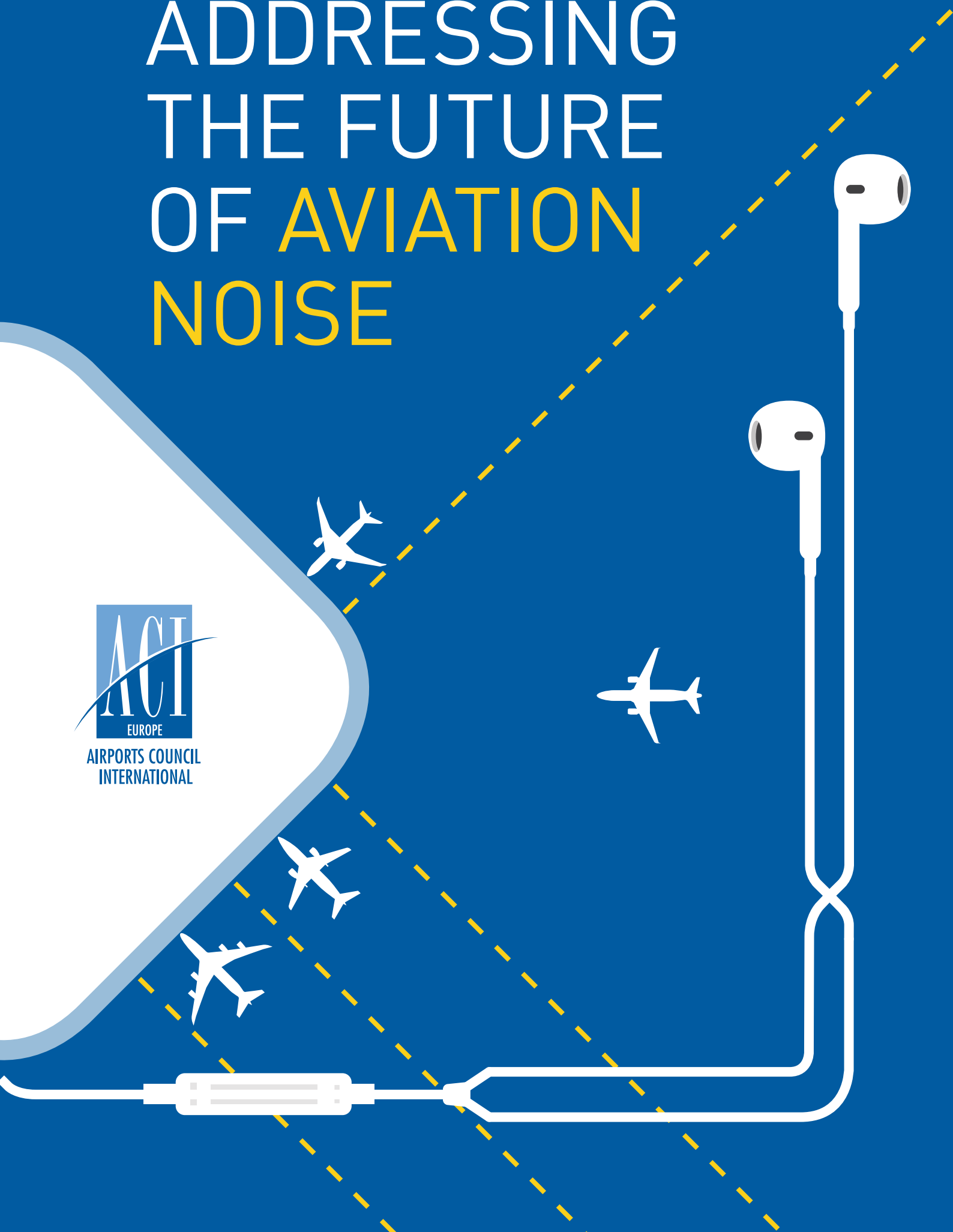
ADDRESSING THE FUTURE OF AVIATION NOISE



ACI EUROPE
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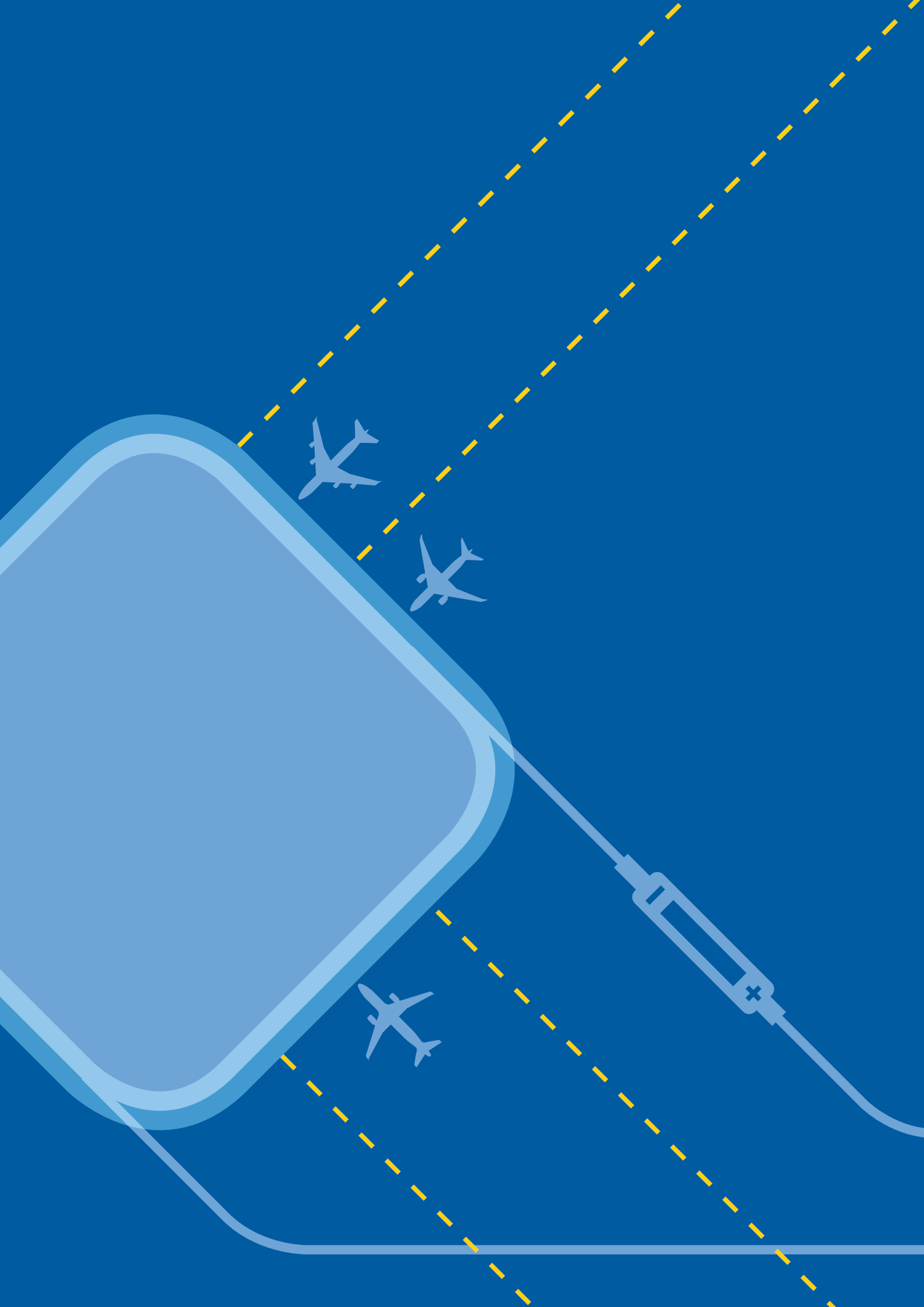

INTRODUCTION

The world we live in is busier, faster and noisier than ever before. At a time where all forms of media and information are being harnessed to heighten our senses to different messages and sensations, the technological advancement of sound and hearing are arguably evolving at a slower pace.

The past decades have seen an established sociological trend of people gravitating more and more towards living in cities. This is set to continue and intensify. These increased city populations naturally generate more noise and are exposed to more noise, as they exploit the mobility that cities offer by bus, by car, by rail and by air.

