges presented by the increasing demand for air transport.

At their 6th meeting ("MATSE/6") in January 2000 the European Ministers of Transport discussed the challenges presented by the growth of air transport demand and delays. In particular, they voiced concerns about safety, shortage of air traffic controllers, growing congestion at airports, the environment and sustainable development. Ministers decided that further work was required and asked the ECAC Directors General and EUROCONTROL to study these issues in co-operation with stakeholders.

The first result of this task was a study called Constraints to Growth, which reported in 2001 (Ref. 1). The study forecast a "growing mismatch between supply and demand", with some 15% of demand "unaccommodated" by 2010, meaning that 15% of flights for which there would be demand would not happen due to lack of capacity. The report highlighted the inter-dependencies between constraints within the air traffic network, and hence the need for a strategy that addressed the network as a whole.

The second study was launched in 2003 to update the initial results in the light of changes to air traffic in Europe, such as the growth of low-cost carriers and the downturn in traffic linked to the events of 11th of September 2001. Challenges to Growth 2004 (CG04) identified that, even if many airports could be brought to best-in-class performance by 2025, 18% of demand could not be accommodated then and that the top 20 airports would be saturated at least 8-10 hours per day (Ref. 2).

This second study has provided a shared reference point for much of the discussion in Europe on airport constraints in the last four years: its results are widely quoted in evidence in SESAR reports and in communications from European Institutions and stakeholder associations.

There are three main reasons for updating CG04 in 2008:

- The **environmental challenges** of growth are much better understood now compared to 2004, and their increasing acceptance is shown by a range of recent legislative and industry actions (see sections 2.4 and 2.5). Therefore the assessment of environmental challenges needed updating.
- The opportunity arose to compile a much **improved database of airport capacity** plans, with the support of the Airports Council International – Europe (ACI-Europe). Section 2.2 discusses the benefits of this approach compared to the previous study.
- The **SESAR Master Plan** has brought a better understanding of the challenges for air traffic management, and a coordinated plan for improvement (see section 2.2).

This new study is called 'Challenges of Growth'. The change of name indicates the increasing recognition that air traffic growth is not an aim in its own right and that, depending on the criteria, it can be a benefit or a threat. Instead, it is seen as an intermediate enabler of larger benefits such as increased prosperity, sustainable economic growth, social cohesion, corporate profitability and job security while carrying with it threats such as increased environment impact. Therefore growth in demand is not only welcomed for its benefits, it is the cause of significant challenges for the air transport industry and more widely for Society.

1.2 Aim of this Study

The challenges ahead need decisions and actions taken now. To ensure these decisions are the best requires good data.

Challenges of Growth 2008 aims to provide decision-makers with accurate estimates of the future demand for air transport in Europe, and of the economic, infrastructure and environmental challenges associated with responding to that demand.

1.3 No time like the present

While 2008 has been a year of upheaval in air traffic, it is important not to lose sight of the long-term challenges and goals, or to decrease the momentum towards those goals achieved in the last four years.

It might seem odd to look 20 years ahead in 2008, when each week seems to bring new economic surprises and upheaval including:

- The Euro area economy has stopped growing.
- Fuel prices have recently doubled before dropping by a third.
- Business aviation and especially low-cost carriers have for years been the driving force for traffic growth in Europe, but that growth has now halved (for low-cost carriers) or stopped (for business aviation).
- A number of long-haul, low-cost operators (including 'low-cost' business) have stopped flying.
- Several major flag carriers are being sold or heavily restructured.
- The banking system is in crisis, so liquidity has dried up, adding to cash-flow difficulties and re-financing challenges in the Industry.
- Passenger numbers, cargo volumes and load factors are falling.
- There are major international discussions about environmental legislation.

The conclusion is clear: 2009 will be enough of a challenge without worrying about 2030.

Such a view would be complacent. This is exactly the right time to forecast and analyse the results. A forecast is after all about **giving structure to uncertainty**. The growth of aviation has hit periods of turbulence and crisis in the past (for example: 1974 oil, 1981 oil, 1991 Iraq, and 2001 terror) and will do so again in the future. This forecast allows a course to be refined and held through turbulent times. Steering through 2009 will certainly be a severe challenge, but the air traffic industry needs to emerge from the storm heading in the right direction (Section 2.7 discusses some of the risks beyond the scope of the forecast).

1.4 Three linked growth modes

Challenges of Growth 2008 starts with three modes of growth: growing economies, growing demand for transport, and growing numbers of flights. The three modes are likely to remain linked for the foreseeable future.

The economy and demand for air transport of goods and people grow together. In some of the more mature markets of Western Europe, there is some evidence that the relationship is weakening, but they are not as the economists says "decoupled". Indeed, many of the air transport markets of Eastern Europe are growing rapidly and have a long way to grow before maturity. Figure 2 shows the relationship between gross domestic product (GDP) and flight departures[2]. There is a clear trend line[3].

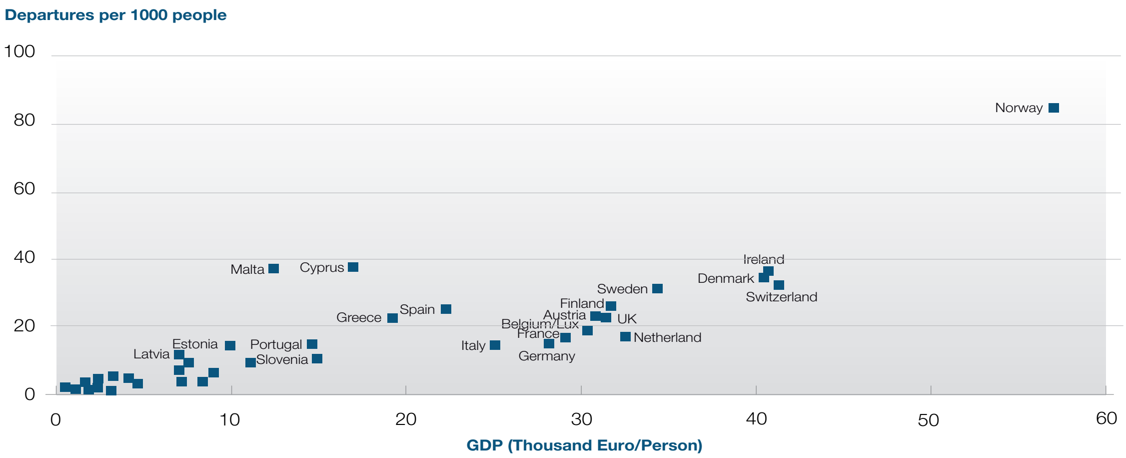

Figure 2. Per Capita Flight Departures v Per Capita GDP (2007 traffic, 2006 GDP)

[2] All the data in this report refer to IFR (Instrument Flight Rules) flights; this therefore includes most commercial air transport, but excludes much of general aviation (such as light-aircraft flying by amateurs and training flights) for which comprehensive data are not available.

[3] Malta & Cyprus are off the trend because they are island nations. Norway is off the trend due to its dispersed population and oil wealth.

1. Introduction

As a result, the outlook is for further growth in demand for air traffic. Growth in demand means growth in traffic, but there are a number of challenges on the way that mean that actual flights will lag behind demand (like the train with elastic connections illustrated in Figure 3).

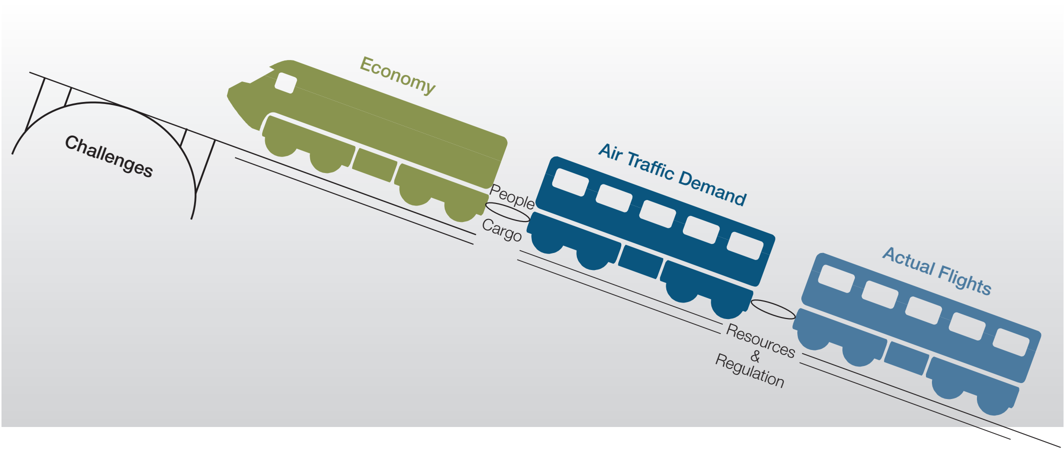

Figure 3. A system with lags and challenges

Locally, on specific routes in the short-term, actual flights can exceed demand, but in the long-term the number of actual flights is lower than demand, so there is always some level of unaccommodated demand. The main reasons are summarised as 'resources and regulation' and can be grouped under four headings:

- **Airlines** have limited human and financial resources and limited information, so typically their networks expand organically and lag behind the real demand growth. If, as is often argued, low-cost carriers do stimulate demand by means of new connections and by price, even then actual flights anticipate demand only in the short-term.
- The **aircraft** types that an airline has in its fleet, or has the resources to obtain, will limit the services the airline can provide and the price they are offered at. For commercial reasons the airline must maximise the use of the fleet that it has. Moreover, an aircraft's lifetime is typically 30 years, and the International Civil Aviation Organisation (ICAO) requires seven years notice for changing on-board requirements, which introduces a significant lag in the aircraft side.
- Airlines can only operate where there is **network capacity**. Section 2.2 discusses the future of system capacity in respect of both airport and air traffic management.
- **Regulation and legislation** restrict, for example, what services can be provided (e.g. through international air services agreements) or when airports are open, or determine what subsidies (for public service obligation (PSO) routes) are available.

