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NOISE CONTROL FOR A BETTER ENVIRONMENT

How to compile the aircraft noise exposure and impact reduction in one noise abatement program in/around airport

Zaporozhets, Oleksandr1[1]
National Aviation University
1, Cosmonaut Komarov avenue, Kyiv, 03058, Ukraine

ABSTRACT

Analytical modelling of system safety and risk methodology is used to describe the relationships between the causes, dangers and effects of aircraft noise impact in various scenarios of aviation system development. Risk and vulnerability are assessed according to the hazard identification, associated with the probability of adverse events and their consequences, and the main emphasize is done on noise annoyance. Dose-response function is applied to estimate the damage in an exposed receptor, and mathematically it gives a relationship between the intensity of the stressor and the effects in the exposed receptor. Hazard, vulnerability and coping capacity are interpreted in accordance with new requirements of the standard ISO 31000:2018.

Keywords: Aircraft Noise, Vulnerability, Annoyance
I-INCE Classification of Subject Number: 30

1.INTRODUCTION

Current ICAO [1] and ACARE [2] targets and goals are not only to reduce the noise levels, *the novel and more real approach is based on the idea that noise level reduction at receiver point is not a final result for society, but it is just a tool to achieve the real final goal, which is the reduction of the noise effects.* By ICAO this effect is defined currently as a reduction of number of people affected by aircraft noise – or simply a number of exposed people by noise over the protection guide value or predefined *number of highly annoyed people*. This is the reason for a number of new current concepts, approaches and efforts to reduce aviation noise annoyance (sleep disturbance and other effects of noise impact), keeping the produced noise levels the same (Fig. 1).

Traditionally taken approaches to aircraft noise management include reducing aircraft noise at source, to devise operational procedures and restrictions, flight routes, and other forms of mitigation, etc., to minimize individual residential exposure via ICAO balanced approach (BA) to aircraft noise control around the airports [3] and to keep the public fully informed about noise management and noise control [4,5]. The main objective is that noise problems can be addressed in an environmentally and economically responsible manner within the system while preserving potential benefits gained from aircraft-related measures. All the four

[1] zap@nau.edu.ua

basic elements of ICAO BA for aircraft noise exposure reduction are necessary to be implemented for reaching the ICAO strategic goal on aircraft noise control, but not enough. Impact analysis of aircraft noise problem last decades has shown that vulnerability and coping capacity of the population exposed to this noise changed dramatically, and both of them are subject of the control also.

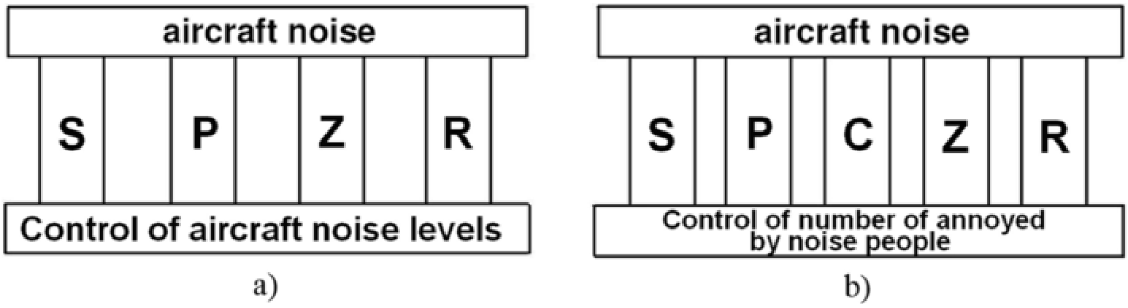

Fig. 1 Two approaches for aircraft noise impact management in airports: (**a**) 4-pillar balanced approach by ICAO (**S** – in source; **P** – noise abatement procedures; **Z** – noise zoning and land use; **R** – flight restrictions); (**b**) new approach including communication (**C**) with population to control its reaction to noise