The circle of growth that comes from this trend has also prompted a greater interest in researching the effects & implications of noise – industrial, transport or other.

In parallel to this, personal technology and communications have advanced in previously unimaginable ways, empowering people to bring a vast array of entertainment with them wherever they go – smartphones, portable speakers, tablets and of course, noise-cancelling headphones. The proliferation of these media and portable devices has created a world where the majority of people you see in the street or on public transport are wearing headphones – insulating them from external noise by cancelling it out and connecting the wearer to their own personal sensory bubble. A walking metaphor for society's simultaneously expanding and contracting relationship with noise.

Look around and observe it for yourself when you next find yourself on a city street, on a bus, in a gym.

All of these developments have prompted greater interest in the health effects of noise, either by source or by the circumstances in which it is heard. So, let's take a moment to consider the nuance between "sound" and "noise".

Noise is defined as "unwanted sound" and therefore, it has both an objective and subjective component. Whether or not a sound is considered as noise depends both on its acoustical properties and its interference with intended activities. Noise at a low volume can be irritating and stressful. Equally, sound you love can be bad for your health, by damaging your hearing if played at too high a volume.

In broad usage, "noise" usually has a pejorative quality, while the connotations of the word "sound" are usually more positive or intriguing.

Now consider the soundscape of transport and mobility. Almost every mode of motorised, commercial and personal transport generates noise – to differing degrees, but as a general rule, consistent, well-maintained city transport makes a sound/noise of some kind.

According to data published by the European Environment Agency in July 2018, over **100 million people** in the European Union are exposed to noise levels of › Lden 55 dB from road transport, **over 18 million** from rail transport and over **4 million** from air transport.

Like any other noise, the irritation experienced by the people nearby is subjective and its intensity can depend on a multitude of different factors – some of which we will expand upon in this publication.

Yet mobility is intrinsic to our existence – at a human level, it enables our daily commutes, our school journeys, weekend visits, city breaks, family reunions, holidays and better intercultural exchange. At a wider societal level, transport and logistics facilities enable producers to get their products to shops, manufacturing supply chains, international business meetings and so much more. It may be a cliché to say that in today's globalised world, everything is connected, but that doesn't make it any less true.

But if 'living is moving', how do we match the essential human ambitions of mobility and discovery, with the noise generated? Due to its scale and its visibility, no other mode of transport has had to deal with this question as bluntly as aviation.

Historically, aircraft noise management has mainly focused on the reduction in noise exposure levels and although this has achieved considerable success, in spite of an increase in air traffic, it has not necessarily led to associated reductions in adverse reactions from residents within local communities. This confirms that the relationship between negative reaction by some residents and aircraft sound exposure is more complex than presumed or portrayed.

We welcome the work undertaken by the World Health Organisation (WHO), to catalogue and analyse and synthesise the research carried out to date on the issue of noise, however for air transport the resulting Environmental Noise Guidelines for the European Regions (Guidelines) are not as constructive as we had initially hoped.

In view of the multi-faceted nature of the subject, the continuing evolution of the sciences involved and the WHO's new publication, ACI EUROPE decided to publish this Analysis Paper. Why? We want to clearly lay out the complexity of the subject and the sciences needed to analyse it properly, highlighting the research gaps that still need to be addressed, in the hope of gaining further momentum to tackle the thornier questions going forward.

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THE ESTABLISHED KNOWLEDGE ABOUT AVIATION NOISE

We acknowledge the fact that there are risks to health arising from noise exposure, however the sources and circumstances of the noise exposure can vary considerably – this makes the assessment of these risks subject to uncertainties.

This essentially breaks down into two categories: **Acoustic factors** and **Non-Acoustic factors**.

Within **Acoustic factors**, research is focused on reducing noise at source (e.g. through better technologies) and improving air traffic management to minimise the number of people in noise-exposed areas – while much of the advancement that has occurred in relation to these has been proactive, it has also been subject to legislation so we will cover that in more detail in a subsequent section relating to regulation.

In addition, research and practitioner work has been conducted into the health outcomes from noise exposure, typically formalised in so-called dose-response relationships, identifying the risk of an adverse health effect depending on different levels of noise exposure. The health impacts considered so far include: cardiovascular diseases, blood pressure, psychological health; sleep disturbance and annoyance. Dedicated attention has also been paid to cognitive impairment and impact on children's learning.

The most recent, comprehensive and authoritative study to date which addresses these health outcomes is the NORAH study.

NORAH (Noise-Related Annoyance, Cognition, and Health) is the most extensive study on the subject of the impacts of noise published so far. The scientists involved in the study come from a wide range of different disciplines: medicine, psychology, social science, physics and acoustics. They were working together to find answers to questions which have remained unanswered in noise impact research up to then. To do this they calculated the past and current, address-specific exposure to aviation, road and rail noise in a large area around the Frankfurt Airport.

The researchers compared these values with data on the health, quality of life and development of a total of more than one million persons in the region. In addition to this, the scientists surveyed several thousand people in the areas around the airports Berlin Brandenburg, Cologne/Bonn and Stuttgart.

THE NORAH STUDY'S MAIN FINDINGS[1]

HEALTH RISKS

This sub-study placed a special focus on the link between noise and cardiovascular disorders. It identified a correlation between exposure to noise from road, rail and aircraft noise, and cardiovascular diseases. The effects of rail and road traffic noise on chronic heart failure, myocardial infarction, and stroke were more clearly seen as compared to the effects of aircraft noise. The study also showed a correlation between traffic noise and the risk of depression: here the identified impacts of aircraft noise were stronger than those of road and rail traffic noise.

SLEEP

The study on this aspect found that there is a correlation between noise levels and the number of awakenings. Since the introduction of the night flight ban from 23:00 to 05:00 at Frankfurt Airport, the number of noise-related awakenings has decreased in these night hours. However, regardless of this, the subjective impression of the population exposed is that the quality of their sleep has deteriorated. Furthermore, people who have a rather critical attitude towards aircraft traffic generally sleep less well than people who do not. The direction of the causality between attitude and sleep quality was not assessed. This points to the importance of subjective factors in the effects of noise on sleep.

BLOOD PRESSURE

The study could not confirm with statistical certainty that chronic aircraft noise increases blood pressure. This result partially contradicts results of earlier studies, but all in all is comparable to most of the previous research. However, it is also based on more accurate blood pressure measurements and more precise acoustic and survey data than were available in earlier studies.

ANNOYANCE

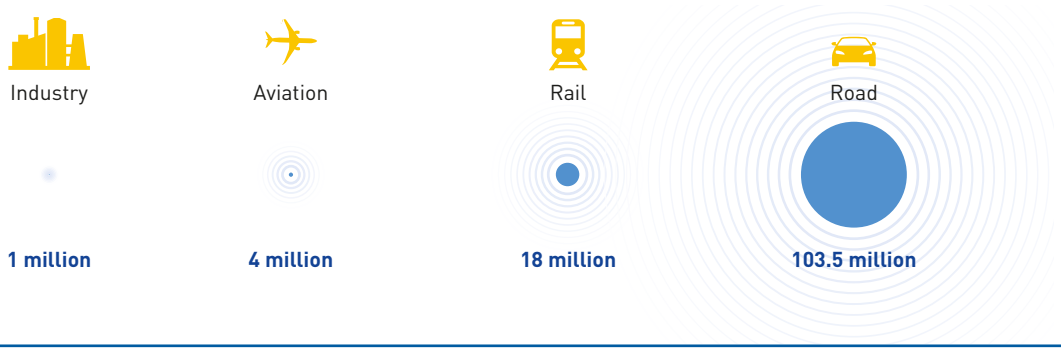
The study identified that compared to other noise sources, aircraft noise is associated with the highest levels of annoyance. Furthermore, for equal average noise levels, the observed annoyance levels have increased since 2011 (and in spite of the night flight restrictions in Frankfurt). However, it has also been stressed that this tendency could not be explained by acoustic changes (i.e. there has been no increase in the level of noise caused by individual flight events (Lmax) and the number of events above a certain noise level (NAT)). It has thus been recognised that non-acoustic factors contribute significantly to annoyance.