Some factors are, however, increasing the responsiveness of air transport to changes in demand. Due to increasing fuel prices, recourse to aircraft leasing, outsourcing etc., the variable part of airlines' costs now typically exceeds 50%. This gives airlines a greater ability to respond to changes in traffic and introduces a higher volatility in traffic demand (higher peaks and troughs, changes in traffic patterns).

This report discusses in more detail the relationship between demand and flights, and the challenges that arise from the long-term growth.

1.5 The Approach

This report brings together the results from five strands of work which together comprise Challenges of Growth 2008

- A survey of **airport capacity** that obtained plans for 2030 from 138 European airports. (See section 2.2).

  CG08 focuses on what level of capacity airports are planning to have rather than what the airports might be able to deliver if they, for example, were able to match some theoretical best-in-class performance. This means that the results directly describe what needs to be done, not just by airports, but also by users of airports, by air traffic managers, by governments and others, to achieve a better match between demand and capacity.

- A review both of the **environmental challenges** of responding to demand, and of the direct impact of climate change on demand for air travel (in particular see sections 2.4 and 2.5).

  This brings the analysis up-to-date with the many scientific and policy changes of the last four years: not least the legislation in Europe on the emission trading scheme for aviation and evidence for the impact of climate change from the Intergovernmental Panel on Climate Change (IPCC) impact reports and elsewhere.

- A survey of leading experts' visions of the **future of European air traffic** and its challenges (in particular see section 2.7).

  A long-term study such as this one aims to help planners understand and manage the risks. Therefore 41 leading experts from air transport sector stakeholder organisations representing airlines, airports, manufacturing industry, air navigation service providers, the European Commission and EUROCONTROL have been interviewed to discover their visions of the future to help reduce the chance that any hidden risks are missed in our analysis.

- An updated **long-term forecast** that quantifies the demand and challenges out to 2030 (in particular see sections 2.1, 2.3 and 3.1).

  As in the previous study, this uses EUROCONTROL's STATFOR forecasting methodology in four possible future scenarios to quantify the likely number of flights through controlled airspace in 2030.

- An assessment of options for **mitigating the effects** of the main challenges (see section 3.2).

  This assessment of mitigation options takes into account discussions with a number of airlines and airports. It was clear that some 'mitigation' actions are just the natural response of aircraft operators and other stakeholders to demand and capacity challenges. Other actions might require a mix of economic incentives and legislative encouragement.

A detailed technical report will be published separately in the coming months for each of the last four of these strands. But the headline results are already available and are reported and discussed here.

2. Future Context

2.1 Future Demand

Four scenarios are used to describe possible levels of future demand. This report focuses on two of them: Global Growth - the most-challenging scenario - has relatively strong economic growth and uses technology partially to mitigate environmental challenges; Regulation & Growth - the most-likely scenario - has more moderate growth and demand is more affected by responses to a range of environmental challenges.

When thinking about 2030, our aim is not to choose a single forecast of traffic for planning purposes. Given the wide range of possible futures over the next 20 years, both within and outside the narrow field of aviation, this would be an extremely risky strategy. Instead a new long-term forecast has been prepared (Ref. 4) that uses four scenarios to span a range of possible futures for European aviation and the economic and political context in which it will operate. As in CG04, the four scenarios draw on the work of the CONSAVE (Ref. 4) project and the IPCC (Ref. 5) amongst others. The scenarios are listed in Figure 4 and are discussed in more detail in Annex A.

	Scenario	Brief Storyline
A	**Global Growth** (Most Challenging)	Strong economic growth in an increasingly globalised economy with technology used to successfully mitigate the effects of challenges such as the environment and security.
B	**Business as usual**	Moderate economic growth and little change from the status quo, that is, trends continue as currently observed.
C	**Regulation & Growth** (Most Likely)	Moderate economic growth, but with stronger regulation to address growing environmental challenges for aviation and for Europe more generally.
D	**Fragmenting World**	A World with increasing tensions between regions, with knock-on effects of weaker economies, reduced trade and less long-haul travel.

Figure 4. Summary of scenarios

Regulation & Growth is increasingly seen as the ‘most likely’ of the four scenarios, even though for planning future capacity and to minimise the risk of delays unexpectedly getting out of hand, it also makes sense to pay close attention to the ‘most challenging’ scenario, which is Global Growth. All four scenarios are described in the long-term forecast report (Ref. 3), but this summary report will focus on the most-likely scenario.

After discussions with a panel of stakeholders, the main refinements to the scenarios compared to CG04 were to the Regulation & Growth scenario, which now includes lower growth that is more consistent with the environmental challenges of that scenario. The input data for all scenarios was also updated, for example to include the latest economic growth forecasts. The forecast model uses some two dozen types of input data of which the more important drivers of growth are:

- **Economic growth** averages some 2.2%/year to 2030 in the current 27 EU Member States.
- The **oil price** is between $90 and $180 per barrel in 2030 (in 2008 US$); partly as a result, the long-term trend that ticket prices get cheaper on a year by year begins to stall.
- The **emissions trading** scheme that will cover all traffic in the EU area from 2012 involves costs of €25-€90/tonne for permits (2012 contracts are currently around €28/tonne); auctioning of permits covers 100% of aviation's emissions by 2030[4]. This would be expected to trigger some fleet renewal, increasing fuel efficiency and hence decreasing emissions per km. This effect is not explicitly modelled, but is included as part of the continuing process by which airlines improve their efficiency.

  As an intermediate result, emissions trading increases average ticket prices by around 0.5%/year (more on long-haul and less on short-haul) and thus reduces demand in 2030 by some 0.9-1.3 million departures (1.3 million in the most-likely scenario).
- Airports manage to expand their capacity according to current plans (more in section 2.2).
- The expansion of the European Union has proven to be a significant source of growth in the past, because joining the EU brings not just an open aviation market, but free trade and free movement of workers and businesses. The EU is assumed to reach 34 members by 2030. If further political union proves elusive, but some degree of open aviation, free trade and free movement are still achieved, then the forecast effects on traffic will still be valid.
- Picking up on a long-term European trend towards larger aircraft, the average aircraft size (excluding business aircraft with <20 seats) increases from 137 seats now to between 161 and 171 in 2030.
- The high-speed train network continues to expand in line with current project plans.

  As an intermediate result, this reduces demand in the forecast by 0.3-0.5 million flights in 2030.
- Business aviation continues to grow, although the rapid growth of 2005-2007 is not maintained at a sustained rate over the next 20 years. This growth includes the continued arrival of very-light jets (VLJs) in particular to serve a growing air-taxi market.
- The number of unmanned air systems (UAS) is also set to increase significantly. Their integration into the airspace is under active discussion at EUROCONTROL and elsewhere. Current expectations are that, while there are likely to be many low-altitude UASs, the number of larger UASs allowed into controlled airspace is likely to be in the hundreds during the forecast timeframe. In terms of IFR flights per day, therefore, they remain a relatively small part of the overall traffic flow.

Putting these factors together gives growth as illustrated in Figure 5. Annex A gives details for the four scenarios. Section 2.3 summarises what these factors imply for future traffic volumes, and section 3.1 translates this into challenges.

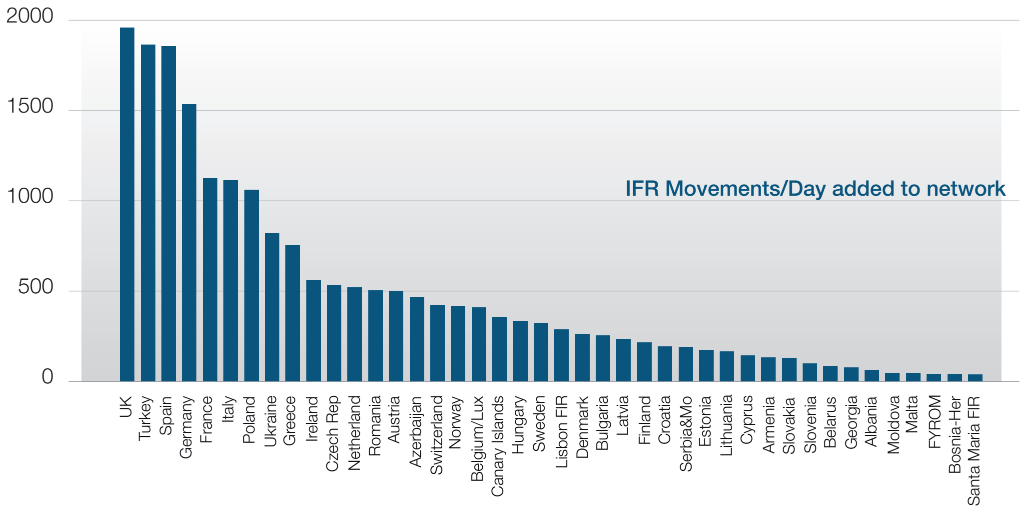

Figure 5. UK, Turkey and Spain add most new departures to the air traffic network. (2007 vs. 2030 in the Regulation & Growth scenario. These numbers exclude overflights. See Figure 7 for total flights through the airspace)

[4] In the legislation, this date has changed to 2020 since the forecast was calculated.

2.2 Future Capacity

In Challenges of Growth 2008 'capacity' is based on a new survey that accessed the current plans of 138 European airports. This survey shows a planned 41% increase in capacity between 2007 and 2030, and is considered to be the best source to highlight the scale of the task facing the air traffic system in responding to future demand.

There is more than one answer to the question of the future capacity of the air traffic network. The Challenges of Growth 2008 study focuses on current airport plans. This section discusses the alternatives and the implications of that choice, in particular in comparison to the method used in CG04[5].

SESAR – Capacity for ATM

The Single European Sky ATM Research (SESAR) programme was launched with objectives which include:

- To enable a three-fold increase in ATM capacity.
- To reduce the environmental impact of each flight by 10%.
- To cut costs by 50% per flight.
- To reduce delays.

