Report on awakenings as a response to noise during sleep

5 September 2023

Note with respect to noise effects on health

Night-time use of the runway system at Dublin Airport

Reference to the Relevant Action Revised EIAR (September 2021)

ABP-314485-22

F20A/0668

DAA PLC

*by **Prof. Dr. Thomas Penzel (Charité Berlin, Germany**)*
*Prepared for **Tom Phillips + Associates***

Purpose of the Report

This report has been prepared at the request of Tom Phillips and Associates (TPA) in support of the preparation of a Response to Further Information Request (RFI) issued by An Bord Pleanála (ABP Ref: 314485-22).

The purpose of the report is to provide a professional opinion in relation to RFI item 1 in particular. The preparation of this opinion has involved a review of the planning application material including the EIAR (September 2021) & the ABP Request Letter as well as the 3rd Party Observations submitted against the proposed development.

The aims of the report are to provide:

a) An outline/guidance on the approach specified in the review supporting the WHO ENG 2018 (as referenced in the ABP Request Letter) including a summary of what the guidelines advise in relation to 'awakenings'

b) A professional opinion as to the suitability of the above referenced approach and why it may or may not be an appropriate assessment tool.

It is intended that the report be used in determining the case for amendment / replacement of two operating restrictions for the North Runway at Dublin Airport.

This includes a replacement of a numerical cap on average number of flights permitted between 23:00 and 7:00 by a noise quota limit for the same time period, and allowing additional flights to take off and land in the transition hours 23:00 to 00:00 and 6:00 to 7:00.

RFI item 1

Item 1 of the RFI request states the following:

> *The assessment in the EIAR of the effects of noise from ATMs at night (2300 to 0700 hrs) is based on energy averaging noise metrics over relatively long periods e.g. 8 hrs, correlated with the percentage of the exposed population likely to self-report being highly sleep disturbed (%HSD), assessed with a standardised scale based on the guidance in the World Health Organisation's (WHO) Environmental Noise Guidelines 2018. (WHO ENG 2018)*
>
> *However, aircraft noise is not experienced in an "average" fashion. It consists of periods of comparative quiet when there are no aircraft flying near or over a receptor interspersed with relatively short periods of noise when an aircraft approaches a receptor, builds to a peak at its closest approach and then decays as the aircraft moves away from a receptor.*
>
> *The EIAR includes information on peak LAmax noise levels from ATMs and the number of these events at night in terms of the N60, N651 noise contours for the 92 day summer average of ATMs and airport modes, and the N60 metric and LAmax2 for the single modes of airport operation. But these data are presented for information purposes only and there is no analysis of the effect of peak LAmax noise levels from ATMs on additional awakenings at night regarding the baseline and consented scenarios.*

You are requested to assess the probability of additional awakening due to the peak LA,s,Max of ATMs at night between 2300 and 0700hrs for the 92 day summer average of ATMs and airport modes, and for the single modes of airport operation and for the likelihood of additional awakenings for the overall annual average number of ATMs at night, based on the approach described in the review supporting the WHO ENG 2018 (Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and the Effects on Sleep - International Journal of Environmental Research and Public Health).

The Scenarios tested should include baseline conditions and the future operation of the airport proposed under the current application.

As indicated in item 1 of the request (above), the EIAR included with the Relevant Action application had provided data on peak noise levels from ATMs and the number of these events per night but had not assessed the effects of same in terms of additional awakenings. There are 2 key factors to consider in this regard.

1. What constitutes an awakening and how do we measure significance?.
2. Is the probability of additional awakenings an appropriate measure of the effects of aircraft noise on the basis of the above question?

1. What constitutes an awakening and how do we measure significance?

In sleep research we distinguish awakenings and arousals. Awakenings are transitions from sleep to wakefulness which last at least 30 seconds. This is, because the sleep recordings are scored in so-called epochs with a duration of 30 seconds. In brain activity recorded during the night, we can quantitatively assess the state of sleep or wakefulness. Each epoch of 30 seconds of brain activity recording, which we call polysomnography, is manually scored and classified as being in light sleep, deep sleep, REM sleep, or wakefulness. Sleep is not just a state of unconsciousness, but we change sleep stages during the night often in order to have all components of light sleep, deep sleep and REM sleep. Perhaps 40 or 50 changes of sleep stages are normal during a night in a healthy person. If there is a move from a deeper sleep stage to a higher one, and if this change is short, shorter than 15 seconds, then we call this arousal. A healthy person has about 24 arousals during a normal night. The number may vary with age, it increases with age, the number may vary with worries due to any condition like stress, family or worklife issues. Usually we do not notice arousals. Only if an arousal is lasting longer than 15 seconds, perhaps 3 minutes, and turns into wakefulness, then we become aware of wakefulness during regular sleep time and we tend to be annoyed.