[1] www.laermstudie.de; see in particular NORAH – Knowledge No.14, NORAH Noise Impact Study, Overview of Results.

QUANTIFYING NOISE

There are different ways to quantify noise, and the most common metrics in use in aviation relate to either single noise events, i.e. overflying aircraft, or average noise levels, accounting for the average sound pressure level generated by several events throughout a defined time period. Single-Event Based Noise Metrics include, for instance, Lmax, the maximum noise level generated by an aircraft. Cumulative Average-Noise Metrics include amongst others the two main indicators used in noise impact research, Lden and Lnight. Lden describes the average noise level during the day, evening and night, and is designed in a way to account for higher sensitivity to noise during the night and the evening. Lnight relates to the average noise level during the night.

Lden and Lnight are also the metrics used in the European Environmental Noise Directive, and consequently form the basis for the mapping of noise exposure from various sources in Europe. The graph below presents the number of people exposed to noise of above Lden 55dB in Europe as of July 2018:



The findings of the NORAH study highlight the complexity of assessing the impacts of noise on health. For instance, aspects such as confounding factors (i.e. factors independent from noise exposure, such as age or lifestyle, which can influence certain health risks) and the difference between correlation and causality have to play an important role in any such analysis.

In preparing the new Environmental Noise Guidelines, the WHO performed a comprehensive review of the existing scientific research on noise and health, and assessed it according to different degrees of certainty with regard to the magnitude of health effects caused by noise exposure. In relation to aircraft noise, the quality of the available evidence is rated as "very low", "low" or "moderate".[1] Moderate quality evidence means that "further research is likely to have an important impact on our certainty in the estimate of effect and may change the estimate".[2] This points to remaining uncertainties regarding the health impacts of aircraft noise and confirms the need for further research.

NON-ACOUSTIC FACTORS

Regardless of the uncertainties outlined above, European airports are taking action to reduce noise exposure in their surroundings, to minimise the risk of adverse health impacts. You can read more about it in the section on airport engagement and expectations. However, many airports are experiencing that while the number of people exposed to noise diminishes, the numbers of noise

[1] WHO Environmental Noise Guidelines, Pages 60-61.

[2] WHO Environmental Noise Guidelines, Page 61

complaints – and thus reports of annoyance – do not decrease and in many instances, actually go up. This has led some to recognise the fact that annoyance cannot just be explained by objective noise levels, but that non-acoustic factors do play an important role. As also mentioned in the NORAH Study, there are estimates that acoustic factors only account for up to 30% of the annoyance response of people.[1]

Non-acoustic factors cover, amongst others, subjective variables related to people's attitudes and perceptions. This goes back to the point made in the introduction about the subjective nature of what constitutes noise and the prompters of irritation. It is widely recognised that the current body of research on noise needs to dig deeper in order to adequately consider these factors.

In relation to aircraft noise, is air transport being singled out because of its unique visibility and the aspirational lifestyle associated with flying? How much does the visual intrusion of the source play a part in the level of irritation generated by noise? Consider the example of wind turbines – a source of clean energy with a broadly positive perception in society, however the level of noise generated by wind turbines can be disturbing for people living nearby (300 metres from a wind turbine, you can experience a sound level of 43dB).

Equally, there has been little or no research to date, assessing the potential benefits for people's well-being associated with the value generated by airports and aviation, as a consequence of their positive economic and social impacts – and correlating that to specific experiences of noise exposure and/or irritation. Such research would be complex, given the mix of sciences involved in correlating the metrics and parameters of economic value, socio-economic benefits and noise exposure.

[1] Kroesen, Maarten et al.: Testing a theory of aircraft noise annoyance: A structural equation analysis Journal of the Acoustical Society of America, June 2008, pages 4250-4260

THE ROLE OF REGULATION

Regulation can only be effective when it is based on the realities in which the subject is operating. In the area of aircraft noise, this means taking into account local factors such as density of population around an airport, number and type of aircraft operations, climatic conditions, while bearing in mind the network characteristics of air transport. Measures implemented on one node on the network thus almost certainly have knock-on effects for the rest of the system. Regulation therefore has to be sufficiently flexible to accommodate the different local noise situations at airports, while at the same time minimising the risk of unintended effects in the network which could occur if too divergent approaches to noise management are adopted in different constituencies.

THE ICAO BALANCED APPROACH

This is recognised in the so-called **Balanced Approach** introduced by **ICAO** in 2001. It is the cornerstone of airport noise management and it is well documented in numerous airport and policy noise management documents and literature. In the EU, the implementation of the Balanced Approach is mandated by Regulation 598/2014 and thus obligatory for all EU Member States. The implementation of this Regulation has been identified as a priority in the EU Aviation Strategy from 2015. The Balanced Approach is based on 4 pillars of aircraft noise management:

REDUCTION OF NOISE AT SOURCE

LAND-USE PLANNING

NOISE ABATEMENT OPERATIONAL PROCEDURES

OPERATING RESTRICTIONS

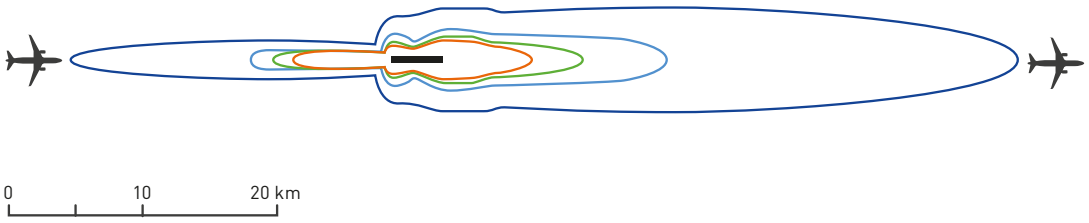
The Balanced Approach requires that the most suitable noise mitigation interventions are identified for each airport based on its individual noise situation. This means that if a noise problem has been identified at an airport, first a noise mitigation objective is defined, and then an assessment takes place to gauge which measure or combination of measures from the 4 pillars can achieve this objective in the most cost-effective manner. When doing so, measures in the three first pillars have to be explored first. Only if they reveal themselves to be insufficient to deliver the expected noise mitigation result, can operating restrictions be considered.

In this way, the Balanced Approach provides the advantage of a consistent, international framework for airport noise management across the world. It also takes into account that the circumstances of airports vary enormously and provides the flexibility of an airport-by-airport perspective, enabling the selection of the most suitable noise mitigation action for each airport.

1 REDUCTION OF NOISE AT SOURCE

Reduction of noise at source refers to improvements in aircraft technologies to reduce the noise generated. These are essentially driven by ICAO's system of 'Chapters' which serve as the standards that aircraft have to comply with across the world. The first noise standard was introduced by ICAO back in 1977 and its stringency has gradually increased over time.

Over the past decades, the various aircraft and engine manufacturers have worked hard to make aircraft lighter, more fuel efficient and less noisy. Readers who have flown in or witnessed the take-off/landing of an Airbus A380 – the largest civilian airliner in the world today – will be aware of how impressively quiet the aircraft is, in stark contrast to its enormous dimensions.