These objectives were refined into more precise performance objectives during preparation of the SESAR Master Plan (Ref. 6). In particular, the three-fold increase in ATM capacity was used as a capability objective in that the ATM system should be capable of being scaled up to this extent as and when the demand justified it. More immediately, a requirement was identified to accommodate a 73% increase in flights between 2005 and 2020, which was derived from the most-challenging scenario in the Long-Term Forecast 2004 (Ref. 7).

As in earlier studies, *en route* air traffic capacity does not constrain growth in the new long-term forecast. Instead the results of the forecast can be taken as indicating the capacity gain that the Single European Sky and SESAR will need to deliver *en route*. The separate benefits of SESAR at airports are considered as a mitigation action (for example, see section 3.2).

Airport & TMA

The foundation of the Challenges of Growth 2008 (CG08) study was a survey of the plans of European airports. With the help of ACI-Europe, information was received on 240 airports, an increase from 67 four years ago for CG04; air navigation service providers also reported information on 14 Terminal Control Areas (TMAs). From this information, a picture was constructed of plans out to 2030 for 138 airports. These included the 50 locations that are forecast to be the busiest in 2030 and which already account for 70% of 2007 departures.

In capacity terms, the results of the survey show that European airports are planning significant investments. If these plans can be delivered, then 138 airports in total projected that their capacity would be 41% higher in 2030 than 2007, consisting of:

- An 18% increase from 27 airports with new runways, in addition to other infrastructure.
- A 17% increase from a further 79 airports which plan to improve the air-side (taxiways, aprons etc.) or ground-side (passenger terminals etc.) infrastructure.
- A 6% increase from five major new airports.
- Only 27 airports reported no current plans to expand capacity.

Planned rather than expected

Two previous studies were principally based on expected or 'best-in-class' airport capacities:

- CG04 (see section 1.1) used an initial set of 'best-in-class' capacities, depending on the number of runways and their configuration and then adjusted these capacities if information was available from the airport survey that was conducted.
- The second study, a sub-task of the SESAR definition phase, built on the CG04 work by adding the benefits from particular SESAR improvements which are expected to improve airport capacity (i.e. dynamic separations based on wake vortex detection, automated brake-to-vacate using datalink, and airborne separation assistance systems (ASAS) in the TMA in support of runway sequencing (Ref. 8)).

The value of such studies is that they show what can be achieved. Moreover, using a model-based estimate of future capacity means that capacity values are available for airports which have not been surveyed or are not in a position to respond. The downside is the risk that in communicating the results from these studies,

[4] In the legislation, this date has changed to 2020 since the forecast was calculated.

the future capacities become misinterpreted as not what 'can' but what 'will' be achieved: the substantial investment required for every airport to reach 'best-in-class' when needed is lost during communication; and individual airports do not plan to expand at the right time. For these reasons, CG08 starts from current airport plans (although a 'best-in-class' what-if case is also discussed in section 3.2).

In fact, it will become clear that those plans are already better matched to demand than the values used four years ago (section 3.1): some of this improvement is due to the feedback and response to the CG04 study; and some of the improvement will be because the present study is based on real, individual airport plans that reflect local or national demand forecasts.

Capacity beyond the airport

Like the previous study in 2004, CG08 has again focused on quantifying airport (and airport/TMA) capacity constraints. The possibility of constraints *en route* is definitely not ruled out, but is analysed qualitatively rather than being modelled numerically. Section 2.7 discusses some of the wider challenges. In terms of constraints on *en route* capacity there are potential challenges which include:

- Availability of frequency spectrum for communications.
- Further imposed limits on noise and gaseous emissions over and above the current noise, air quality and emissions trading regulations.
- A mix of operational trade-offs including those between fuel efficiency, delays incurred, gaseous emissions and local noise.
- Implementation timescales for, and ability to invest in, ground-based and on-board system and capacity enhancements (e.g. environmentally-driven, long lead times for new runways).
- Reducing fragmentation of air traffic management and its associated costs.
- Maintaining stable and efficient operations in an air traffic network where spare capacity is increasingly scarce.
- Improving safety rates according to the targets, in face of declining tolerance of risk and increasingly complex ATM and aviation systems.

It is important not to lose sight of these challenges. However, the results of CG08 will be used in support of planning the size of the future ATM system. Moreover, SESAR should deliver solutions that enable *en route* capacity requirements to be met on time. Therefore to include these particular challenges quantitatively would risk double-counting of effects.

[5] Which assumed that all airports could operate at best-in-class performance levels, unless there was information to the contrary.

2.3 Future Flights

The new forecast is that in 2030 there will be between 1.7 and 2.2 times the number of flights in Europe seen in 2007, with 1.8 the most-likely forecast. Within this growth there will be significant variations, for example: strong growth in Eastern Europe in percentage terms, and limited growth in domestic traffic for many of the currently busier States.

The outcome of this new long-term forecast is that between 16.5 and 22.1 million IFR flight movements will take place in Europe[6] in 2030. That is 50,000-61,000 flights per day, which is between 1.7 and 2.2 times the traffic level in 2007[7] (Ref. 3). This is an average growth of 2.2%-3.5% per year. The most-likely scenario (Regulation & Growth, see section 2.1) shows average growth of 2.7%, resulting in traffic levels in 2030 of 1.8 times that in 2007. This flight growth is significantly slower than the growth in demand. Figure 6 shows the underlying demand growing to between 1.7 and 2.9 times the 2007 level by 2030. Section 1.4 discussed the background to the difference between demand and traffic, and section 3.1 will compare the two numerically.

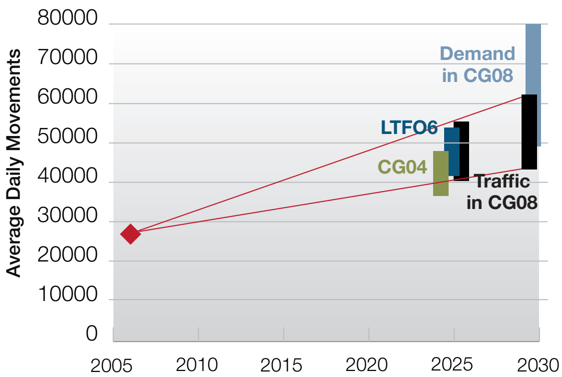

Figure 6. Forecast traffic growth

Figure 6 also shows this growth schematically, and for 2025 compares the results with those from the CG04 study (Ref. 2) and the long-term forecast that was published in 2006 (LTF06 - Ref. 9); all refer to the same geographical area. The forecast is similar to the forecast from two years ago, and is higher than that used in the CG04 study, mainly due to a higher starting point because of rapid growth following EU expansion in 2005, and due to more airport capacity to serve this growing traffic.

Within this overall level of growth, there are important variations. In particular, one third of European States in the dataset had fewer domestic flights in 2007 than ten years earlier. Picking up on this trend, in the forecast average domestic (i.e. intra-State) annual growth is just 1.4%-2.5% depending on the scenario and many larger States have domestic traffic growth less than 1%. Other, non-domestic but still intra-European traffic grows at 1.7-2.7%. Stronger growth is seen in traffic to and from Europe (3.8%-5.8%/year), with Russia, India and China contributing significantly to this. But the strongest growth is in the remaining flows, which are overflights; these are small, but growing at 5.0%-7.1%/year as connections are increasingly made between, for example, the Middle East and North America or Russia and Africa. Thus current trends for European airports to be by-passed by flights over-flying the region are assumed to continue.

6 "Europe" totals refer to the EUROCONTROL Statistical Reference Area (ESRA), which is defined in the glossary.

7 SESAR targeted a 73% increase in traffic by 2020 compared to 2005 (SESAR D2). In the most-challenging scenario that was used for D2, this figure has increased to 93%. In the most-likely scenario the expected growth over that period is now 65%.

Figure 7 shows in more detail where those 18,000 - 33,000 additional flights per day will be seen in the network, in terms of additional flights per day through the airspace of each State. It is natural that there are more flights in the larger airspaces than in the smaller, but it is noticeable that markets which have historically been smaller are beginning to catch up. For example, Turkey moves from 10th to 8th place in the list of busiest States, Poland climbs from 18th and, in most scenarios, joins the top 10.

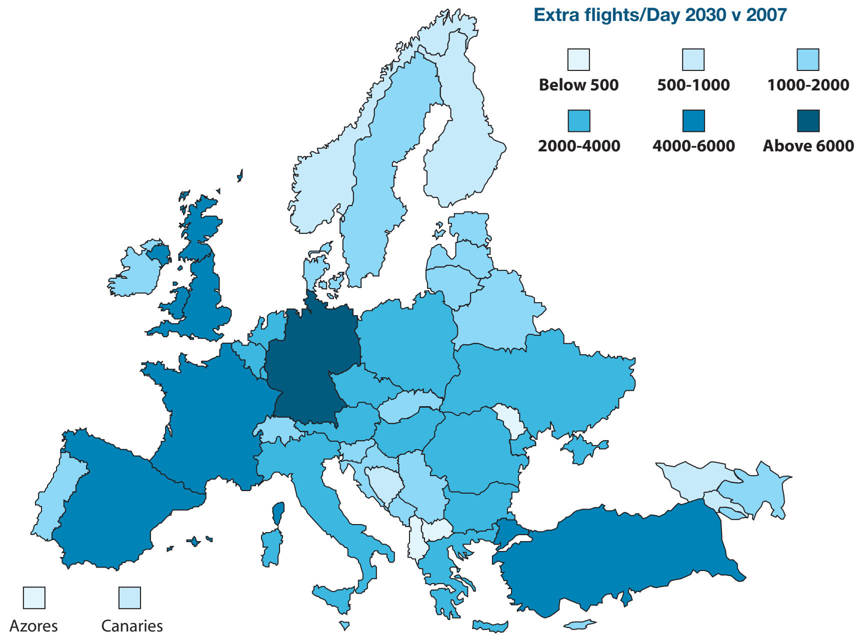

Figure 7. Extra flights through the airspace in 2030 compared to 2007 (Regulation & Growth scenario)

In terms of percentage growth, it is clear that the airspace of the States of Eastern Europe will be seeing the fastest growth in the coming years. This is illustrated in Figure 8.

