AVOIDING THE PREDICTABLE SURPRISE: EARLY ACTION IS THE KEY TO BUILDING A CLIMATE-RESILIENT AVIATION NETWORK

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ABSTRACT

Impacts of climate change, such as sea level rise, higher temperatures and greater weather extremes create an operational, financial and business risk for European aviation. However these are risks which the sector can work to avoid by taking early, and cost-effective, action. A growing but limited number of stakeholders are already implementing comprehensive resilience measures. Yet, a survey of European aviation organisations shows that although awareness is growing many stakeholders are still not acting, often due to a lack of information and guidance. Five key recommendations have been developed to promote cost-effective climate resilience within the sector. These include local and network-wide risk assessment, better use of MET information and the implementation of 'no-regrets' or 'win-win' measures which also address issues such as capacity. Overall, climate change is an issue of risk management and early action is the key to cost-effective mitigation of those risks.

Keywords: climate change, risk assessment, stakeholders

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1. INTRODUCTION

A predictable surprise is "an event that leads an organization or nation to react with surprise, despite the fact that the information necessary to anticipate the event and its consequences was available" (Bazerman, 2006, p.179). A recent example is the US sub-prime mortgage crisis. In theory, decision-makers had access to all the information which they needed to predict and prevent it occurring. And yet they failed to act (Watkins, 2007). Climate change is another often cited example. Scientific evidence that our climate is changing is now beyond doubt. Many parts of the world are already experiencing increasing temperatures, altered precipitation patterns and more frequent and more intense extreme weather events (*see* EEA, 2012; IPCC 2007). Without significant reductions in global carbon dioxide emissions such changes will become more severe and all sectors of global society will be affected. Given this consensus, the requirement to reduce vulnerability and increase resilience to climate change impacts would seem to be obvious. Yet many sectors have yet to initiate comprehensive action to address these risks.

This article will explore the extent to which the European aviation sector is building resilience to the predictable surprise of climate change. It is based on work carried out by EUROCONTROL, the European Organisation for the Safety of Air Navigation, as part of its Challenges of Growth 2013 (CG13) study[1]. The article presents a summary of the study's findings. It will first set out an overview of the potential impacts of climate change for the European aviation sector. It will then review the results of the stakeholder consultation, held as part of the CG13 work, in order to give an indication of the extent to which the European aviation sector is taking action to build resilience to those impacts. Finally it will present a set of recommendations intended to promote the development of climate resilience both within individual organisations and across the European network.

[1] Challenges of Growth is a series of studies intended to provide decision-makers with the best-achievable set of information to support long-term planning decisions for aviation in Europe, with a particular focus on the capacity of the air transport network. Studies were completed in 2001, 2004, 2008 and 2013. They are available from http://www.eurocontrol.int/articles/challenges-growth.

2. BACKGROUND

EUROCONTROL first identified the impacts of climate change as a potential operational and financial risk to European aviation as part of its Challenges of Growth 2008 (CG08) environment report (Thomas *et al*, 2009). Following this, three case studies were commissioned to explore possible outcomes in more detail and to examine gaps and weaknesses in the current understanding of aviation's potential climate change risk. The case studies focussed on three climate change impacts which were identified as potentially significant for the European aviation sector: climate-driven changes in demand, sea-level rise and increased extreme weather. Each case study included modelling and analysis of the climate change-related risks and potential impacts for European aviation over a 2020-2090 timescale (*see* Thomas and Drew, *eds.* 2010).

Subsequent work, such as that of the two European Union Research Framework Programme 7 projects *EWENT* and *WEATHER*, as well as studies carried out by individual aviation organisations, reinforces the findings of EUROCONTROL's initial work and contributes to developing a broad understanding of what the key impacts for the aviation sector will be (*see* Doll *et al,* 2011; LHR, 2011; Molarius *et al,* 2012; SCVV, 2007).