There is a relationship between noise events and arousals. A steady level of noise does not increase the number of awakenings. But isolated noise events, like airplane overflight, may cause arousals. The dB which causes an arousal is not the same across the night. In the beginning of the night sleep we have ‘deep sleep’ where much higher noise levels are needed for awakenings. In the morning hours we have ‘light sleep’ and ‘rapid eye movement (REM) sleep / so called dream sleep’. During light sleep much lower noise levels can cause awakenings. And during REM sleep it is pretty unpredictable what happens with noise events. A noise event can just be built into the dream and nothing happens. But a noise event of the same physical level L_{Aeq} can also cause an abrupt awakening and very uncomfortable perceptions. The worst case scenario in terms of perceptions is, that a person wakes up and does not fall back to sleep. Because of the natural sleep structure the morning hour between 6:00 and 7:00 is more vulnerable to awakenings and a bigger concern than the evening hour between 23:00 and 0:00.

The WHO guidance does not set significance criteria in terms of increased awakenings. This is considered to be appropriate, because “increased awakenings” is a matter of probabilities.

One cannot say that an additional noise event or an increase in level of noise creates an additional awakening but merely that it increases the probability for awakenings. This is depicted in figure 1. The figure shows that increases in the level of noise steadily increase the probability. It may be more a matter of negotiations whether 5% or 9 or 11% are acceptable.

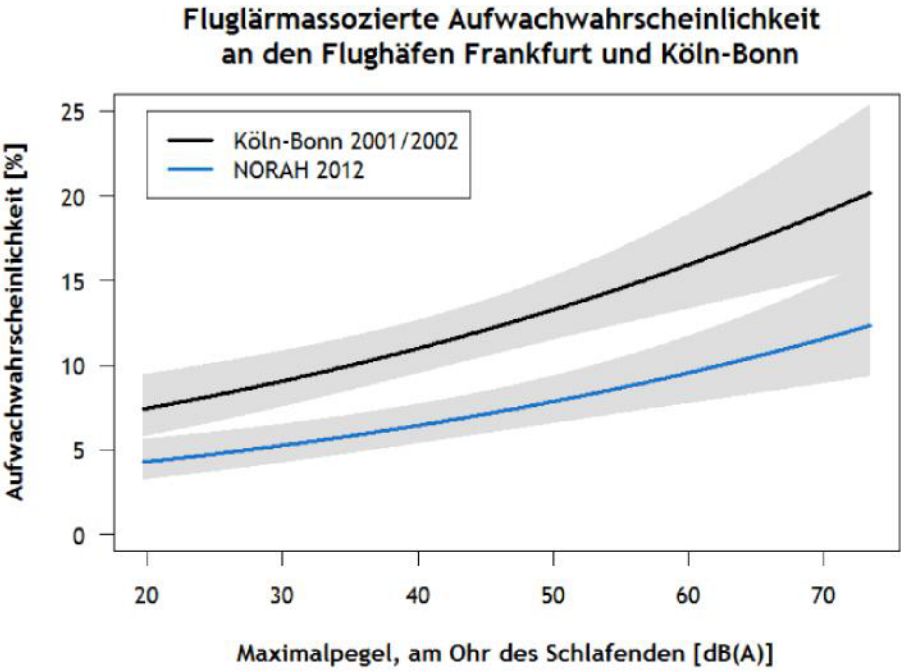

Abbildung 3-21: Expositions-Wirkungskurve zwischen maximalem Schalldruckpegel eines Fluglärmereignisses und der fluglärmassoziierten Aufwachwahrscheinlichkeit der Probanden aus NORAH im Jahr 2012 (N=41) sowie den Probanden am Flughafen Köln-Bonn (N=61) (Basner et al., 2006) beruhend auf dem Modell in Tabelle 3-7. Schraffiert dargestellt sind die 95%-Konfidenzintervalle der Köln-Bonner Studie und der NORAH-Studie des Jahres 2012. L_{ASeq} eine Minute vor dem Fluglärmereignis=27,6 dB(A) (Median), aktuelles Schlafstadium=S2, verstrichene Schlafdauer=766 Epochen, d.h. 383 min und entspricht ca. 5:30 Uhr in NORAH 2012.