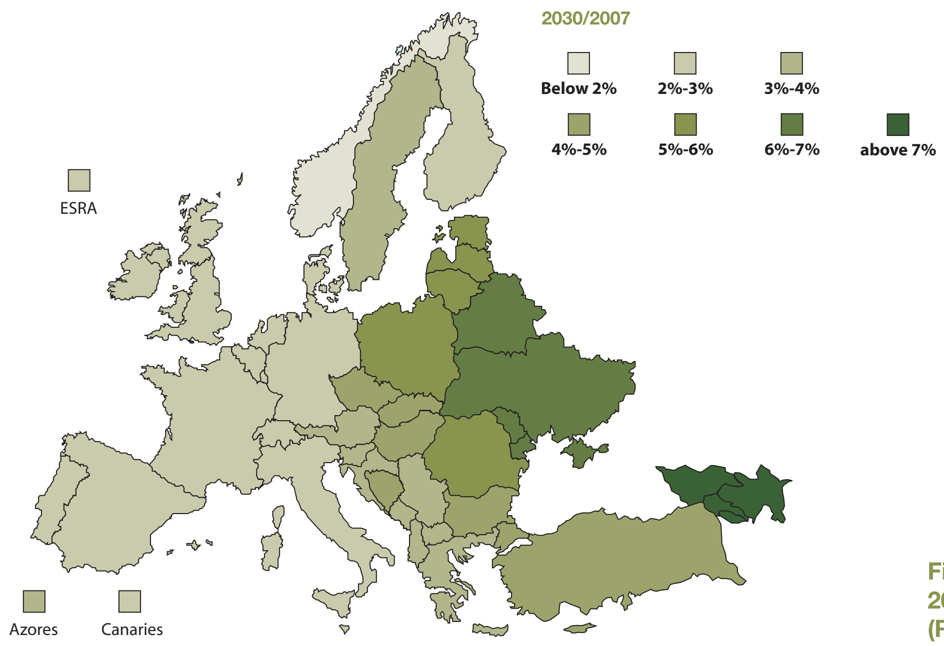

Figure 8. Average annual growth 2030 v 2007 (Regulation & Growth scenario)

2.4 Sustainability and the Global Environmental Challenge

Aviation is increasingly recognising and acting on its environmental impacts. However, Air Traffic Management is expected to provide, at best, a 10% reduction in aviation's CO_2 emissions per flight. Even with greater improvements from other sources such as cleaner aircraft technologies, aviation growth will continue to be a significant environmental challenge.

Environmental challenges for aviation are simultaneously global (e.g. CO_2 emissions) and local (e.g. local air quality and noise). This section focuses exclusively on the global issues. The following section addresses the possible trade-offs that ATMs face and that are more oriented to local issues. A more detailed discussion of the evidence is provided in the environmental technical report (Ref. 10).

Introduction – The Push for Sustainability

Air transport delivers substantial benefits to European economies and societies and makes an important contribution to sustainable development. However, aviation also has adverse environmental impacts that impose costs on society and the economy. In response to both the continued growth in demand for air transport (section 2.1), to increasing environmental concerns and greater scientific certainty on climate impacts, the aviation industry and its regulators are addressing environmental challenges through:

- Current and emerging sustainable development policies such as environmental legislation (e.g. Ref. 11, 12).
- Continuing technology improvements, e.g. following on from high bypass-ratio turbofan engines.
- Immediate air traffic procedural and flight-planning improvements, e.g. continuous descent approaches (Ref. 13).
- Medium and longer-term research such as SESAR or the "Clean Sky" initiative (Ref. 14).
- Industry bodies and associations initiating new actions and policies:

> For example, ICAO is raising the tempo of its activity in response to the environmental challenge and has established the Group on International Aviation and Climate Change (GIACC). The International Air Transport Association (IATA) has set out the objective to reach carbon-neutral growth by 2020 and a vision to become carbon free within 50 years. ACI Europe in 2008 adopted a policy on the need for airports to achieve carbon neutral status.

Environmental sustainability is now established as a key performance area (KPA) for ATM in Europe; it includes sub-areas related to climate change, noise, third party risk, land use, local air quality, water quality, airborne flight efficiency and fuel use (Ref. 6, 15). ATM can influence environmental performance in most of these sub-areas by imposing or relaxing constraints on the lateral routes, vertical profiles and cruise speeds of aircraft in flight, and on the operations of aircraft on the ground whilst under their own power.

ATM has limited, direct influence over constraints imposed by airport infrastructure. However, ATM is the means to deliver airside capacity from available infrastructure and can have a significant influence on the infrastructure that is provided (e.g. in respect of both airside and airspace design), and on some aircraft-related environmental mitigation (e.g. efficient flight profiles). Section 2.5 discusses this further.

Climate Change

It is estimated that globally a 50% reduction in CO_2 emissions over 1990 levels is required over the next 40-50 years to avoid dangerous climate change. Civil aviation contributes approximately 2% to global CO_2 emissions, as well as non-CO_2 effects that contribute to climate change[8]. Non-CO_2 effects include the influence of oxides of nitrogen (NOx) on tropospheric ozone (O_3) and methane (CH_4) emissions; aviation is also responsible for contrail formation and contributes to the formation of cirrus clouds, although considerable uncertainty is associated with these processes and their impact on climate (Ref. 16).

> To put aviation's 2% contribution to CO_2 emissions into context, that is similar to the emissions from all data centres worldwide (Ref. 17), which could itself increase fourfold between 2005 and 2020 (Ref. 18). Meanwhile the UN International Maritime Organisation is working on an emissions abatement scheme for global shipping after estimating that it was responsible for 3.5% of global CO_2 emissions in 2007 and this was likely to grow by a further 30% by 2020 (Ref. 19).

[8] Although there is widespread discussion of the magnitude of these effects at present, recent research suggests that aviation's contribution to climate change is approximately twice (1.9) that of its CO_2 emissions, although this estimate is subject to change.

In Europe, the EU Advisory Council for Aeronautics Research in Europe (ACARE) has set challenging targets of 50% reduction in CO_2 (per passenger km), 80% reduction in NOx emissions, and halving of perceived aircraft noise (Ref. 20).

To achieve these improvements three types of policy are being considered: carbon pricing; technology policy; and action to remove barriers to energy efficiency improvements and to secure the engagement of individuals. For aviation:

- Carbon pricing will increase the cost of air transport (see section 2.1 for modelling of this). Proposals to use aviation fuel taxation and emissions charges uniformly across Europe appear to be politically and logistically unrealistic, at least in the short term. The use of tradable permits is making more progress; in October 2008, legislation to include international aviation in the EU Emissions Trading Scheme by 2012 was approved.
- Technology policy means achieving step changes in airframe and engine design and alternative fuels, as well as ATM improvements. With respect to the ACARE 50% CO_2 target previously mentioned, SESAR analysis suggests that at most 10% might be obtainable from ATM, the rest coming from airframe and engine improvements. Yet even with the most optimistic forecasts for technological improvements, such efforts to mitigate the climate impacts of aviation will probably be insufficient given current growth.
- Action to remove barriers to energy efficiency and to secure the engagement of individuals could influence public attitudes to air transport. This could weaken further the relationship between growth in incomes and growth in demand for air transport (section 1.4). It could also increase the difficulty of achieving the current plans for the expansion of airports.

2.5 The challenge of environmental trade-offs

Air traffic growth presents not just one, but several simultaneous environmental challenges. These can conflict with each other, e.g. local noise mitigation versus fuel efficiency, and air traffic management has a role in the trade-offs that result.

ATM has an important role in resolving trade-offs and exploiting synergies between the different ICAO key environmental performance areas. This is examined, for example, in SESAR Deliverable 2 (Ref. 6). This section of the report focuses on two particular trade-offs, where the challenge is to get as close as possible to a "win-win" result:

- Environment versus capacity, where aviation growth and environmental goals cannot both be achieved in full.
- Environment versus environment, where different environmental objectives clash.

Environment and Capacity

Specifically at airports, the environmental impacts arising from aviation have the potential to constrain the operational capacity or potential for growth of airports when:

- Noise or emissions exceed regulatory limits, planning agreements or tolerance criteria within surrounding communities[9].
- Energy and water supplies are scarce[10].
- Infrastructure growth is constrained by sensitive habitats or existing buildings.
- Policy responses to, or the costs of, environmental mitigation increase operating costs.

These factors can constrain the current operation or future capacity of the European ATM system. Communities in the vicinity of airports have an increasing range of methods for challenging, constraining or delaying airport expansion and airspace changes. Current delays in expanding capacity at Prague, London/Heathrow and other major airports across Europe are linked to such environmental issues, and demonstrate the difficulty of balancing local sensitivities and wider national needs.

Just as at the global level (section 2.4), improvements in technology are unlikely to be a sufficient answer to these constraints at the local level. However, ATM improvements can still help to mitigate some of the local environmental constraints and hence release additional capacity, because ATM improvements have an effect on all aircraft within the system.

ATM's role in environmental trade-offs

There are trade-offs between conflicting environmental impacts. For example, a noise mitigation procedure may route aircraft away from noise-sensitive areas but require longer track length, hence greater fuel use and more greenhouse gas emissions. Decisions about the environmental benefits of ATM procedures involve balancing different environmental impacts that are unevenly distributed and that have consequences of varying severity according to their nature and location.

Research into the trade-offs between fuel efficiency and other climate-related factors (such as contrails and cirrus cloud formation) suggests that cruising levels and speeds could be altered for environmental reasons, with potential changes to the vertical and lateral distribution of flights. The impact of this on *en route* capacity has not been investigated in detail, though the effect is unlikely to be trivial. Moreover, the knock-on environmental impact could potentially outweigh the benefit. Another example is that the use of more fuel-efficient operational procedures (e.g. continuous descent approaches and continuous climb departures) may increase, as might pressures to minimise deviations from optimal trajectories (e.g. through level restrictions). These factors could have positive and negative implications for capacity both at airports and *en route*.