Therefore, with this basic understanding established, the climate change resilience work for the EUROCONTROL Challenges of Growth 2013 report had two objectives:

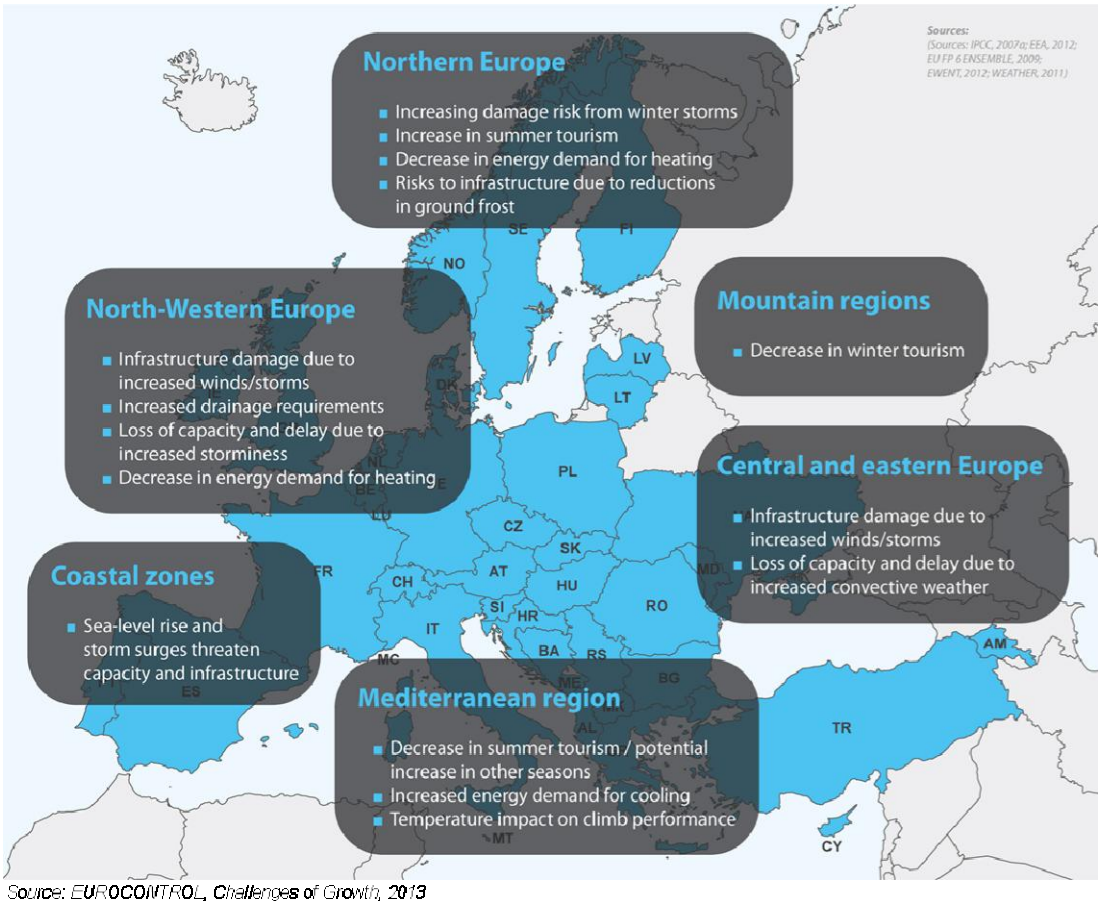
- to update the 2008-2010 work on identifying the potential impacts of climate change for the aviation industry and the resulting resilience measures which may be required, and
- to gather stakeholder views as to whether the industry now considers adaptation actions are necessary, and what actions they are taking.

The results of the two tasks could then be combined to assess the extent to which European aviation is already preparing for the impacts of climate change, and to develop a set of recommendations to facilitate the further development of local and network-wide resilience.

3. POTENTIAL CLIMATE CHANGE IMPACTS FOR EUROPEAN AVIATION

There is now broad agreement on the qualitative issues that will be faced by European aviation, namely: increased summer heat and humidity in the Mediterranean Basin impacting the amount and location of demand; increased frequency and intensity of storm systems and snow events disrupting operations; and, mean-sea level rise threatening coastal airports and thus network capacity. Such impacts will affect infrastructure, operations and operating costs. However, these impacts will vary according to existing regional climate, geographical location and scale of operation (Figure 1).