Figure 1: Probability for awakenings in percent over aircraft noise exposure for two airports: Frankfurt and Köln, as assessed in the NORAH field studies. NORAH report, volume 4, 2015

Translations - X axis *– Maximalpegel, am Ohr des Schlafenden - Maximum level on the ear of the sleeper [dB(A)];*
Y axis *– aufwachwahrsheinlichkeit -Awakening probability.*
Additional text *- Exposure-response curve between the maximum sound pressure level of a flight alarm event and the flight alarm-associated probability of waking up of the test subjects from NORAH in 2012 (N = 41) and the test subjects at Cologne-Bonn Airport (N = 61) (Basner et al., 2006) based on the model in Table 3.7. The 95% confidence intervals of the Cologne-Bonn study and the NORAH study of 2012 are shown hatched. Laseq one minute before the aircraft noise event = 27.6 dB (A) (median), current sleep stage = 52, elapsed sleep duration = 766 epochs, i.e. 383 min and corresponds to approx. 5:30 a.m. in NORAH 2012.*

2. Is the probability of additional awakenings an appropriate measure of the effects of aircraft noise on the basis of the above question?

There are debates within the scientific community whether the probability of additional awakenings is an appropriate measure due to the following variables:.

i. As alluded to above, while isolated noise events, like airplane overflight, may cause arousals, the dB level required to causes an arousal is not the same across the night. During light sleep much lower noise levels can cause awakenings. And during REM sleep it is pretty unpredictable what happens with noise events.

ii. There are large differences between so called laboratory studies where noise events are played back to a sleeping person in a sleep laboratory and field studies, where the sleeping person sleeps at home and the noise measurement is performed near the ear of the sleeping person. In the home environment, the candidates tend to tolerate much higher noise levels before they wake up. These studies have been carried out by the DLR in Cologne, by Griefahn, Basner and others as part of the study 'Leiser Flugverkehr'[1]. Therefore it is well accepted, that results from experimental studies cannot be transferred one-to-one to real life environment in the home.

iii. It has been found that the perception of study participants in relation to air traffic in general is a significant factor in reporting of disturbance. The perception was assessed in the NORAH study[2] with a question: what is your overall opinion on air traffic on a scale between 1=negative to 5=positive. See the figure 2 below, which shows how many people were negative or positive for air traffic in general. Roughly this is about a third on both sides, 30% a little or fully negative and 30% a little or fully positive. If the study participants had critical thoughts against the air traffic, then they had more objective sleep disturbance (awakenings) than those who had no concerns against the air traffic. This means the perception of the air traffic appears to have a real objective impact on health and sleep.