[9] One difficulty here is that local air quality around airports may be more strongly influenced by ground transport than by the aircraft themselves.
[10] Water availability was considered by the UK Department for Transport as a potential long term constraint for London/Heathrow.

2.6 Climate change will affect aviation

The climate is going to change. A different climate means different demand for air transport, threats to infrastructure and changes to air transport operations.

It is difficult to overstate the magnitude of the challenge, the speed and the extent to which life and the economy are likely to change over the coming half century due to climate change. The extent of change may be assessed by looking at four main effects:

- The **sea level rise** is projected to continue even if emissions are stabilised as the ocean possesses substantial thermal inertia. Predicted rises of 0.2m-0.6m from 1980 to 2090 do not include major uncertainties such as the melting of ice sheets in Greenland (another 0.2m) or the West Antarctic (up to 6m), or a potential reduction if the Arctic ice sheet absorbs more snow.

  Several major European airports are located on coastlines or tidal river floodplains. Some have runways constructed on reclaimed land stretching out into the sea. Smaller domestic airports situated in coastal and floodplain areas may also be at risk. Those on floodplains could be at risk in the future as rivers experience tide-locking (where high-fluvial flows and high tides coincide) higher up their course as a result of sea level rise. Predictions imply fewer but more extreme tidal surge events in the Baltic and southern North Sea with implications for low altitude airports.

- There is high confidence that mean **temperatures will increase**. Over northern and eastern Europe most of this warming will occur in the winter months, whereas over the Mediterranean and central and western Europe, the greatest temperature increases are projected for the Summer: the Iberian Peninsula and south-west France may see the greatest degree of warming over the 21st century, possibly greater than 6°C.

  Within 10-20 years parts of the Mediterranean are forecast to become so hot during mid summer that this could cause a decline in the tourism economy during July and August.

  More generally, demand for flights will change as holiday patterns change, and because GDP will be affected by the agricultural productivity of areas of Europe both as a result of temperature change and precipitation changes.

  Spring is likely to arrive earlier and winter start later, creating a longer holiday season.

  Milder winters will change each airport's requirement for de-icing and snow clearance services and supply/demand patterns for winter sport-related holidays.

  With higher summer extreme temperatures, payload lift is likely to be affected necessitating longer runways and higher average temperatures will change take-off trajectories.

- Climate change is highly likely to have an impact on European **water resources**. The regions most at risk from this are the Mediterranean and parts of central and eastern Europe. This could further change patterns of demand for travel.

  Heatwaves and drought are likely to become more frequent, possibly up to 50% more in France and central Europe.

  Some models estimate that by the 2070's, a one in 100 year drought by today's reckoning would return, on average, more frequently than every ten years in parts of Spain and Portugal, western France, the Vistula Basin in Poland and western Turkey.

- Climate projections indicate that **extreme weather events** are likely to occur more frequently and may also be more severe.

  Increases in the occurrence of significant convection areas, winter storms, ice, frost, moderate and severe turbulence, windshear, fog, and runway contamination may cause considerable delays to aircraft operations. Meteorological factors may cause aircraft diversions and may result in aircraft being grounded and airports closed. In fact, extreme weather conditions are already affecting airport operational capacity - one UK airport recently reported melting taxiways during a prolonged period of extremely hot weather, necessitating the redesign of infrastructure.

More detail of the environmental challenges and the challenge of climate change on demand, is given in the environmental technical report (Ref. 10).

2.7 Other Challenges & Risks

A forecast gives structure to uncertainty, but there remain further risks which decision-makers should take into account; turning-points that could each lead to a significantly different future. These include climate change affecting demand, rapid fuel price changes and changing public attitudes to risk and the environment.

A prospective study such as Challenges of Growth 2008 has the basic purposes of giving structure to uncertainty about the future and providing an explicit description of risks. Four scenarios (section 2.1) have been used when putting numbers to the risks, but there remain important risks that are not included in the numerical results and which decision-makers still need to take into account.

From a distance, most aviation trends over the last 50 years look like evolutionary changes: smaller effects gradually becoming larger, others dying away, leaving a long-term trend of a little under 4.0% annual growth in flights (see Figure 9). Look closer, however, and there are a few events which could be argued to be turning points: changes in the system which led to substantial, structurally-different growth. The de-regulation of aviation in Europe of the early 1990s, and perhaps the expansion of European Union, especially in 2004, were such events. This section identifies the events that have the potential to change the industry in the future.

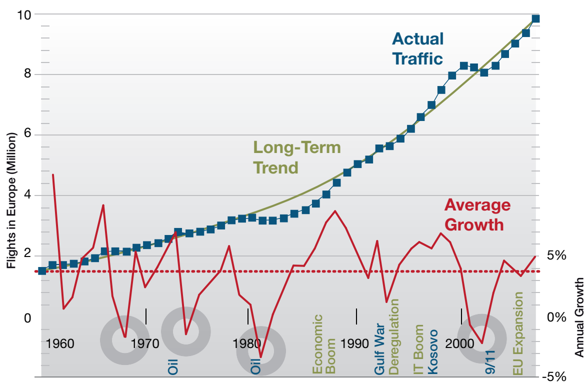

Figure 9. The long-term view of growth is of a stable long-term trend

With the aim of capturing the fullest possible description of the risks, 41 experts from the industry were interviewed, to explore their vision of aviation in 2030 and its economic and social context. This brief section draws widely on these interviews, which are analysed in more detail in a visions and challenges report (Ref 21). Following the structure of that analysis, the risks are grouped under two headings: external from the air transport industry and internal to the air transport industry.

External risks

The mutual dependence of the economy and air transport means that the link between them seems unlikely to be broken in the next 20 years. However, the relationship is not risk-free:

- Environment.

  Sections 2.4 and 2.5 discuss the environmental challenges of growth. Section 2.6 indicates some of the ways in which a changing climate means changing demand.

- Delays in switching to alternative fuels.

  Over and above the environmental issues related to aviation's use of fossil fuel, the time taken to shift aviation to an alternative furl source may have been underestimated, or the long-term availability of fuel overestimated.

- Ticket prices could have reached the bottom of the curve.

  Air transport is not the only product that has followed an arc from luxury to mass-market commodity in the last 50 years as prices have declined both in real terms and as a percentage of disposable income. This trend could stop, or even reverse, in which case there would be economic, social and political changes to the nature of demand and to the perception of air transport demand. If disposable income declines, e.g. as energy or social security costs rise, then the effects of rising ticket prices will be even stronger.

- Fuel price increases might not just lead to more of the same.

  Whichever way prices go now, the peak in fuel prices of Summer 2008 has shown that rate-of-change is important: a rapid increase has the ability to accelerate change and to alter priorities. The forecast scenarios consider a wide range of future oil prices (section 2.1), but a much more profound re-structuring could be possible given a rapid and sustained movement in fuel costs.

- Air transport could be both vector and victim.

  According to the UN World Health Organisation, once a pandemic virus develops, its global spread is "inevitable" (Ref. 22). If it happens then, beyond the obvious reduction in demand, air transport is likely to have a role as a vector in transmitting such a pandemic, as well as in enabling an international response.

- Less long-term investment.

  As European air traffic growth slows, as aircraft operators cut costs and if the Euro remains strong, there will be less longer-term investment and fewer local suppliers. The air traffic industry will be less agile and could therefore be unable to respond to a sudden challenge.

Internal risks

The Single European Sky (SES) is planned to be the framework for European air transport. It is stimulated by the challenge of the growth in air traffic and aims at defragmentation of the ATM/CNS infrastructure, not only at the technical, but also at the political level. SESAR is the technical pillar of the SES. It will modernise ATM through technology and hence deliver more capacity and better environmental and economic performance (see section 2.2). However, a move from a fragmented to a better-organised approach to ATM is not without risk:

- As public resources become scarce, so behaviour changes.

  As resources become scarce, issues of ownership and management become critical: a readily-available public resource becomes a protected asset. Today this behaviour is seen at key airports, e.g. in the way airlines behave to protect their 'grandfather rights' to flight slots. In the future not only runway slots, but airport facilities, TMA access, and even radio frequencies will be more scarce (relative to demand). Therefore not only airlines, but also airports and air navigation service providers (ANSPs) will adopt different behaviours to protect their assets. When will a radio frequency first appear on an ANSP's balance sheet as an asset?

- Investment, standardisation and compliance.

  The costs of achieving the SES are significant and each participant does not bear the same portion of costs and benefits. For example, the military will have significant costs of compliance, though the capacity benefits are more for the commercial stakeholders.

- A potential for industrial conflict.

  Increasing capacity will require automation that will change the role of air traffic controllers and could meet resistance.

- Airlines and infrastructure respond on different timescales.

  Airlines can move capacity quickly to where there is demand, or invest rapidly in new equipment (even if some airframe and engine changes take longer). Innovation in ATM and at airports is more about infrastructure, so comes about more slowly. If demand shifts radically, as discussed earlier in this section, some parts of the air traffic system will be able to respond more quickly than others. A regular instance of this is in overflight patterns, which can change rapidly and present a small State with sudden excess or lack of *en route* capacity.

- Liability and governance.

  Air transport is governed by a complex, fragmented web of rights and competencies, within Europe and worldwide. There is a recognition that this can and should be improved and simplified. However, the increasing profile of liability and the decreasing toleration in society for risks will make improving the governance system a challenge that could easily slow down the ability of the system to respond to other challenges.

3. Measuring and Mitigating the Challenges

3.1 Summary and Impact of Challenges

There are five main challenges: airport capacity, sustainability, operating a highly-congested air traffic network, fully-exploiting SESAR and climate change. In particular, from 2025 to 2030 unaccommodated flight demand nearly doubles, reaching 2.3 million flights (11% of demand) more than capacity in the Regulation & Growth scenario.