Figure 1 - Potential vulnerabilities and opportunities of climate change

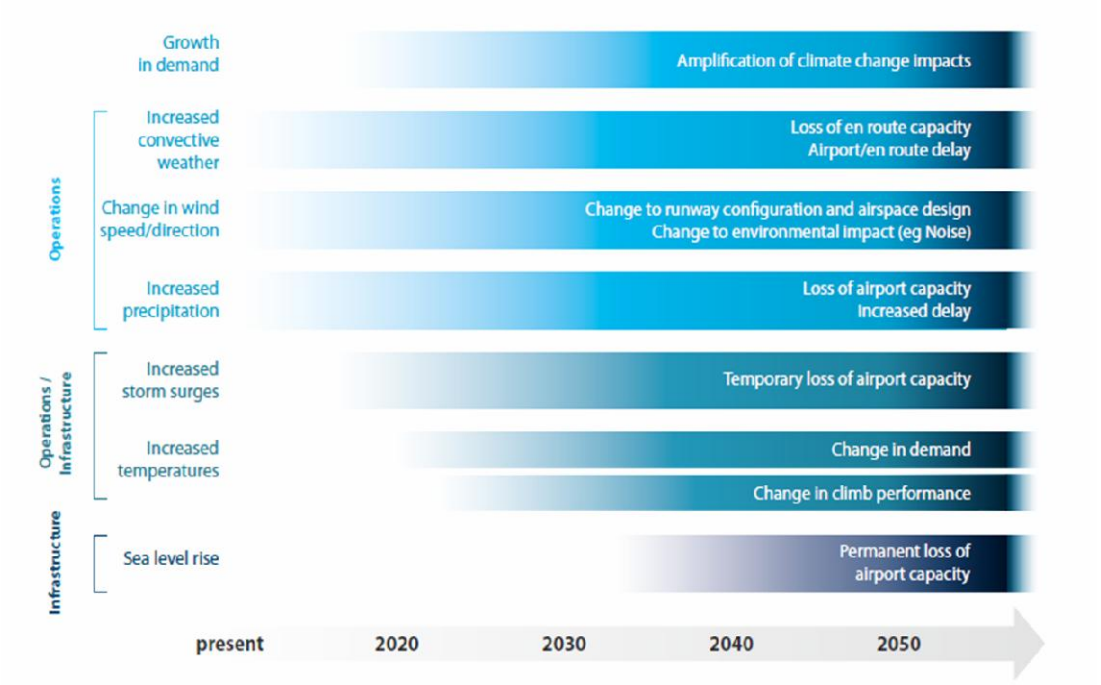


Source: EUROCONTROL, Challenges of Growth, 2013

Timescales will also vary, whilst impacts can be both intermittent and persistent. This will affect the resilience measures which are required (Table 1). Impacts such as sea level rise and temperature increase will be experienced persistently but gradually, allowing for longer term planning which can be based on cost benefit analyses if, for example, it needs to be decided whether to protect an airport from rising seas or relocate it. However, intermittent disruptive weather impacts such as heavy

precipitation events or convective weather will be experienced in the shorter term and require resilience measures which can be applied in anticipation of the situation (Figure 2).

Figure 2 - Time line of expected impacts



NB. This is a broad indication which does not account for regional differences nor future emissions trajectories/climate sensitivity. Timescales are based on analysis for Europe and may vary for other regions. **Sources:** *IPCC 2007b; Thomas et al 2008; Thomas and Drew (eds) 2010; SESAR 2012*
Analysis: *EUROCONTROL, Challenges of Growth, 2013*

Heavy precipitation events or more powerful and more frequent storms can lead to temporary loss of capacity and increased delays, especially if multiple hub airports in a region are affected. Heavy snow in unexpected locations can have a particularly large effect on airport operations due to the relative lack of preparedness. Moreover, the impact of disruptive weather can be exacerbated when airports are operating close to capacity. Consequently, busier airports may experience more significant disruption. As well as shifts in average climatic conditions, extreme conditions such as very hot or very cold temperatures, can be expected to become greater and last for longer, increasing operational challenges. Moreover, some impacts, such as changes to aircraft performance due to increased temperatures or changes in procedures due to a shift in local wind direction, may incur an additional environmental risk due to the redistribution of noise impact around airports, possibly constraining their ability to grow.