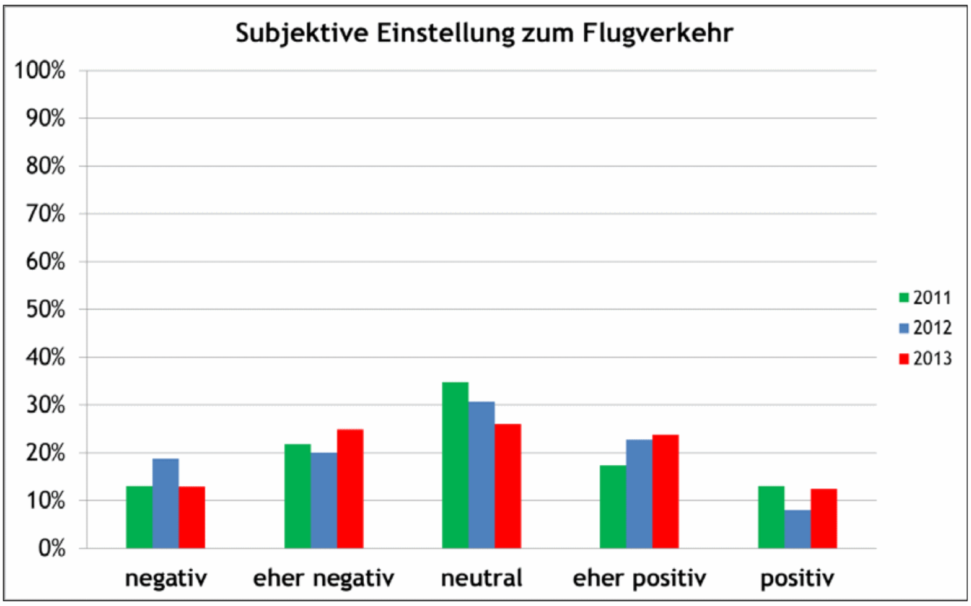

Abbildung 2-21: Subjektive Einstellung zum Flugverkehr in den Stichproben 2011 (N=46), 2012 (N=75), 2013 (N=185).

Figure 2: Subjective perception on airport in Frankfurt assessed for the NORAH study in 2011, 2012,2013 (from NORAH report, volume 4, 2015).

There are researchers who consider that the probability of additional awakenings is an appropriate measure of the impact of aircraft noise including Matthias Basner, who worked at DLR in Cologne and now at University of Pennsylvania in Philadelphia. He has written a review on aviation noise impacts in the Journal Noise and Health 2017 vol 19, page 41-50.

While the paper identifies a link between aircraft noise and awakenings, it does not include advice on noise thresholds or a definitive assessment of impacts. We therefore have no

[1] Mathias Basner et al, *Effects of Nocturnal Noise Vol. 1* (Published in German) (2004)
[2] U. Muller et al, *NORAH – Noise Related Annoyance, Cognition, and Health Study* (2015)

conclusive research on the appropriateness of using the probability of additional awakenings in order to assess the effects of peak noise levels of ATMs.

Concluding Remarks

To conclude, while a systematic approach to measuring the probability of increased awakenings would be beneficial, it is my opinion that none exists to date. The making of evidence based decisions is dependent on clearly defined thresholds in the literature, which are not available. An accurate measure of the probability of awakenings would involve an assessment of sleep and sleep awakenings with appropriate equipment which would allow us to assess sleep and awakenings. There would also be additional considerations such as the need for sleep electroencephalography, similar to the home sleep studies, as done in the NORAH study in Frankfurt.

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Prof. Dr. Thomas Penzel

Summary of CV Professor Dr. Thomas Penzel

Dr. Thomas Penzel is a IEEE fellow member. He graduated from physics (1986), human biology (1991), and physiology (1995) at the University Marburg, Germany. In 1997 he received a certificate for sleep medicine and a certificate for medical informatics. In 2001 he was awarded Professor at the University of Marburg. He was with the University of Marburg since 1982 and started many initiatives (cardiorespiratory sleep conferences and medical/engineering interdisciplinary symposia) to promote and strengthen sleep medicine in Germany and Europe. In 2006 he moved to Berlin to join the interdisciplinary sleep medicine center at the Charité University hospital and serves as scientific director of the sleep center. In 2001 he received the Bial award for clinical medicine in Portugal, 2008 the Bill Gruen Award for Innovations in Sleep Research by the Sleep Research Society, 2012 the Somnus Award by Sleep apnea patient groups in Germany, and 2014 the distinguished development award by the Chinese sleep research society. In 2022 he became fellow of IEEE for contributions to biosignal analysis for sleep medicine.

He was conference chair of IEEE-EMBC 2019. He is distinguished lecturer of EMBS and mentor in the EMBS mentoring program. 2021. He is an editorial board member on IEEE T-BME, IEEE TEHM. He holds the role of Editor and Associate Editor for journals in biomedical engineering and sleep research. He authored more than 400 papers in Pubmed with an H-index over 60 and many conference papers. His research bridges biomedical engineering and sleep research.

He had been asked to be an expert on airport noise to health issues for a number of projects. The first project was in 2002 together with DLR in Cologne on the assessment of awakenings during sleep with M. Basner, B. Griefahn and A. Samel. The next project was 2012 with the German association of companies in air traffic (BDL – Bundesverband Deutsche Luftfahrtwirtschaft) to produce a review on the impact of airport noise on health. The report was compiled with people from five German research institutes working on the impact of noise on health and was published in 2017. Since 2015 he was involved as an expert in airport expansion cases in Düsseldorf, Frankfurt, Memmingen, Köln, Dortmund, Hannover, and Vienna.