Putting together the discussions in the previous section, the main challenges are given below. The order of these challenges is intended to indicate approximately their impact on air traffic operations, but this order is not carved in stone: the challenges are closely inter-linked and overlapping. Indeed, understanding of the challenges will continue to improve in the coming years, so the order should be seen as subject to change.

- Lack of **airport capacity**.

  More accurately, this is a mismatch between where (and when) capacity is available, and where the demand is present. In fact the situation has improved significantly since CG04. Demand in the new long-term forecast is 1.7 million flights higher in 2025 than it was in the CG04 forecast, but more demand is accommodated (see details in Annex B). The improvement comes from a better match between newly forecast demand and planned capacity. However, the difficulties of achieving the plans reported by airports should not be underestimated.

  In the most-likely, Regulation & Growth scenario, the forecast is that demand for flights will exceed capacity by 0.9 million IFR flights in 2025. This rises quickly and more than doubles to 2.3 million unaccommodated flights by 2030. Once airports start to reach their capacity limits, the number of unaccommodated flights grows rapidly: at 20%/year, compared to just 1.7% annual growth in actual traffic for the same period. (Section 2.3).

Scenario	Flight Demand	Accommodated Flights	Unaccommodated demand		Airports at Capacity 8/hours day	
			Flights	Percentage	Num. Airports	Flights Affected
Global Growth	29.1 million	22.1 million	7.0 million	25%	39	70%
Business as usual	22.7 million	19.5 million	3.2 million	14%	25	60%
Regulation & Growth	**20.4 million**	**18.2 million**	**2.3 million**	**11%**	**19**	**50%**
Fragmenting World	17.3 million	16.5 million	0.8 million	5%	14	43%

Figure 10. Summary of the capacity challenge in Europe

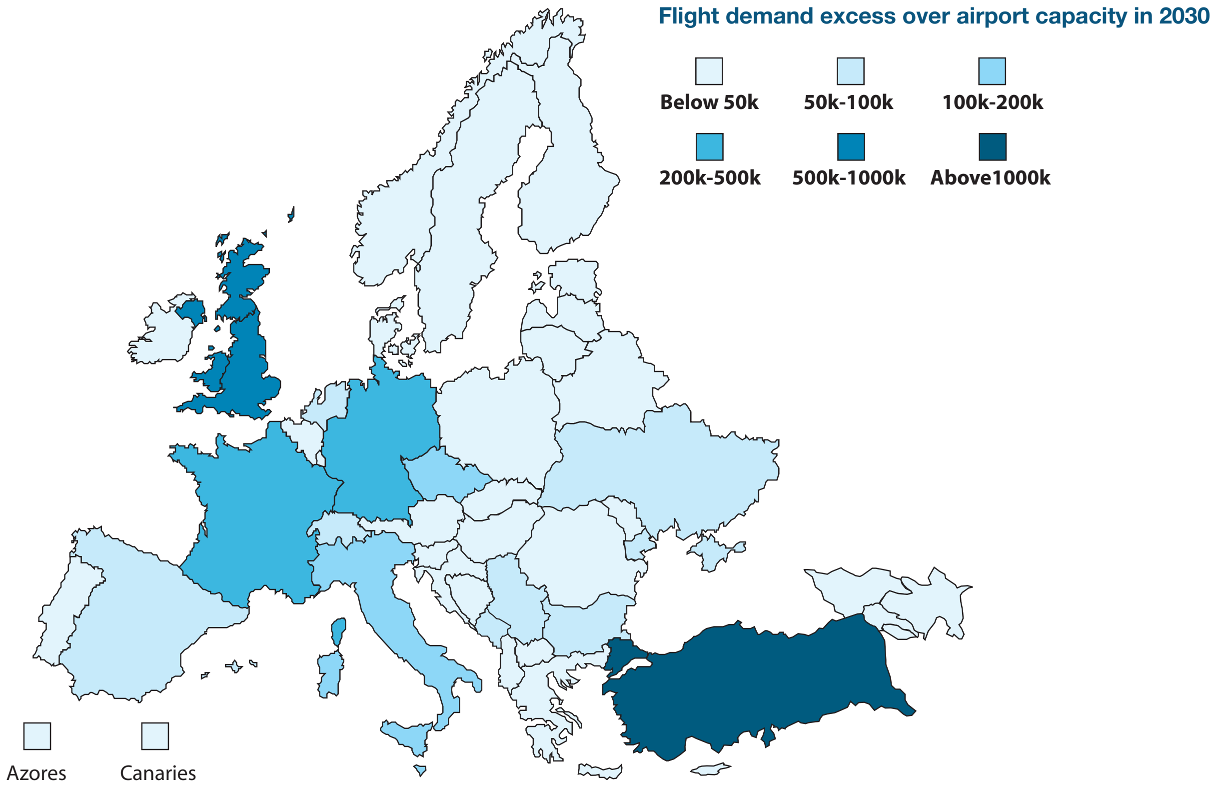

Figure 11. Summary of where the capacity shortfall is largest (Regulation & Growth scenario)

- Environmental **sustainability**.

  Aviation has recognised that the benefits it delivers to the economy are not without their costs to the environment. The industry is acting and improving on this key area of performance. But continued growth will make the global challenge of CO_2 emission reductions (section 2.4) and, at a local level, of noise and air quality (section 2.5) even more acute. In some cases there are difficult trade-off decisions to be made. Air traffic management has a role in these trade-offs.

- Efficient management of a **highly-congested air traffic network**.

  In 2030, in the Regulation & Growth scenario, nearly 11% of demand is not accommodated by airports' expansion plans. Demand is for 20.4 million flights, compared to 18.2 million that can be accommodated. The air traffic network cannot be expected just to ignore that excess demand and continue to work smoothly. Even with this extreme volume of unaccommodated flights, i.e. flights that would not even reach planning stage, there are many extremely congested airports. In the forecast, achieving the 18.2 million throughput involves 19 airports operating at capacity 8 hours/day every day. Section 3.3 discusses what this could mean for the airspace user's experience of flying.

- Delivering and exploiting the benefits of SES, especially **SESAR**.

  The air traffic industry is coming together to plan and deliver SESAR, therefore SESAR is certainly not the biggest challenge to growth: indeed it will deliver additional capacity (section 3.2) and hence mitigate some of the challenges. But as section 2.7 has discussed, it is not without risks. In particular, resolution of the large-scale institutional and social issues associated with reform has, at best, an uncertain timescale.

- The impact of **climate change** on demand and operations.

  This challenge is better understood than it was four years ago. It has a potentially high impact on traffic, but with considerable uncertainty: a significant number of European airports are at risk from rising sea levels; there is increased risk of disruptive weather; changed wind patterns and temperature can affect aircraft performance; in the longer term significant shifts in tourism and other migration as local regions become more or less desirable. (Section 2.6)

3. Measuring and Mitigating the Challenges

3.1 Mitigation

Five mitigation methods have been examined that could reduce the impact of the challenges described. Schedule smoothing, accelerated investment in additional high-speed train infrastructure and accelerated shift to large aircraft to reduce frequencies all have limited benefits as mitigation actions for the air traffic network as a whole. Use of alternative airports can reduce unaccommodated demand by 25-40%, but this is also limited due to capacity constraints elsewhere. Investment to bring all airports to best-in-class standard together with SESAR improvements could bring 40% gains. Best results would come from a mix of methods that takes into account different airline business models and local demand.

The mitigation task of the Challenges of Growth 2008 analysed five methods by which users and providers of the air traffic network might respond to mitigate the challenges. These methods are likely to be particularly effective in response to the airport capacity and congested network challenges (section 3.1).

Discussions with airspace users and air navigation service providers allowed the methods to be adapted taking into account the distinctive characteristics of the different aircraft operators. Each method consists of actions which, in part, could be a natural response of an airspace user or provider to a congested environment. However, achieving the full effect for the mitigation could require action to a degree that is unlikely to happen without legislative pressure. In summary the methods are:

- Schedule smoothing.

  Move flights to times of the day when more capacity is available, even when this might not be the first choice for the passenger. (This typically concerns passenger rather than cargo flights.) The extent of the shift that was analysed varies between thirty minutes for some point-to-point flights (mainly business demand) to three hours for some short- and medium-haul hub flights. This mitigation is likely to happen to some degree anyway, in response to the trade-off between passenger demand profile during the day and making the best use of aircraft, staff and other resources. However, the method could be constrained locally due to environmental considerations relating to noise abatement.

- Alternative airports.

  Move excess traffic either to a secondary airport (within 45 nautical miles of a hub) or to a regional airport (at a greater distance from the hub) depending on the type of flight. Charter and cargo flights are moved to regional airports while some low-cost flights are transferred to secondary airports. This has the knock-on effect of increasing complexity of traffic flows *en route*, but this was not modeled.

- Using larger aircraft to reduce daily frequencies on congested airport pairs.

  Accelerate the introduction of larger aircraft at congested airports on airport-pairs with more than 15 or 30 one-way flights per day. The result in effect caps frequencies on high-frequency airport pairs at congested airports.

- Accelerated investment in high-speed train networks.

  The forecast already assumes that the European high-speed train (HST) network continues to develop (see 2.1, which showed that this would replace the equivalent of 0.3-0.5 million flights/year). This mitigation action assumes that an additional large investment is made in extending the HST network by a further 205 city pairs, focusing on replacing busy, short-range airport pairs (more than 10 flights/day and less than 400km air distance). This results in a network shown in Figure 12. Depending on the HST travel time, a proportion of air passengers would then shift to HST.

- Exploitation of benefits of SESAR.

  The SESAR programme will be making a major contribution to the efficiency of air traffic management in the 2020-2030 timeframe. Indeed, SESAR is the principal justification for assuming that *en route* capacity is not an issue (see 2.2). For airport capacity, CG08 is based on airport plans. This mitigation sub-task instead follows the approach used in CG04: assume that with sufficient investment each airport can, if required, be brought to 'best-in-class' performance, where that 'best-in-class' is based on performance per runway configuration today, up-lifted by an amount to represent the further improvements of SESAR.