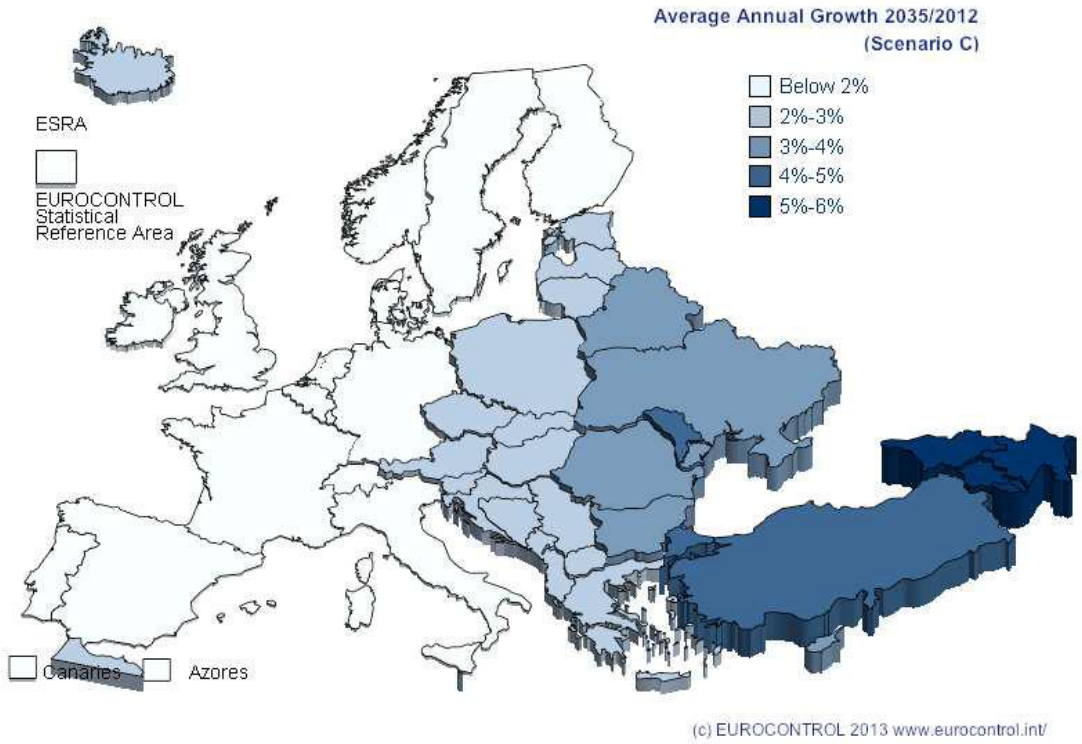
Table 1 - Overview of key climate change impacts and resilience measures identified

	Impact				
	Temperature increase	**Changes to precipitation (rain and snow)**	**Increase in intensity and frequency of convective weather**	**Changes in Wind patterns**	**Sea level rise**
Potential impact for aviation	Changes in demand Changes in climb performance Redistribution of noise impact Heat damage to tarmac surfaces	Operational impacts: loss of capacity and efficiency. Increased delay. Increased de-icing requirements. Increased pressure on drainage systems. Structural issues due to changes in ground frost depth and duration	Operational impacts: loss of capacity and efficiency. Increased delay.	Increased crosswinds and loss of runway capacity Redistribution of noise impact due to procedural changes	Loss of network capacity, increased delays, network disruption. Temporary or permanent airport closure
Type of impact	Persistent	Intermittent	Intermittent	Intermittent	Persistent
Approximate timescales	>20 years before impacts become serious	< 20 years but potentially much sooner	< 20 years but potentially much sooner	< 20 years but potentially much sooner	>40 years before impacts become serious
Potential resilience measures required	• Research to understand potential demand shifts • Review of infrastructure and personnel requirements (+/-) • Airspace redesign • Community engagement	• Operational improvements to increase robustness and flexibility • Improved use of MET forecasting • Information sharing (SWIM) • Training • A-CDM	• Operational improvements to increase robustness and flexibility • Onboard technology for weather detection • Improved use of MET forecasting • Information sharing (SWIM) • Training • A-CDM	• Local risk assessments • Operational improvements to increase robustness and flexibility	• Operational improvements to increase robustness and flexibility • sea defences • development of secondary airports
EUROCONTROL, Challenges of Growth 2013. ***Timescales are based on analysis for Europe and may vary for other regions***					