It is important to differentiate between noise exposure and the resulting noise nuisance in different communities and manage each appropriately. ICAO Circular [5] suggests that community engagement in noise management around the airport should improve the situation and specific instruments are proposed currently how to provide it in various forms depending on task to be solved. In [6, 7] the risk assessment methodology was proposed to be used for aircraft (or in general – environmental) noise impact assessment, including the effect of human annoyance in population exposed to this noise. It was concluded that in parallel to exposure analysis the vulnerability of the population to noise is dominant value also for final results of noise impact assessment. In general case vulnerability of the *elements-at-risk* (population living around the airports) to the hazard under consideration (aircraft noise) – "the conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards" [8], so a term *vulnerability* "describes such characteristics and circumstances of a community, system or asset under consideration that make them susceptible to the damaging effects of a hazard" [8]. Relating to a number of interrelated conditions vulnerability may increase the susceptibility of a community to the impact of any hazards, including noise. In this case the level of noise exposure is considered as the significant determinant of perceived disturbance by residents.

2. VULNERABILITYASPECTS FOR NOISE IMPACT ASSESSMENT

2.1. Concept of vulnerability

Concept of vulnerability is proposed to be widening to include the coping capacity of the system under consideration, as it is considered by [9] and it takes into account the multifunctional dependent concept-formula between *hazard*, *vulnerability* and *capacity* [10]. In such context, in dependence with conditions and requirements for aircraft noise impact assessment in values of human annoyance to noise the main terms are defined as following: the *intrinsic vulnerability* is a known receptor (human) sensitivity to noise; *human centered experience with* *ham* (noise annoyance) is a differentiation between the receptor susceptibility to source of noise and other possible vulnerability factors; *dualistic susceptibility/coping capacity* approach defines the changed susceptibility of the receptor to noise impact if any kind of protection measure is realized at a receptor point at the moment of noise impact assessment; *multiple structure of the vulnerability* to noise annoyance is a balanced approach to noise exposure control (in source, along propagation path, at receptor point); *multi-dimensional vulnerability* is combined exposure control with control of social, economic, environmental and institutional factors of the vulnerability of the elements-at-risk (expose by noise population).

Comparing with traditional ICAO BA elements, which are defined by physical effects of sound generation and propagation, an annoyance is a psychological phenomenon. The type of information collected and the way in which it is analyzed and reported will differ according to the objective of the program of noise control. Usual option of quantifying overall noise exposure – through noise contour modelling and quantifying the number of people inside the contour with specified noise level. Efforts to reduce exposure should primarily reduce annoyance and sleep disturbance, improve learning conditions for children and lower the prevalence of cardiovascular risk factors and cardiovascular disease [11] – they usually have different coping capacities for all these types of health consequences. Evidence is increasing to support preventive measures separately to them, such as noise insulation, policy, guidelines and limit values.

2.2. Vulnerability to noise adjustments

It was found that human response to noise is varying differently among environmental sound sources that are observed to have the same acoustic levels. Vulnerability of the people to type of transportation noise is different due to a number of reasons, described elsewhere [12, 13]. Percentage of highly annoyed (*HA*) people in dependence from day-night average sound level L_{DN} for three modes of transportation is a classical picture of *population vulnerability to the type of transportation noise source* – it is the highest for aviation in comparison with road and railway noise effects. For the level L_{DN} = 65 dBA (a limit proposed to be used for prohibition of residential area in airports vicinity), the percentage of *HA* people under the aircraft noise is expected to be 30%, while for railway noise it is equal to 12% only, so the noise exposure level is the same, but damage for population (their annoyance) is assessed as two to three times higher. For this reason, the standard ISO 1996-1:2003 [14] recommends 3–6 dB penalties and bonuses (or simply adjustments) for aircraft and train noise, respectively. Moreover, the noise response curves were changed dramatically during the last decades, becoming more “annoying” in comparison with their first definitions [15], it may be concluded that exposure levels are still the same, never mind that flight traffic grew sufficiently, but vulnerability effects are changed huge (community expectations first of all).