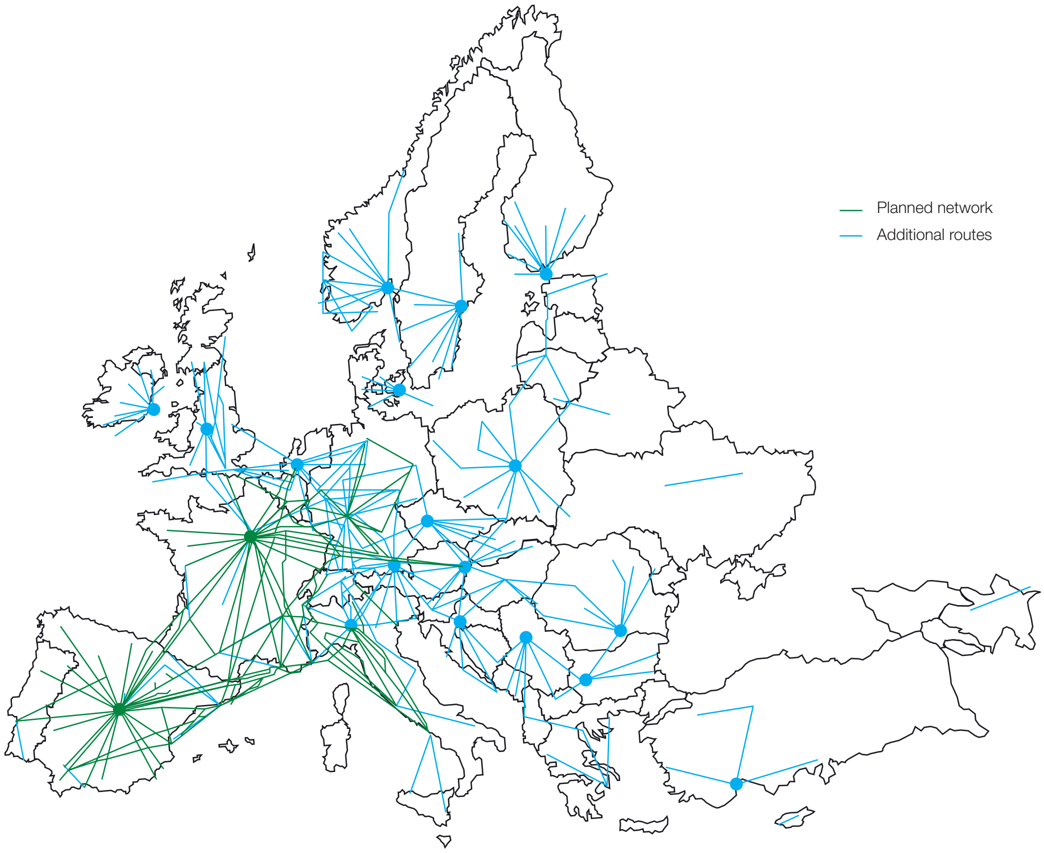

Figure 12. High-speed rail network[11] that would be required if the aim were to replace major short-haul airport pairs. **(Links in grey are already included in the main forecast.)**

Figure 13 summarises the reductions in unaccommodated demand which the modelling of these mitigation actions indicates might be achieved. The first two actions could have widespread benefits, the other three are of more limited applicability:

- SESAR at airports together with investment to bring each airport to the performance of the 'best in class' has the potential on paper to increase airport capacity by a significant margin, thus reducing unaccommodated demand by up to 40%. However, these capacity gains require investment which is not yet reflected in airports' plans.
- Shifting to alternative airports – the 'low-cost' or 'business aviation' business model – reduces unaccommodated demand by 25%-40%. It is more effective in the less-congested scenario. However, there will be environmental costs if additional ground transport is needed to reach more remote airports, and there are limits to this strategy, since ultimately the location of demand is decided by passengers and shippers.
- Shifting short-haul flights to HST by extending the HST network from 98 city-pairs to over 300 city-pairs reduces demand by a further 0.3-0.5 million flights. Therefore it takes three times the connections to double the reduction. Given the cost of building HST lines, this is unlikely to be justifiable in its own right as a means to reduce demand.
- Schedule smoothing is also of limited benefit. The limit here is largely that in the most congested case, there are only a few quiet times that can absorb shifted flights: that is why the gain is higher (10%) in the less-congested Regulation & Growth scenario. Smoothing schedules could also mean using quieter hours currently occupied by cargo operations.
- Using larger aircraft to reduce frequencies to 15 flights at congested airports reduces unaccommodated demand there by more than a third. However the overall reduction in network congestion is limited because there are relatively few such airport pairs. In this case, only the most-challenging, Global Growth scenario was analysed, but similar conclusions could be expected in the most-likely, Regulation & Growth scenario.

[11] The network is shown as city-pairs, not as the physical HST network that would need to be built.

The limits to mitigation because of a widely-constrained network imply that the best results would be from a mix of methods, which takes into account the different airline business models. For full details of the mitigation activity, see the mitigation technical report (Ref. 23).

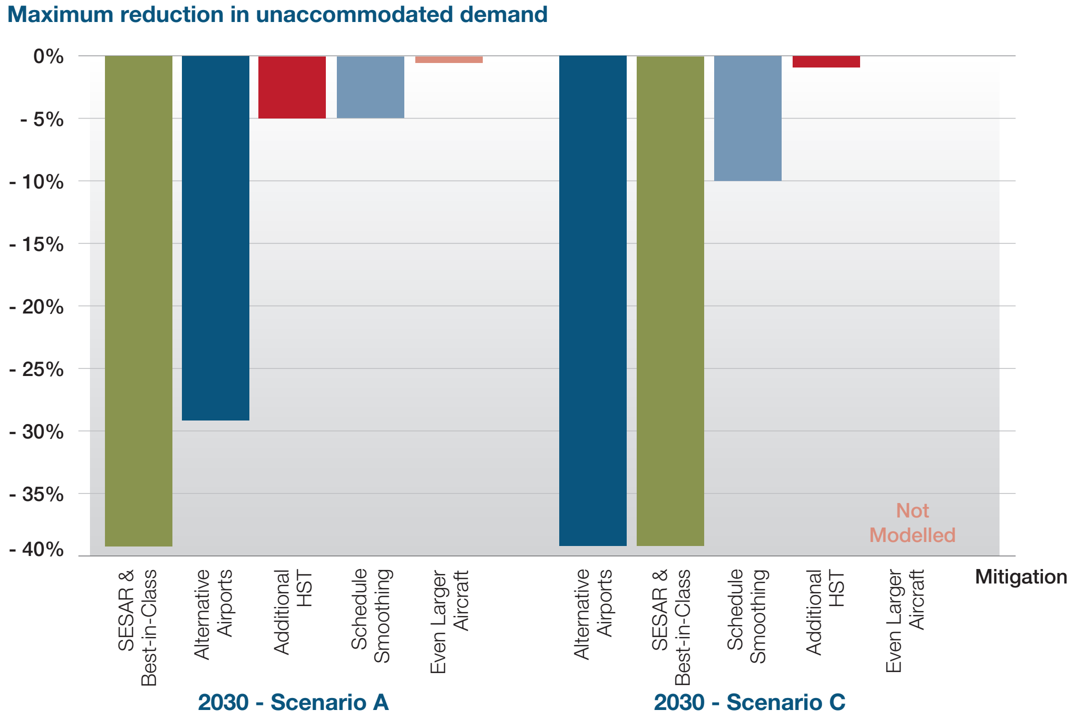

Figure 13. Summary of gains from mitigation modelling

3.3 Flying in a highly-challenged air network

A highly-challenged air traffic network does not just reject a large portion of potential demand: it will be vulnerable to regular delay and flight cancellations on an unprecedented scale.

What would an airspace user's experience be of an air traffic network that was as challenged by growth and as congested as described in section 3.1?

In the Regulation & Growth scenario: 19 airports are operating at full capacity eight hours a day, every day of the year (section 3.1). On a busy day in 2008, 50% of all flights passed through one of the top 39 airports, and 20% passed through two of the top 39. So the level of congestion in the most-challenging, Global Growth scenario has the potential to affect 70% of all flights each day. Even the Regulation & Growth scenario of 19 airports at full capacity means 50% of flights affected on departure or arrival or both.

Compare that with the situation in 2007: only five airports were operating at or near capacity even for 10% of the time. Those five airports were the departure point or destination of 17% of flights. Running near capacity to that extent did not necessarily imply delay: only three of those five were in the top 50 departure or arrival airports for all-causes of average delay/movement (Ref. 24), but they were involved in 22 out of the worst 50 airport-to-airport flows in terms of delay per movement, largely because of the inclusion of London/Heathrow in the list.

Even if delay-causing events were only as frequent as today, delays would propagate rapidly and more widely through the challenging network of 2030. This is illustrated schematically in Figure 14. In more detail:

- A flight with delay will be much more likely to be already at or flying to an airport that has limited capacity to respond to a delayed flight plan.
- Once airborne the aircraft will stick to a slower, fuel-optimum speed, rather than attempting to catch up with the timetable.
- The airport is more likely to have made agreements with residents which exchanges additional flights during the day for stronger restrictions at night, so more airports will have less ability to catch up.

This means that reactionary delays will accumulate even more strongly during the day. Catching up and getting aircraft back into position for the following day will not be able to commence until later into the evening. The result is that delays will stay in the system for longer.