A potentially significant risk, which is still poorly understood from an aviation perspective, is the potential change in traffic demand patterns due to climate-related changes in both tourist destination preferences and global supply chains. The Mediterranean region currently attracts around 100 million visitors from Northern Europe each year (Amelung and Moreno, 2009). The CG08 Case Study on climate change and traffic demand estimated that 73% of tourist arrivals to Greece were by air (Dimitriou and Drew, 2010). Of course, some but not all Mediterranean destinations are more easily accessible from Northern Europe by other modes of transport. Yet, this still suggests that even relatively small numbers of tourists who fly to the Mediterranean during the summer months deciding to travel to alternative destinations could lead to significant changes in infrastructure and staffing requirements at both traditional and potential new destinations. More positively, if a proportion of those tourists decide to change their habits and travel to traditional holiday destinations in the spring or autumn months instead of the customary summer period, then this could ease congestion during the traditional peak season. Although such issues will seldom be isolated from other factors affecting demand, it is important to understand their potential impacts, particularly when investing in long-term infrastructure projects.

Furthermore, despite the current global economic crisis, overall aviation demand is expected to continue to grow in coming years, putting increasing pressure on operations in both emerging and established markets. However, this growth in demand is not expected to be distributed equally, with some states with emerging markets potentially experiencing up to 5-6% average annual growth (Figure 3). Further, some of the areas where the highest growth is predicted, such as South East and Central Europe, are also some of the areas where the greatest potential climate change impacts are predicted. Consequently, such states may have to cope with growing demand whilst dealing with climate change impacts such as water stress or increased extreme weather. Moreover, as the impacts of disruptive events such as convective weather or heavy precipitation can be exacerbated when capacity at an airport is constrained, it is essential to build resilience at locations which may experience both high growth in demand and significant impacts from climate change.

Figure 3 - Forecast annual average annual growth in European traffic 2035/2012



4. EUROPEAN AVIATION STAKEHOLDER CONSULTATION

The second part of the CG13 work consisted of a stakeholder consultation carried out in two stages; the first part was an online survey for operational stakeholders[3] to investigate whether the industry now considers adaptation actions are necessary, and what actions they are taking. This was followed by a one day stakeholder workshop open to operational stakeholders, decision-makers, and the research community.

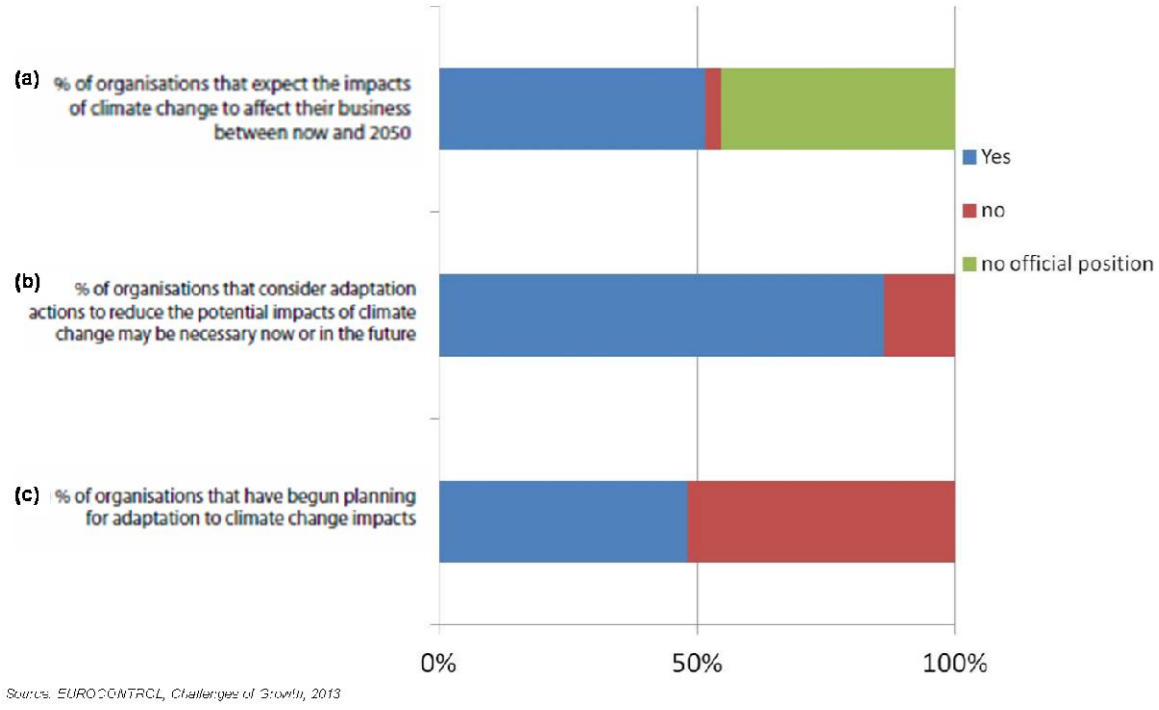
The survey was sent to approximately 100 organisations and 35 valid responses were received. The majority of respondents were either ANSPs or Airport Operators. No responses were received from aircraft operators. This may be due to aircraft operators' shorter planning horizons, because this is not yet an issue on their agenda, or because we did not reach the correct people in individual organisations. However, it does represent an important gap in our knowledge. In terms of