Chapter 2 (before 1977), cumulative level: 309.0 EPNdB, 80 dB SEL contour area: 300 km²

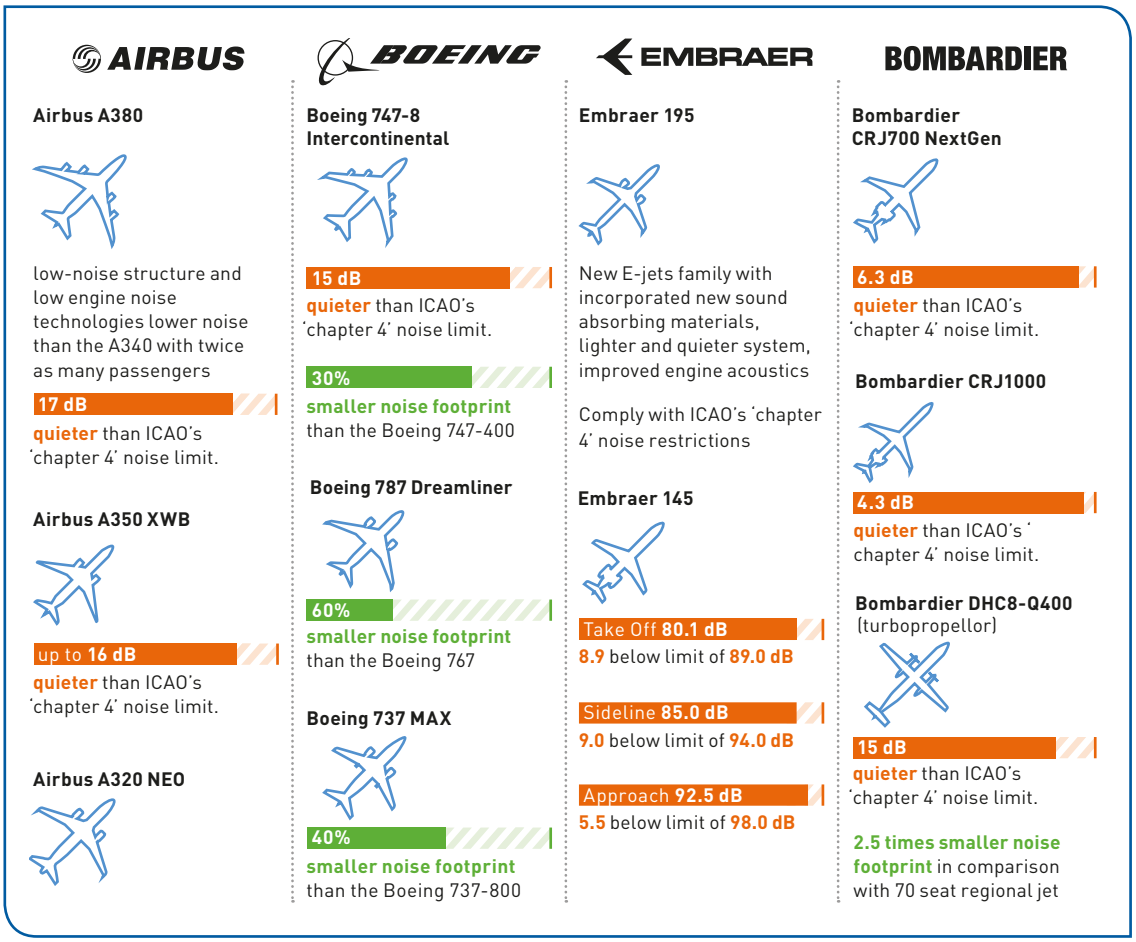
Chapter 3 (1977), cumulative level: 285.2 EPNdB, 80 dB SEL contour area: 67 km²

Chapter 4 (2006), cumulative level: 275.2 EPNdB, 80 dB SEL contour area 34 km²

Chapter 14 (2017), cumulative level: 268.2 EPNdB, 80 dB SEL contour area: 21km²

Source: EASA, EEA, EUROCONTROL: European Aviation Environmental Report 2016.

The graphic below spells out how each of the key manufacturers have advanced with reducing the noise emissions of their aircraft, in line with changes to ICAO's Chapters.



Research initiatives such as the EU's CleanSky programme work to continue making aircraft quieter by exploring innovative engine and aircraft designs. Since aircraft development and airline fleet renewal take time, the introduction of new, quieter aircraft can take several years to have a significant impact on noise exposure around an airport.

2 LAND-USE PLANNING

Land-use planning aims to ensure that land in the vicinity of airports is managed in a way that is compatible with aircraft operations. This means that areas near airports which are overflown frequently by approaching or departing aircraft, should not be used for residential purposes or for noise-sensitive buildings such as schools or hospitals. The set-up of sound insulation schemes for dwellings and noise-sensitive buildings is also associated to land-use planning.

Land-use planning is usually the responsibility of local authorities. In some EU Member States, noise protection zones have been defined at the national level, including areas in which construction for residential purposes is not allowed. This is, for instance, the case in Germany. In Spain, in areas exposed to high levels of noise around airports, restrictions to certain types of land-use, activities or building types are applied as well. In addition, in such areas, dedicated

action plans need to be defined and implemented to mitigate the noise impact on communities. These action plans are established based on the ICAO Balanced Approach.

However, there are some airports that have had to contend with questionable land-use planning decisions at local level, which have actually seen the populations living nearby increase in recent decades – essentially creating a bigger problem, as more people reside closer to these airports – in parallel to more air traffic flying overhead as well. For instance, according to an analysis by the UK Civil Aviation Authority (ERCD Report 1701)[1], between 2006 and 2016, at London-Heathrow Airport, 89,400 people moved into the area exposed to noise levels above Lden 55 dBA. As a consequence, while this area decreased by 19% between 2006 and 2016, the population exposed decreased by only 9%. Without encroachment, population exposure reduction would have been 21%.

In this regard, the role of local regulation is critical – land-use planning must be aligned and harmonious with the long term vision of the ambitions of the city and/or region and the airport masterplan.

NOISE-ABATEMENT OPERATIONAL PROCEDURES

Noise-abatement operational procedures refer to changes in the way aircraft approach or depart from the airport. This can imply changes in aircraft routes or the way they are flown, affecting aspects of speed and altitude. Such changes are usually the result of initiatives taken by airport operators, air navigation service providers and airlines, rather than regulation, and are therefore discussed in more detail in the next chapter.

OPERATING RESTRICTIONS

The EU Regulation 598/2014 defines operating restrictions as “any noise-related restriction that limits access to or reduces the operational capacity of an airport”. Restrictions include limits on total movements, curfews, restrictions of the use of certain runways or routes. They are usually imposed by public authorities and are today in place at many major airports.

A COMPREHENSIVE APPROACH TO NOISE MANAGEMENT IN EUROPE

In the European Union, the Balanced Approach Regulation 598/2014 is complementary to and builds on the Environmental Noise Directive (Directive 2002/49). This transversal Directive, addressing various noise sources, requires Member States to regularly map noise exposure around key infrastructure, including major airports, and to set up noise action plans to address identified noise problems for each of these sources. Both pieces of legislation require that public participation is an intrinsic part of the related decision-making processes.

These European policy instruments provide a methodological framework, aimed at ensuring that a uniform process is followed at European airports, when it comes to noise management. They

[1] UK CAA ERCD Report 1701, page 8

do not prejudge the ambition of noise action to be taken. This is consistent with the Balanced Approach and allows for noise mitigation at every airport to be considered with the necessary flexibility. One-size-fits-all solutions not being effective in noise management, this also ensures the EU regulatory framework is aligned with the principle of subsidiarity, according to which the EU should only take policy action where it can be more effective than Member States.

Through the Environmental Noise Directive and the Balanced Approach Regulation, the European Union established a comprehensive framework for aircraft noise management. In a recent evaluation, the European Commission concluded that the Environmental Noise Directive was fit-for-purpose, but also identified the need to enhance its implementation by Member States. European airports are committed to continue supporting their national authorities in the implementation of the Directive.

In addition to providing a consistent noise policy framework, the EU clearly has an important role to play as far as the enforcement of aircraft noise standards is concerned. Defined at ICAO, they are then implemented in a harmonised manner in the EU, mainly through the certification work of the European Aviation Safety Agency (EASA).

Furthermore, major airport infrastructure development projects, such as the construction of new runways, are covered by the Environmental Impact Assessment Directive (Directive 2011/92/EU, amended by Directive 2014/52/EU). It requires that such projects undergo a detailed environmental assessment process which includes public participation before they can be delivered.

At the local level, operating permits represent an important regulatory instrument for noise mitigation at airports. For major airports, they usually include requirements to reduce or limit the noise exposure around an airport. In some constituencies, such requirements are embedded in dedicated environmental permits granted to airport operators.

AIRPORTS' ENGAGEMENT

Airports are, by their nature, collaborative spaces and the most effective airport operators have long recognised that for better or for worse, they are essentially aviation's ambassadors on the ground. In this role, they must maintain positive cooperation between the stakeholders on the airport site and champion their collective achievements off-site to local and regional communities, city councils and sometimes, national governments.