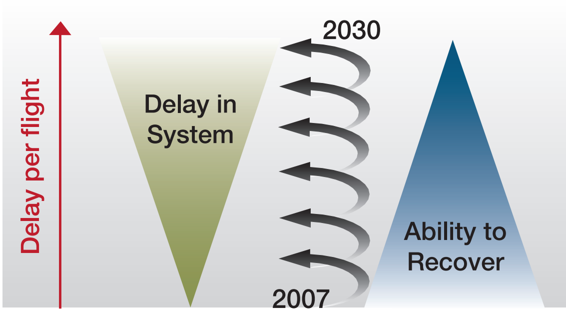

Figure 14. An air traffic network challenged by growth faces an upward spiral of delay as the network's ability to recover declines

In fact, events that cause delays will be more common:

- High price of fuel means airlines cannot afford to take a longer route to avoid a congested area, so more delay is taken on the ground.
- The incidence of extreme weather events is higher (see section 2.6).
- Cancellations will be a less useful option, because load factors are higher (meaning less spare capacity on later flights), aircraft are larger (so more passengers per cancelled flight) and, in the case of the larger-aircraft mitigation action (section 3.2) there will be fewer alternative flights anyway.

All of these considerations reinforce the need for a European air traffic network management capability, which is included in the proposed second package of Single European Sky.

4. Summary and Outstanding Issues

The link between economic growth and growth in transport demand may weaken, but will remain. Therefore growth of air transport demand will continue to be a feature of the years to 2030. The economic turbulence of 2008 and the difficulties of operating in 2009 might buy a few years extra to respond, but this will not allow the air transport industry to escape five main challenges for the longer term:

- **Airport capacity**, which in 2030 in the Regulation & Growth forecast scenario will lag demand by some 2.3 million IFR flights (equivalent to 11%). In the stronger-growth, most-challenging scenario, 25% of demand is not accommodated in 2030.
- **Environmental impact**, including difficult trade-offs not just between growth and environmental impact, but between CO_2 emissions, noise and local air quality.
- Operating a **congested air traffic network** which, as more parts of it operate at near to capacity, will be more prone to delay and less able to recover from delay.
- Achieving **institutional and social change** so that SESAR can fully deliver enhanced air traffic capacity on time.
- The impacts of **climate change** that will affect demand for travel, threaten parts of the infrastructure and make operations more difficult.

The situation both within air transport and outside continues to change. So this is not the final answer, but it is the best assessment currently available. More detail will be provided in a set of technical reports in the coming months. These will cover: mitigation, the forecast, the future and its challenges, and the environment.

It is not the role of this report to propose actions for the Industry. But the project team will be identifying and learning lessons, so that future assessments, such as the next update of the long-term forecast in 2010 can be refined even further. In summary, the conclusions of Challenges of Growth 2008 are that:

- Airport plans are now better adapted to demand than they were four years ago.
- There remains a significant airport capacity challenge, not least in delivering the plans already reported by airports.
- Air traffic management needs to be ready to manage a highly-congested air traffic network.
- High-speed train networks are of narrow applicability in reducing congestion; other mitigation actions appear more effective in this respect.
- In addition to greenhouse gas emissions, local air quality and noise will remain significant challenges and will be compounded by the requirement to reduce emissions.
- Climate change can change demand, and will also affect infrastructure and operations as the weather changes.

All in all, the European air transport system will have to become more agile to respond to the challenges of growth.

5. Acknowledgements

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These groups were supported by ADV Systèmes, Hume Brophy, the Omega Consortium and Met Office in the UK.

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Annex A. Summary of Long-Term Forecast Scenarios

The new long-term forecast includes four separate scenarios for aviation and its context in 2030. These are discussed in some detail in the long-term forecast report (Ref. 3). In summary, some of the main parameters are shown in Figure 15.

	A: Global Growth	B: Business as Usual	C: Regulation & Growth	D: Fragmenting World
2014 Baseline	High growth	Base	Base	Low growth
Economic Growth (EU27 Average 2014-2030)	2.7%	2.2%	2.2%	1.7%
EU Expansion[12]	+7 States 2015-2025	+8 States 2012-2020	+8 States 2012-2025	+7 States 2014-2025
Price/tonne of CO_2 under emissions trading scheme	2012: €25 2030: €25	2012: €30 2030: €40	2012: €50 2030: €90	2012: €30 2030: €55
2030 price of oil (/barrel in 2008 US$)	$90	$125	$180	$180
Network Structure	No Change	No change	More hub & spoke	More point-to-point
2030 price of oil (/barrel in 2008 US$)	1.6%	1.2%	1.6%	1.1%
High-speed rail	6 years later	3 years later	Earliest dates	3 years later
Tourism	Increasing long-haul	No change	Shift from Mediterranean	Moderate

Figure 15. Summary of main scenario parameters

[12] If political union proves elusive, but some degree of open aviation, free trade and free movement are still achieved, then the forecast effects on traffic will still be valid.

Other factors not detailed here include: free trade, security costs, elasticity of travel demand as a function of economic growth and price, airport capacity, demographic trends, open skies, ETS auctioning (100% by 2030[13]). The baseline year for the long-term forecast is 2014; traffic in this year is taken from the medium-term forecast (see Figure 16).

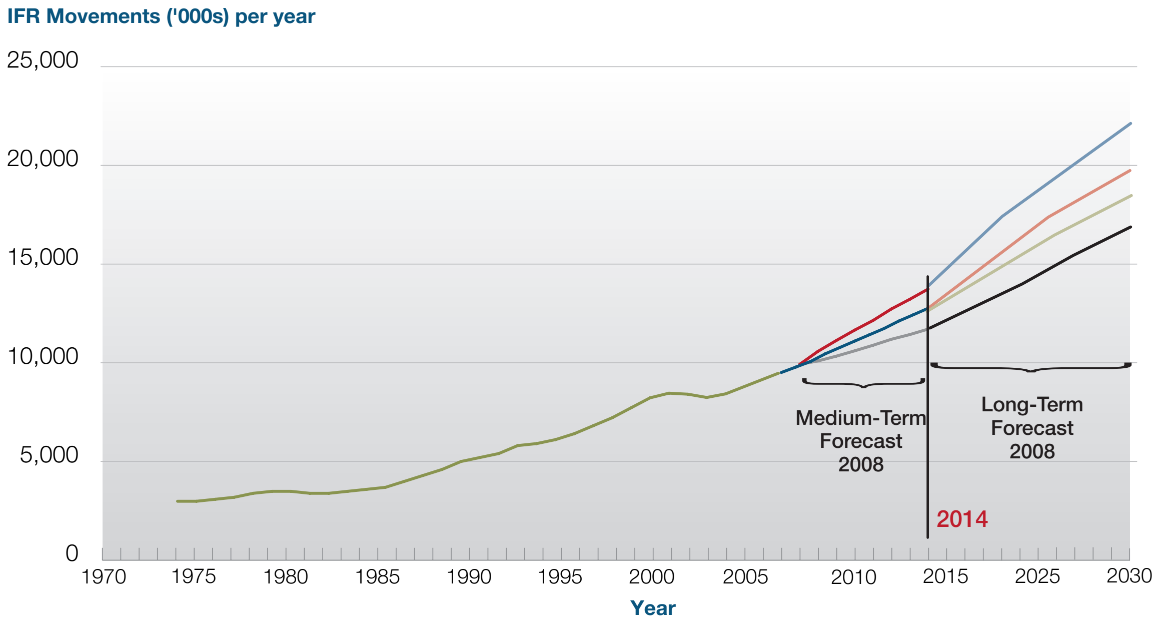

Figure 16. Four scenarios for long-term traffic growth

[13] In the legislation, this date has changed to 2020 since the forecast was calculated.

Annex B. Comparison with Challenges to Growth 2004

This annex provides a brief, like-for-like comparison with the results of the 2004 study. Challenges to Growth 2004 (CG04) forecast to 2025, therefore 2025 is used in this annex as the shared reference year.

CG04 reported traffic for the whole ECAC region, but this region is not fixed, and statistics are also more complete for the region than they were in 2003. So for the purposes of this comparison, the EUROCONTROL Statistical Reference Area is used instead ("ESRA", see Annex C for definition). This is a fixed geographical region, with constant coverage of statistics during the period. The long-term forecast report from 2004 (Ref. 7) provided the values found in Figure 17.

		Scenario A	Scenario C
Challenges To Growth 2004	Demand	20.9	16.7
	Flights	17.2	15.1
Challenges Of Growth 2008	Demand	23.6	17.6
	Flights	19.9	16.7

Figure 17. Comparison of 2008 and 2004 studies (Millions of IFR Flights in 2025 for the ESRA)

CG04 focused on the most-challenging scenario (A), and calculated that in 2025 those levels of congestion would be costing the European economy €90bn per year. Figure 17 provides the background to the observation in section 3.1 that in scenario A the level of unaccommodated demand in 2025 is similar (20.9-17.2≈23.6-19.9≈3.7), although the air traffic system is handling significantly more flights.

In scenario C, the throughput is higher by 1.6 million flights in 2025 in CG08 compared to CG04, and the level of unaccommodated demand has fallen from 1.6 million to 0.9 million flights.

Annex C. Glossary

ACARE	Advisory Council for Aeronautics Research in Europe
ANSP	air navigation service provider
ASAS	airborne separation assistance/assurance system
ATM	air traffic management
CNS	communications, navigation, surveillance
CONSAVE	Constrained Scenarios on Aviation and Emissions
CG08	Challenges of Growth 2008
CG04	Challenges to Growth 2004
ECAC	European Civil Aviation Conference
ESRA	The EUROCONTROL Statistical Reference Area comprising the combined airspace of Austria, Belgium, Bulgaria, Canary Islands, Croatia, Cyprus, Czech Republic, Denmark, Finland, France, FYROM, Germany, Greece, Hungary, Ireland, Italy, Lisbon FIR, Luxembourg, Malta, Moldova, Netherlands, Norway, Romania, Santa Maria FIR, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom
EU	European Union
GDP	gross domestic product
HST	high-speed train
IFR	instrument flight rules
IPCC	United Nations Intergovernmental Panel on Climate Change
SES	Single European Sky
SESAR	SES ATM Research
STATFOR	Statistics and Forecast Service of EUROCONTROL
TMA	terminal control area
UAS	unmanned air system (= UAV + infrastructure)
UAV	unmanned air vehicle
VLJ	very-light jet

Notes

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