[3] Air navigation service providers (ANSPs), airport operators, aircraft operators, civil aviation authorities and industry associations in Eurocontrol Member States.

geographical spread, responses were received from all of the main European climate zones.

The survey identified that just over half of respondents now consider climate change will be a risk for their organisation between now and 2050 with just under half not yet having an official position (*N* = 33, Figure 4a). For those that do not currently have an official position it was suggested that the risks had not yet been assessed or it was not yet on their long-term agenda. This is a shift in opinion from four years ago when very few organisations had begun to address the issue. However, despite many organisations not yet having an official position, over 80% of respondents do consider that resilience measures to adapt to climate change will be necessary now or in the future (*N* = 29, Figure 4b). The main climate change impacts which stakeholders expect to be affected by are more incidences of extreme weather such as storms, an increase in precipitation (rain and snow) and higher temperatures. A potential change to predominant wind directions was also a recurring concern. For those that did not think it will be necessary to take action the main reasons were because they do not expect to experience significant impacts or because the risks have not yet been assessed.

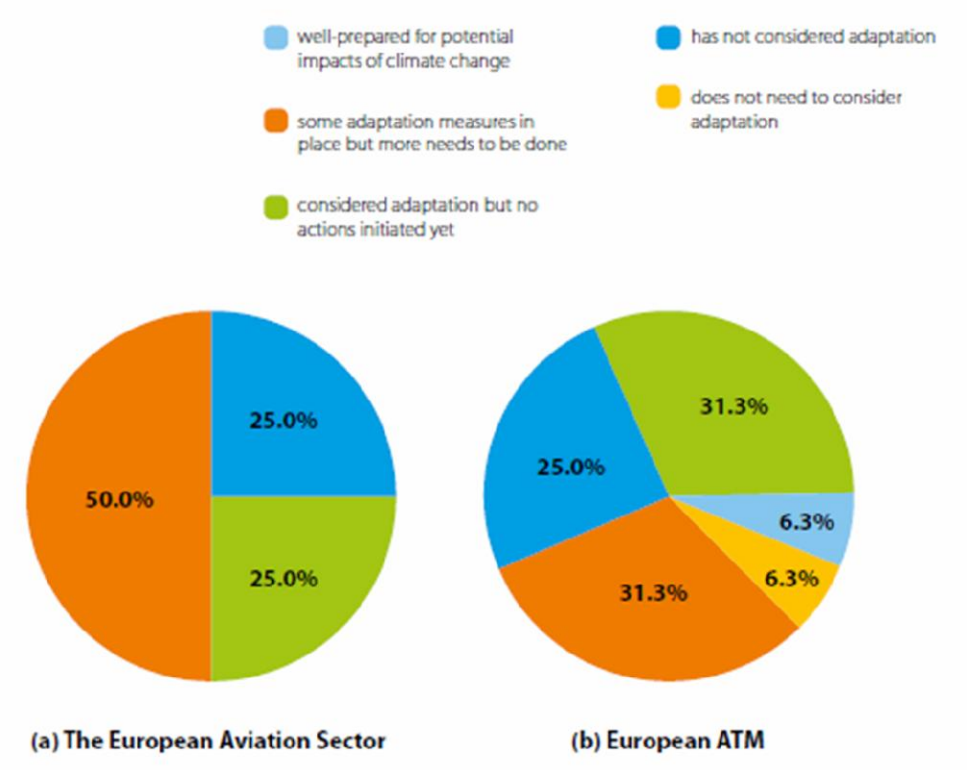
Figure 4 - Percentage of respondents who (a) expect to be impacted by climate change by 2050; (b) consider adaptation to climate change will be necessary (c) have begun adaptation planning