Over the past two decades, the majority of Europe's airports have been intensely proactive in their pursuit of positive relations with their local communities – not just in terms of supporting local employment, donating to or sponsoring local teams and events, but also through properly executed environmental stewardship. Their work in this regard has gradually gained momentum over time, in parallel to the steady evolution of environmental science that has occurred over the past decades.

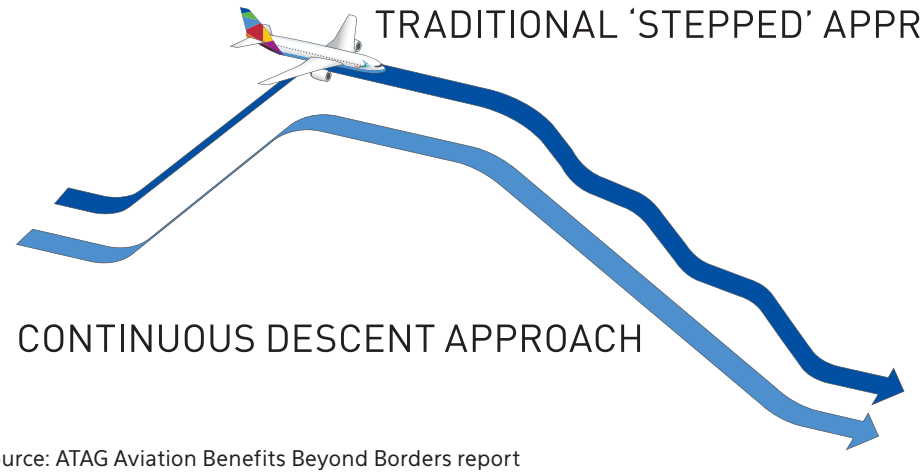
As already outlined, aviation noise is one of the most significant environmental aspects that an airport has to address, not least because of the combined factors of air traffic growth and the fact that the body of research about the impact of noise is still building. Indeed, this is one of the reasons why the airport industry was looking to the WHO Guidelines to provide more insight into the issue.

In that respect, there is one important question to be addressed: **what does it actually mean to reduce noise exposure?** One straightforward answer would be that in a community, less people are exposed to a certain level of noise. But are we still reducing noise if at a certain distance of the airport, noise levels decrease – but a higher number of people are being exposed to it? Or less people, but to higher noise levels? Or if following the implementation of new air navigation routing, relief for one community is achieved, but new communities are overflown?

The complexity of this topic highlights that noise mitigation is as much about technical and operational improvements as it is about finding socially acceptable solutions. Social acceptability is often related to fairness. Yet, what people will perceive as fair might differ from community to community. This is why involving and engaging communities in noise management at an airport is nowadays recognised as the main key success factor for mitigating noise.

In keeping with ICAO's Balanced Approach, airports put a lot of effort into building confidence and trust with their local communities, so as to facilitate better mutual understanding of the issues affecting both sides and more significantly, find solutions that address the nexus of the positives that air traffic growth brings, with the negative effects related to noise and emissions.

This can be done, for instance, by reducing the noise impact of aircraft approaches or departures, by making sure aircraft fly higher for a longer period of time than usual when approaching the airport (e.g. through steeper approaches) or land in a smoother way, requiring less thrust and thus producing less noise (e.g. through Continuous Descent Operations – see graph below). Another option is to circumvent densely populated areas by changing aircraft routes. The Single European Sky Air Traffic Management Research (SESAR) programme is working on developing innovative solutions in this area. Most of the major airports in Europe are involved in this work.



Source: ATAG Aviation Benefits Beyond Borders report

CONDITIONS FOR SOLUTIONS

To implement such improvements, it is critical that all stakeholders involved in airport operations work in a collaborative manner, to consider all the potential implications of different solutions. For instance, with safety being paramount in air transport, new procedures must not imply increased operational risks. This also means that certain weather conditions, for instance heavy winds or low visibility at the airport, are usually incompatible with the use of procedures aimed at reducing noise. Some procedures require the aircraft and/or the airport to be equipped with certain technologies. If they are not available, a procedure cannot be flown.

It is also important to ensure noise reduction does not compromise other environmental goals. For instance, aircraft flying longer routes to avoid densely populated areas can lead to increased fuel burn and emissions.

Frameworks such as Environmental Management Systems and EUROCONTROL's Collaborative Environmental Management approach support airports and their partners in addressing all these aspects, but as you can see, like a Rubik's cube – solving one part of the puzzle usually has implications on the wider operation.

To demonstrate what and how airports do this, in real terms, let us consider some examples:

LONDON HEATHROW

Heathrow
Making every journey better

The busiest airport in Europe, Heathrow has noise limits and operating restrictions in force, and in particular some that apply to flights at night, to promote the use of 'best in class' aircraft. The airport operator's *Fly Quiet and Green* programme is the UK's first ever league table which ranks airlines according to their fleet and operational performance and is intended to encourage airlines to use quieter (and lowest NOx) aircraft and to fly them in the quietest possible way.

The league table provides airlines with regular feedback and can help them identify their strengths and weaknesses or highlights areas they can target for improvements.This is done through metrics like the Continuous Descent Approach (CDA) violations and Track deviations on departure (TK violations). Heathrow works actively with airlines to help them improve their performance and efficiency.

Heathrow also provides financial incentives for airlines to use the quietest aircraft through variable landing charges. The landing fee for the noisiest aircraft category is now nearly 12 times that of the quietest.

VIENNA AIRPORT

VIE Vienna International Airport
Offen für neue Horizonte.

As part of Vienna Airport's Masterplan published in the late 1990's, it embarked on a mediation process with the local neighbouring communities, ultimately securing the signatory of over 50 parties to the General Mediation contract in 2005. This contract lays down the requirements to be respected by the airport in its future infrastructure development. This mediation process successfully demonstrated that even in the context of highly controversial infrastructure projects, it is still possible to carry out a participatory, transparent and fair procedure in which everyone affected can have a voice.

This in turn blossomed into a full on Dialogue Forum in 2006, which has met on a regular basis ever since – in its first 10 years, there was 330 meetings of various committees involves and 120 regional conferences. As a result, the growth of the noise contours has been decoupled from the growth in passenger numbers, despite the use of noisier aircraft.

LONDON GATWICK

YOUR LONDON AIRPORT Gatwick

The Airbus A320 is one of the most popular aircraft in Europe, with easyJet counting as one of their most significant users in Europe. The Noise Management Board of Gatwick Airport decided to incentivise airlines to make a modification to the Fuel Over Pressure Port (FOPP) flow deflector of the aircraft. The modification reduces noise on arrivals. As a result, over 300 aircraft were modified before the new regime came into effect.

By 2018, 97% of the Airbus A320 family of aircraft flying from Gatwick, which account for half of all of the airport's flights – had been modified to reduce noise. This initiative has reduced the airport's noise footprint by 3% in the last full calendar year according to independent noise contour analysis by the UK Civil Aviation Authority, despite the number of aircraft increasing over the same period.

NAPLES

AEROPORTO INTERNAZIONALE di NAPOLI

Naples International Airport is a classic example of "city airport", as it is very close to the city centre of Naples, a UNESCO World Heritage Site. The city of Naples has a very high urban density and there are as well some hills that have implications on flight procedures, making it very difficult to avoid populated areas during take-off or landing on the western side of the Runway.

In 2005, the airport decided to upgrade the Air Navigation Systems, in order to have more precise approach and departure systems.

The ANS Provider developed a new procedure for the initial climb overflying the city of Naples, that was mainly based on the different performance of the aircraft rather than a fixed point on the ground. The aircraft had to reach a specific height before starting a long turn to the right. Due to several factors influencing the aircraft performances (load, temperature, engines characteristics, etc.), the turning altitude was being reached at different points, having a very wide dispersion of the radar tracks on the territory. This resulted in more of the city's population being exposed to aviation noise.

People started to complain very vocally, asking for a drastic reduction of the airport capacity. GESAC, the management company of the airport took these complaints on board and suggested a noise abatement procedure. This was approved by ENAC (the Italian CAA) and adopted by ENAV (the Italian ANSP). GESAC installed a noise monitoring system in order to identify the aircraft infringing the noise abatement procedure, and asked the CAA to fine airlines accordingly.