Source: EUROCONTROL, Challenges of Growth, 2013

Yet, despite this growing awareness of potential impacts, less than half of organisations that responded have begun planning for adaptation (*N* = 25, Figure 4c). Some organisations feel it is too early whilst others feel they do not have enough information or resources. Of those that have begun planning, only four respondents had produced adaptation plans. When respondents were asked their opinion as to the current adaptation status of the European aviation industry 50% thought that some adaptation measures were in place but more needs to be done 25% thought that adaptation had been considered but nothing concrete had been done yet and another 25% thought that adaptation has not yet been considered (*N* = 16, Figure 5a).. When asking specifically about ATM, that rose to a third with just a third thinking that some adaptation measures are in place (*N* = 16, Figure 5b).

Figure 5 - Stakeholder perception of level of preparedness for the potential impacts of climate change for (a) the European Aviation Sector as a whole (b) European ATM



Source: EUROCONTROL, Challenges of Growth, 2013

Overall, the results indicated that a growing number of organisations expect to need to take action to adapt to the potential impacts of climate change, but that this is still an emerging issue, with a perceived lack of information and guidance. It should also be kept in mind that the results may demonstrate a certain amount of self-selection

in that organisations which are already experiencing an increase in incidences of disruptive weather, or who are already implementing measures to adapt to climate change, may have been more likely to respond to the survey. In order to gain a clearer picture of the current status of climate change adaptation for the European aviation industry, it would be necessary to carry out a more strategic state by state analysis of vulnerabilities, resilience measures being implemented and action gaps.

Following the survey, a one day workshop was held at EUROCONTROL Headquarters in Brussels. Participants represented 20 organisations including airport operators, air navigation service providers, the Single European Sky ATM Research programme (SESAR, 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. However, concerns were expressed about acquiring financial resources for something which may not be within immediate planning horizons. To address this issue it was proposed that no-regrets solutions, measures which are already being implemented to address other issues such as capacity but which also contribute to building climate resilience, and low-cost actions such as training should be identified. The next section will consider how these proposals can be translated into concrete action to build climate resilience.

5. BUILDING CLIMATE RESILIENCE

Despite geographical variations in impact, there is now broad agreement as to the challenges which will be faced. This knowledge should be used as the basis to take action to identify adaptation measures which develop resilience to those impacts. Following the constructive discussions during the workshop, we have developed a set of five key resilience measures which the sector should consider.

a. Assessment of gaps and vulnerabilities for the sector at local, regional and global levels

Risk assessment and resilience planning are required at both network and local levels. Indeed, due to the interconnectedness of the regional and global aviation systems, an integrated approach to building resilience is essential to ensure that vulnerabilities in one part of the network do not exacerbate impacts in other parts. During the peak of 2012's Hurricane Sandy, 8-9% of global airline capacity was

grounded leading to lost revenues conservatively estimated at around US$0.5 billion (IATA, 2012). An increase in such events will have a significant operational and financial impact. Therefore, even if one part of the global integrated transport system is fully protected against such risk, the overall network is still vulnerable if another vital part does not take the necessary action.

b. Identification and implementation of local, regional and global resilience measures, particularly no-regrets measures such as operational improvements

Early action to address climate change is widely agreed to be cost-effective (EC, 2013; EEA, 2013). Therefore now is the time to proceed with implementation. In particular, 'no-regrets' or 'win-win' measures can contribute to reducing the costs of building long-term climate resilience. For example, measures which are intended to build greater weather resilience and facilitate operations in adverse conditions, address issues such as capacity, or improve infrastructure can be cost and resource efficient solutions.

Moreover, the interconnectedness of the global aviation network suggests that a holistic approach which integrates local and regional impact assessments and resilience planning may be required. Resilience measures should also be coordinated with other parts of the transport network, including ground transport access to airports, so as to reduce overall vulnerability to the maximum extent possible.

c. Identification and implementation of cost-effective measures such as training

Some of the cheapest and potentially most effective ways 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. Moreover, whilst situational and meteorological information flows are vital (see below), people still need to be trained in how to use the information. Training in how to respond to the actual disruptive weather itself is also required.

d. Increased collaboration with MET Services to better exploit advanced forecasting techniques