After few months, the issue was completely solved and the radar track showed that almost all the aircraft were strictly following the noise abatement procedure.

In 2017, the overall compliance to the noise abatement procedure was 99.7 % and a 42% reduction in noise exposure was achieved, compared to the airport's 2002 noise footprint, with a number of air traffic movements of 21% more in the reference period.

INSULATION

As part of their efforts to be a good neighbor and recognising their responsibility to address negative impacts of noise, many airports invest substantially in retrofitting homes and noise-sensitive buildings that are heavily exposed with sound insulation and ventilation. Many of them offer special assistance and service to the residents concerned. For instance, at Cologne/Bonn Airport, the airport operator informs the residents of available insulation options, accompanies the construction works and provides on-site assistance in case of questions or issues. The operator also verifies whether works have been correctly completed. Stuttgart Airport specifically promotes the installation of sound-absorbing ventilators, helping maintain good air quality in houses with closed windows. In Spain, the airport operator Aena has 18 on-going noise insulation programmes, with 23,096 dwellings and noise-sensitive buildings being insulated between 2000 and 2017.

It is important to note that sound insulation schemes at airports differ based on the regulatory regime, planning conditions and other aspects so that all insulation schemes are not the same.

As you can see from the broad sample of case studies cited, airports are approaching the issue of aviation noise and its associated impacts in a wide variety of ways – each taking into account challenges that are particular to their circumstances, not to mention their region and culture. Some operational solutions can be applied broadly, while others require a deep understanding of the dynamics of the local communities and their perception of aviation.

WHO ENVIRONMENTAL NOISE GUIDELINES FOR THE EUROPEAN REGION

In its new Environmental Noise Guidelines for the European Region, published on 10 October 2018, the World Health Organisation (WHO) identified three main recommendations in relation to aircraft noise:

- For average noise exposure, the GDG [Guideline Development Group] **strongly recommends** reducing noise levels produced by aircraft below **45 dB Lden**, as aircraft noise above this level is associated with adverse health effects.
- For night noise exposure, the GDG **strongly recommends** reducing noise level produced by aircraft during night time below **40 dB Lnight**, as night-time aircraft noise above this levels is associated with adverse effect on sleep.
- To reduce health effects, the GDG **strongly recommends** that policy-makers implement suitable measures to reduce noise exposure from aircraft in the population exposed to levels above the guideline values for average and night noise exposure. For specific interventions it recommends **implementing suitable changes in infrastructure**." Changes in infrastructure are defined as "opening and/or closing of runways, or flight path rearrangements" (page 62).[1]

According to the WHO, a strong recommendation "can be adopted as policy in most situations. The guideline is based on the confidence that the desirable effects of adherence to the recommendation outweigh the undesirable consequences. The quality of evidence for a net benefit – combined with information about the values, preferences and resources – inform this recommendation, which should be implemented in most circumstances" (page 23).

[1]The page numbers in this section refer to the WHO Environmental Noise Guidelines for the European Region, 2018

The airport industry acknowledges that certain levels of aviation noise can be undesirable and entail a risk for people's health. Indeed, as the previous section reveal, there is a growing movement in the industry to try to understand the complexity of the issue more comprehensively and to address it accordingly.

We welcome the systematic reviews of scientific literature undertaken by the WHO in preparation of the Guidelines and do not question the results of these reviews. However, we have our concerns in relation to the methodology of the guideline development and the logic of the links it makes and the claims that it asserts in formulating its recommendations. Our concerns regarding the guidelines for aircraft noise are related to the following questions:

CAN MEDIUM QUALITY EVIDENCE BE A BASIS FOR STRONG RECOMMENDATIONS?

The WHO rates the scientific evidence available according to four quality degrees – very low, low, moderate and high, differentiated based on the level of certainty in the estimates of health effects that a piece of evidence conveys. As mentioned above, moderate quality means that "further research is likely to have an important impact on the certainty of the effect estimate and is likely to change the estimate" (page 16).

The WHO set the following decision rule when defining the noise guidelines: "Setting a strong recommendation was only considered if the evidence was at least moderate quality" (page 25). ACI EUROPE acknowledges that quality of evidence was not the only factor assessed and that additional, contextual elements were also considered. Nevertheless, the notion of an "important impact on our certainty" in the definition of moderate evidence seems inconsistent with the confidence referred to in the definition of a strong recommendation. At the least, the decision of the WHO to adopt such a decision rule should have been explained and justified.

This approach is worrying as actually, the overall quality of the evidence used for the three recommendations on aircraft noise has been assessed as either very low, low or moderate.

WHY ARE INDOOR NIGHT NOISE LEVELS NOT CONSIDERED?

The guidelines for night noise exposure are based on outdoor noise levels. At the same time, the WHO acknowledges that the "differences between indoor and outdoor levels are usually estimated at around 10dB for open, 15 dB for tilted or half-open and about 25 dB for closed windows" (page 9). It also recognises that indoor noise levels are "particularly relevant for effects on sleep" (page 103).

The recommendation to limit night noise exposure to Lnight 40dB can thus be translated to indoor levels ranging from 30 dB to 15 dB. To put these noise levels into context, a conversation at home in a quiet suburb on average produces 50 dB, while 30 dB is the noise level usually experienced in quiet rural areas. 20 dB can be produced by whisper and rustling leaves.[1]

[1] http://www.industrialnoisecontrol.com/comparative-noise-examples.htm

Given the considerable differences between indoor – and outdoor noise levels and the fact that in Europe, a very large majority of population sleeps inside dwellings, is it appropriate to only consider outdoor noise levels when establishing recommendations on night noise exposure?

HAVE NON-ACOUSTIC FACTORS BEEN SUFFICIENTLY ADDRESSED?

The guideline values for average and night noise exposure from aircraft have been derived from research on annoyance and self-reported sleep disturbance. As outlined in one of the previous chapters, these health outcomes are those for which non-acoustic factors play an important role.

Self-reported sleep disturbance

As pointed out by the WHO, self-reported sleep disturbance is a valid health outcome to be considered in its own right. The WHO also acknowledges that "self-reported sleep disturbance might differ considerably from objectively measured parameters of sleep physiology" (page 11). Against this background, it is worth asking whether considering self-reported sleep disturbance is actually sufficient to guide policy-making on night noise exposure. For instance, as outlined in one of the previous sections, the NORAH-Study found that the introduction of a night flight ban at Frankfurt Airport and the resulting noise reduction were not associated with a positive impact on the self-reported sleep disturbance of residents in the vicinity of the airport. While reducing noise exposure is of course necessary, it does not automatically entail an improvement in the way people perceive their sleep quality.

Annoyance

The WHO acknowledges the existence of non-acoustic factors of annoyance (e.g. pages 13-14), however it is not clear to what extent it did consider them in the definition of recommendations. This raises questions with regard to their potential effectiveness. If a recommendation aims to minimise the risk of annoyance, how can it be properly defined without addressing all the factors that contribute to annoyance?

For instance, the WHO notes that "cultural differences around what is considered annoying are significant, even within Europe. It is therefore not possible to determine the 'exact value' of %HA [highly annoyed population] for each exposure level in any generalised situation" (page 109). Consequently, the WHO advises to use local dose-response relationships for annoyance whenever possible. How does this match with the setting of a strong recommendation for average noise exposure based on annoyance risks, bearing in mind that a strong recommendation "can be adopted as policy in most situations"?

The consideration of non-acoustic factors is also very relevant for the WHO's recommendation to implement infrastructure changes. The WHO acknowledges that "opening new runways or increasing the number of flights usually means considerable change in the environment for inhabitants of the affected area. It has been postulated that the change of exposure itself may be an annoying factor" (page 74). If change can contribute to annoyance, doesn't a generalised recommendation to implement changes (opening and/or closing of runways, or flight path rearrangements) imply the risk of actually increasing annoyance in some cases, at least temporarily?

WHY ARE INTERVENTION RECOMMENDATIONS FOCUSING ON INFRASTRUCTURE CHANGES?

As explained in the previous sections, the aviation sector works with a wide array of noise mitigation measures, based on the ICAO Balanced Approach. The WHO acknowledges that "examples of best practice already exist for the management of noise from aircraft" (page 62). Changes in infrastructure are one of these measures and can effectively limit or reduce noise exposure around some airports. However, it cannot be maintained that such changes are effective in all instances and should thus be recommended to be adopted as policy in most situations. Achieving such a one-size-fits-all solution is unlikely to be compatible with existing requirements for noise management within Europe.

As foreseen by the Balanced Approach, and the associated EU regulation, the noise situation at every airport needs to be assessed individually and the most suitable intervention(s) selected accordingly. In addition, as outlined above, the Environmental Impact Assessment Directive requires that projects such as new runways must go through a detailed environmental assessment process which includes public participation before they can be delivered.

Furthermore, the WHO recognises that "it is widely acknowledged that the most effective actions to reduce noise exposure tend to be those that reduce noise at source" (page 106). Specifically, in relation to aircraft noise, it notes that progress is being made in research & development of quieter aircraft (page 75 of the report). Why is this not reflected in the recommendations (whereas reducing noise at source is recommended for road noise)?

The answer to this question seems to be related to the studies reviewed during the guideline development process. Only seven studies have been considered, and "the largest body of research concentrated on the opening and closing of runways, leading to subsequent changes in flight paths" (page 72). In this regard, it seems that the recommendation to implement infrastructure changes actually simply reflects the limited availability of relevant research, rather than being the result of a comprehensive analysis of different types of interventions.

Overall, the WHO recognises that the "limited evidence base on the health effects of environmental noise interventions is thinly spread" (page 102). ACI EUROPE fully agrees with this finding and strongly supports the WHO's call for further research on the effectiveness of interventions. In the meantime, we believe that the limited, currently available research does not justify the setting of a generalised recommendation on infrastructure changes.

HAVE THE COSTS AND BENEFITS OF THE GUIDELINES IMPLEMENTATION BEEN ASSESSED?

The WHO indicates that in addition to the review of scientific literature on noise impacts on health, it also considered other factors when developing recommendations, including the values and preferences of the population, as well the costs and benefits of noise mitigation. ACI EUROPE welcomes such a comprehensive approach, aimed at putting noise issues into a broader societal context, however we believe that the guidelines do not properly reflect the findings of this additional analysis.

Example 1:

The Guidelines rely on the estimation that the benefits of adhering to the recommendations exceed the related costs, while no comprehensive cost-benefit analysis has been performed.

The WHO recognises that "no comprehensive cost-benefit analysis for the WHO European Region yet exists" (Page 74). It also acknowledges that "resources needed to implement different intervention measures may vary considerably, because they depend on the situation and the type of intervention required" (Page 74). This rightly points to the complexity of assessing costs and benefits of noise mitigation and the need to do so at a local level.

However, another statement in the same section contradicts these earlier notes: "the GDG [Guideline Development Group] estimated that the benefits gained from minimizing adverse health impacts due to aircraft noise exposure outweigh the possible (economic) harms". (page 73)

If the costs would vary from an airport to another, then on what basis can it be confidently concluded that the benefits would outweigh the costs of reducing noise?

Example 2:

The Guidelines do not seem to take account of the complexity of noise mitigation and the significant resources required to implement it.

For instance, in relation to changes in flight paths, the WHO notes that "[i]n principle, such intervention measures do not involve any direct costs" (page 75). This statement is incorrect because changes in flight paths might require new technological capabilities for air traffic control and aircraft, for instance those using satellite-based navigation. Acquiring the relevant equipment does imply costs. Longer routes to circumvent populated areas do also entail more fuel burn and subsequently higher costs for aircraft operators.

The Guidelines also state that some noise mitigation interventions can be implemented "at very low cost" (page 76). It is not clear which interventions are covered by this statement. Any aircraft noise mitigation intervention requires a thorough, complex and long analysis process, as well as engagement and discussion with the stakeholders concerned. This requires substantial resources, let alone the technological and operational implementation of noise reduction.

Example 3:

The Guidelines rely on the assumption that the majority of the population would welcome the implementation of the recommendations, while at the same time recognising that people's attitudes towards air transport and noise can vary.

The WHO notes that "those benefitting from the services and revenues generated by an airport may disregard noise reduction measures as an additional, unnecessary cost, while those living around an airport and affected by aircraft noise may be in favour of noise reductions" (page 74). This statement contradicts an earlier one, according to which "values and preferences of individuals living in the vicinity of different airports may vary" (page 73). Furthermore, it suggests that people living close to the airport might not experience any positive impact from the airport activity. European airports recognise that in some cases the negative impacts of

aviation do prevail for local residents. They therefore increasingly focus on ways to provide local communities with more benefits, thus enhancing their quality of life. For instance, some airports do offer preferential opportunities for employment to local residents, such as Heathrow Airport. It must also be noted that there are communities which value their proximity to the airport in spite of noise exposure, as evidenced by the existence of local community groups supporting airport activity. Noise-related policy making needs to take account of the overall impact of an airport on local communities and the variety of people's values and preferences.

DOES REDUCING NOISE NECESSARILY REDUCE EMISSIONS?

The WHO rightly calls for the coordination of "approaches to control noise sources and other environmental health risks" (page 106). Such holistic policy-making is required because of the interdependencies that exist between noise and emissions. However, we wonder whether the complexity of addressing these interdependencies has been sufficiently analysed.

The general recommendation to implement infrastructure changes, including flight path diversions, seems to disregard that while circumventing densely populated areas can indeed reduce noise exposure, it can also lead to increased gaseous emissions, due to potentially longer routes. Whether a flight path change is relevant and not entailing unacceptable environmental side-effects therefore needs to be assessed locally on a case-by-case basis, for each airport individually, as prescribed by the ICAO Balanced Approach.

In another statement, the WHO notes the following: "The GDG also acknowledged that intervention measures like night flight bans might also reduce carbon emissions, thereby positively influencing the shift towards a greener and more sustainable economy" (page 73).

In this regard, it is important to note that night flight bans and other types of operating restrictions do not necessarily contribute to reducing the overall number of flights in a country or region. As long as people want to travel and to benefit from associated services, such interventions rather move demand from one airport to another. In the end, this can imply that passengers travel longer routes to reach a certain destination. This can potentially increase emissions. Therefore, a comprehensive assessment of the implications of an operating restriction is required before deciding on its implementation, to rule out negative side-effects.

HOW WOULD THE IMPLEMENTATION OF THE RECOMMENDATIONS IMPACT THE SOCIETY'S MOBILITY NEEDS?

At a distance of 3 km from the airport, 10 day-time flight movements of a Boeing B737-800 are likely to result in an average noise exposure of Lden 45 dB .[1] To put these figures into perspective, the top 20 European airports handled on average 17,879 daily movements in 2017, which means on average 894 movements per day per airport. It is therefore very unlikely that the WHO guideline values could be reached through infrastructure changes. Instead, they would imply a very severe limitation of the number of aircraft operations.

[1] Overhead flights, calculations based on the Integrated Noise Model (INM) 7.0

For example, assuming a constant aircraft fleet mix, it is estimated that at Frankfurt Airport (which is operating under a night flight ban from 23:00 to 5:00), limiting the air traffic to a mere 2% of the traffic handled in 2017 is likely to be required to meet the guideline values at all housing areas around the airport. This would be equal to 26 aircraft movements a day compared to approximately 1,300 that occurred in 2017.

If attempting to avoid severe impacts on air transport, achieving the WHO guideline values would potentially imply a massive relocation of people from areas within the Lnight 40dB / Lden 45 dB contours. Compared to the noise contours in use for noise mitigation at European airports today, Lnight 40 dB / Lden 45 dB contours would significantly increase the areas and populations concerned. For instance, estimations show that at Madrid Barajas Airport such contours could potentially encompass areas as far as 40 km away from the airport, and 70 km in the case of Frankfurt Airport.

Generic recommendations, which suggest that there can be a one-size-fits-all solution to noise, can generate unrealistic expectations with regard to their feasibility. Over time, this could actually even be expected to intensify the annoyance felt in a local community – potentially jeopardising the population's protection from adverse health effects.