Good MET information combined with proactive responses can improve operational resilience. Improved MET support is now available to ATM to enable better advance planning. Probabilistic forecasting can identify potential weather issues several days

in advance and models can now run at a much higher resolution than previously. Trials have demonstrated that effective proactive planning responses to severe weather can produce significant performance gains in adverse conditions compared to unstructured reactive responses which could reduce capacity and compromise safety margins. This means that decision-making needs to be built on confidence in good meteorological information and an understanding of what those conditions mean in practice.

e. Analysis of the potential impacts of climate change on air traffic demand to inform medium and long-term operational and business planning

Several studies have now been completed which analyse the potential impacts of climate change for tourist preferences (*see* EEA, 2012). However, as yet, only limited work has been done to translate those changes of preferences into potential changes of demand for aviation (*see* Dimitriou and Drew, 2010). Therefore the potential impacts of climate change on traffic demand and its interaction with other economic and social factors could be better understood. It would be prudent to instigate further work to examine any possible trends. The results of such studies could then be used to inform medium and long-term operational and business planning. Other factors such as the implications that climate change may have for en-route capacity would also benefit from greater understanding, whilst the more general consequences of a changing climate, such as potential changes in wind vector, need to be translated into specific local impacts. Therefore, whilst implementing concrete measures to build resilience to those impacts which have already been identified should not be delayed, it would be judicious to carry out further specific analyses at both local and network level.

6. EARLY ACTION TO BUILD RESILIENCE

Despite indications that climate change adaptation is still a low priority for European aviation as a whole, some stakeholders are already taking comprehensive action. EUROCONTROL in its role as Network Manager[4] has been working in partnership with

[4] The ATM Network Manager is a function established by the European Commission to optimise the performance of the aviation network in Europe. The Network Manager brings together the different aviation and air traffic management actors involved in the design, planning and management the European ATM network. EUROCONTROL was appointed as the Network Manager in 2011. http://www.eurocontrol.int/dossiers/network-manager-new-key-role-european-aviation

air navigation service providers, airports and airlines to re-enforce the operational management of adverse weather conditions, both en-route and at airports. This has involved measures such as the implementation of procedures to facilitate planning, coordination and communication during disruptive events, as well as to proactively manage demand. On the other side of the Atlantic, the FAA has developed a programme to build infrastructural and operational climate resilience.

Also in Europe, the SESAR research programme is developing MET infrastructure and services to integrate improved MET capabilities to European network operations. This increases resilience by promoting better information sharing, which in turn allows for more proactive and flexible responses to disruptive weather events. Some individual organisations have also begun to take action. For example, the Norwegian Airport operator and ANSP, Avinor, has recently introduced guidance stipulating that runways should not be built lower than 7 metres above sea level whilst implementing an extensive programme to increase wave and storm surge protection at coastal airports. And whilst relatively few organisations have developed climate change adaptation plans, those that have been put in place tend to be comprehensive (*see* LHR, 2011; MAG, 2011).

However, as the *Challenges of Growth* stakeholder consultation demonstrates, many organisations have either yet to consider this issue, or do not have the knowledge and resources to act. This suggests that more data, information and guidance are required, and that climate adaptation needs to be addressed collaboratively as an industry. Moreover, it should not be forgotten that there is a financial implication to this preparedness; cost-benefit analyses will be required to determine what level of impact it is feasible to cope with.

7. CONCLUSIONS

The potential impacts of climate change on the aviation industry will vary according to location and scale of operation, and may be further exacerbated by the challenge of accommodating increased growth in demand. The impacts and consequences for European aviation can already be anticipated and, at a high-level, many potential measures to mitigate those impacts are either already being implemented, or at least have been identified. Cost-effective climate adaptation can be achieved by building

resilience into current infrastructure and operations planning and identifying cheap and no-regrets measures such as training. This suggests that the predictable surprise can be avoided.

Yet, the *Challenges of Growth 2013* stakeholder consultation demonstrates that many organisations are not yet taking action. In many cases this is due to lack of information or guidance. Moreover, aviation is a global industry and vulnerabilities in one part of the network can translate into costs and operational impacts for other parts. Therefore, we need to communicate and collaborate at all levels in order to implement resilience measures as efficiently and effectively as possible. Overall, climate change is an issue of risk management and early action is the key to cost-effective mitigation of those risks. Therefore, if we want to avoid a predictable surprise the time to act is now.

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