Based on the above concerns, ACI EUROPE considers that given the potential implications of the new guidelines on mobility and related services that our modern societies rely on, the discussion on their potential implementation needs to be considered in a broader context. We cannot talk about acceptable noise levels in isolation from the question of different pathways for the development of our societies as a whole. In light of the growing emphasis of travel as part of 'experiential living' beloved of millennials, boomers and Generation Z, it is time for a critical discussion on the growing mobility needs of our societies and the environmental impacts of transportation – a discussion that takes into account all the positive and negative impacts of mobility.

THE PURSUIT OF PROGRESS

So where does this put the issue of Aviation Noise?

The subjective experience of noise and its associated impacts require most considered and thoroughly thought through solutions.

In spite of several achievements in addressing aviation noise, there is clearly still a long road to be travelled in the pursuit of progress on this issue. ACI EUROPE and its members recognise this.

One of the main challenges of noise mitigation is finding a palatable balance between noise reduction and the societal role that aviation plays in delivering the value-creating connectivity that makes cities thrive.

Mobility and health are inescapable themes in today's society – whether you live in a city or in the countryside. Building upon the EU right to free movement, the EU Aviation Strategy launched in December 2015 is unequivocal about its goal to achieve an enhanced transport network that fundamentally improves the quality of life of EU citizens.

That includes infrastructure investment through Trans-European Networks funding and other associated programmes. It includes intensifying connectivity by securing more Open Skies agreements with third countries. It also includes the priority of lowering environmental impacts through priorities like decarbonisation. In parallel, the EU 7th Environment Action Programme (7th EAP° sets the objective that by 2020, noise pollution in the EU (broadly, not just in aviation)) will have significantly decreased, so there is no question of mobility progressing without noise management advancing as well.

So, in view of the concerns the airport industry has in relation to the WHO Environmental Noise Guidelines for the European Region, you might well ask what are airports going to do to better address the issue of aviation noise?

The airport industry now recognises that scientific research plays a key role in providing the appropriate basis for policy and decision making on aircraft noise. Noise mitigation policy and regulation need to be based on comprehensive, scientific knowledge about the positive and negative impacts of aviation – helping achieve the best outcomes in terms of reducing impacts and enhancing benefits for local communities.

In its recently completed Airport Noise Research Roadmap, ACI EUROPE's dedicated Noise Taskforce identified the following priority research needs that require immediate attention.

1. Research consensus on a balanced scorecard of aviation-related "quality of life" indicators, to assess the aggregated positive and negative impacts of aviation on local communities and consequently, identify the best ways for the airport to improve the overall quality of life of communities.

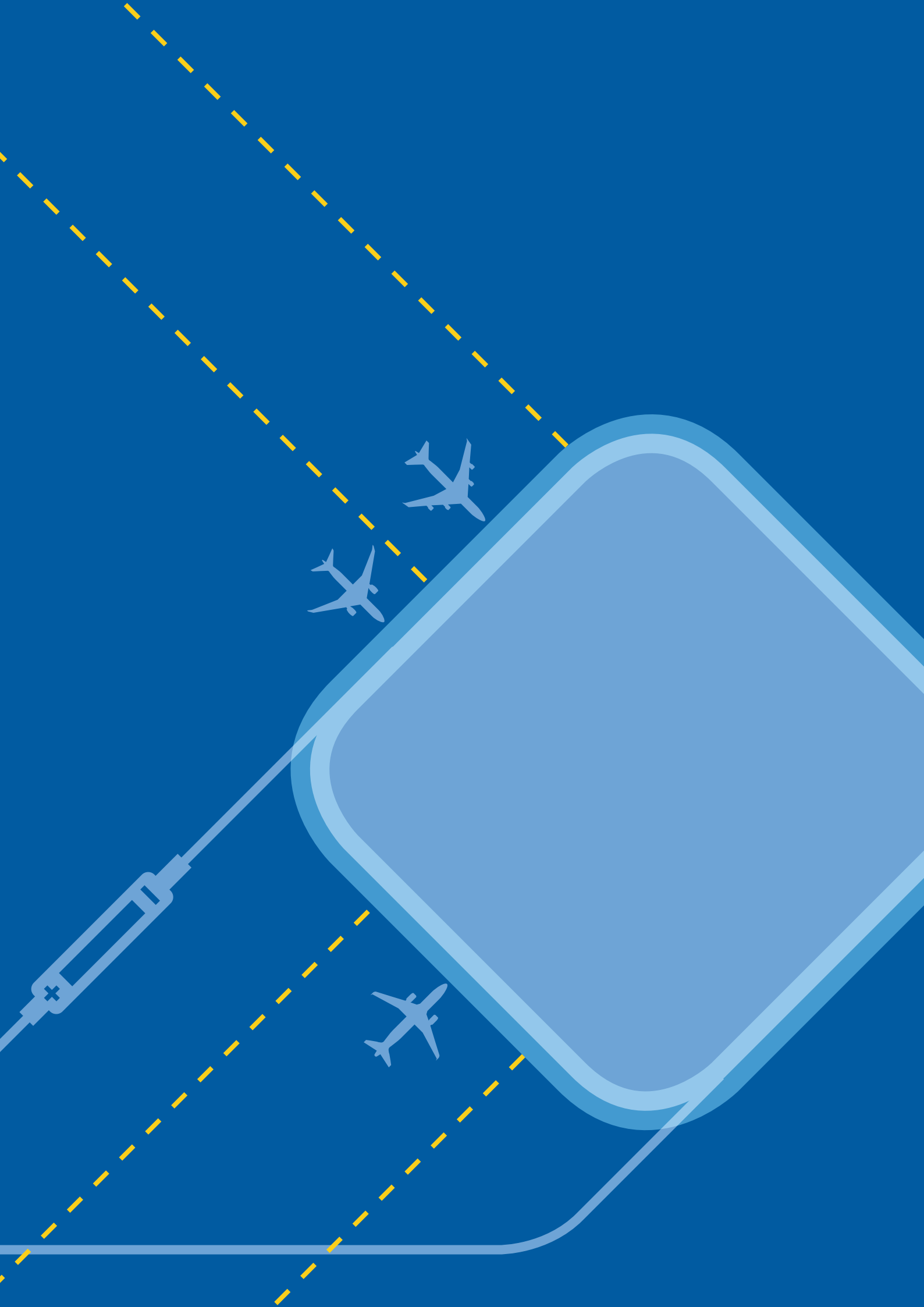
2. Establish an internationally recognised methodology that enables a structured and consistent approach for assessing initiatives and outcomes, by valuing and setting in context, the positive and negative impacts of aviation.

3. Understand the various values of the noise mitigation interventions and initiatives that airports undertake.

4. Aim to better understand the relationship between non-acoustic factors and health outcomes and whether they can be addressed in a way that reduce negative health impacts.

5. Develop the metrics and communication tools that can help build effective relationships with communities, by enhancing transparency and clarity in explaining noise and any adjustments to the noise dynamics around an airport.

These 5 priorities form the basis of a 5 year research strategy – one that pursues the advanced understanding of the issue of aviation noise in a more comprehensive and joined up way. ACI EUROPE believes that addressing these research needs will help enhance the effectiveness of noise management around airports and contribute to reconciling the mobility needs of today's societies with environmental and public health protection.



On 10 October 2018, the World Health Organisation (WHO) issued a long-awaited study on noise, with guidelines recommending measures to be implemented in Europe – the Environmental Noise Guidelines for the European region. The Guidelines naturally contain a significant section on the noise generated by transport & mobility.

In view of the multi-faceted nature of the subject, the continuing evolution of the sciences involved, ACI EUROPE decided to publish this Analysis Paper. Why? We want to clearly lay out complexity of the subject and the sciences needed to analyse it in a comprehensive manner, as well as the research gaps that still need to be addressed, in the hope of setting a course that will can enable us the make genuine progress on this challenging issue.

ACI EUROPE is the European region of Airports Council International (ACI), the only worldwide professional association of airport operators. ACI EUROPE represents over **500 airports** in 45 European countries. Our members facilitate over 90% of commercial air traffic in Europe: **2 billion passengers**, **20 million tonnes of freight** and **23.7 million aircraft movements** in 2016. These airports contribute to the employment of **12.3 million people**, generating **€675 billion each year (4.1%) of GDP** in Europe.

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