Due to these and other differences, ISO 1996-1 [14] provides and describes a number of adjustments for sounds that have different characteristics. The term “rating level” is used to describe physical sound predictions to which these adjustments may have been added. On the basis of such rating levels, the long-term community response can be estimated, for example, an Equation D.1 in ISO 1996-1 [14] is the original Schultz interpolation curve, showing the portion of a community that may be assessed as highly annoyed by transportation noise sources in dependence to the long-term (up to the year averaging) day-night sound level L_{DN}. Taking this in mind, it may be proposed to be considered as a normalized value of noise annoyance in population L_{DNISO}, so any particular type of environmental noise (any type of transportation, or building construction, or wind turbine noise, etc.) L_{DNs} should be assessed using specific noise source adjustment ΔL_s, which is character for environmental noise under consideration:

$$L_{DN\,s}=L_{DNISO}+\Delta L_s. \quad (1)$$

The extent of noise annoyance is clearly influenced by numerous non-acoustic factors such as personal, attitudinal and situational in addition to the amount of noise exposure per se [16]. Different models have been developed that aim to provide insight into the processes that result in noise annoyance [12, 13]. However, all these models are developed based on empirical evidence related to previously found results of correlation analysis or multiple regression analysis between noise annoyance and other variables. Both these methods have severe deficiencies in modelling noise annoyance; even the direction of causation may remain uncertain. The results of correlation analysis can be misinterpreted since the effect of the factor under investigation is not controlled for noise exposure or other factors [17]. Also, in [13] it was noted that "many of the models which are tested by using path analysis are exploratory. As such, they probably do not adequately represent the processes leading to the outcome in question e.g., noise annoyance".

Community response against aviation noise is closely related to perception, attitudes and expectations of the population under the impact of this noise as it follows (Table 3.5 in [6]). The most important determinants of any of the factors (variable) are shown also, so as their effect on noise annoyance as well (the data for standardized total effects of each variable are taken mostly from [18]). Vader in [19] compiled an array of 31 non-acoustic factors and classified each of them according to two dimensions: its *influence* on annoyance (strong, intermediate, weak – also shown in Table 3.5 in [6]) and the possibility to be modified.

In an attempt to reduce the scatter to the community response data, the EPA [15] suggested the use of "normalized" L_{DN}, which is the measured or predicted L_{DN} with a number of *adjustments* like in Equation (1) added to account for specific characteristics of the sound [20]: *seasonal considerations* – summer (or year-round operation) ΔL=0 dB, winter only (or windows always closed) ΔL=-5 dB; *outdoor background noise* measured in the absence of intruding noise – quiet suburban or rural community (remote from large cities and from industrial activity and trucking) ΔL=10 dB, normal suburban community (not located near an industrial activity) ΔL=5 dB, urban residential community (not immediately adjacent to heavily travelled roads or industrial areas) ΔL=0 dB, noisy urban residential community (near relatively busy roads or industrial areas) ΔL=-5 dB, very noisy urban residential community ΔL=-10 dB; *change in noise environment* and *community attitudes* – community has had some previous exposure to the intruding noise, but little effort is being made to control the noise ΔL=0 dB, community has had considerable previous exposure to the intruding noise, and the noisemaker's relations with the community are good ΔL=-5 dB, community is aware that the operation causing the noise is very necessary and will not continue indefinitely ΔL=-10 dB, etc.

All of them in proposed above risk terminology are *vulnerability factors* for the risk to be annoyed by noise assessment also. For new situations, especially when the community is not familiar with the sound source in question, greater community annoyance than predicted by application of the equation can be expected, the difference may be as much as +5 dB. One more classical example of noise impact vulnerability is additional guideline values, which are suggested for specific environments [21].

2.3. Expectation rate to noise adjustments

Looking in Equation (1) and considering the noise annoyance effect, it was proposed to represent the likelihood of the consequences (effect or damage) $P_{d/f}$ in individual risk calculation [6, 7] for noise impact as a dependence of *HA*% from noise metric L_{DN} (or its analogue L_{DEN}), currently it should be noted that normalized dependence is considered. A vulnerability shift in relation to noise source (ΔL_s) is proposed to be included in a form of adjustment used in [14] – Eq. (1). Today it is highest for noise from wind turbines, because expectation rate among the population in quiet suburban or rural community, where wind farms are usually installed, is highest. Such expectation rate is introduced to assess the expected vulnerability effect on a value of response of the population on noise via the factor of expectation (Fig. 2):

$$\Delta L_{s\,i} = \Delta L_{s\,i\,\max} F_{ex}, \quad (2)$$

where *i* is a type of vulnerability considered and $\Delta L_{s\ i\ max}$ is a maximum possible value of vulnerability shift.

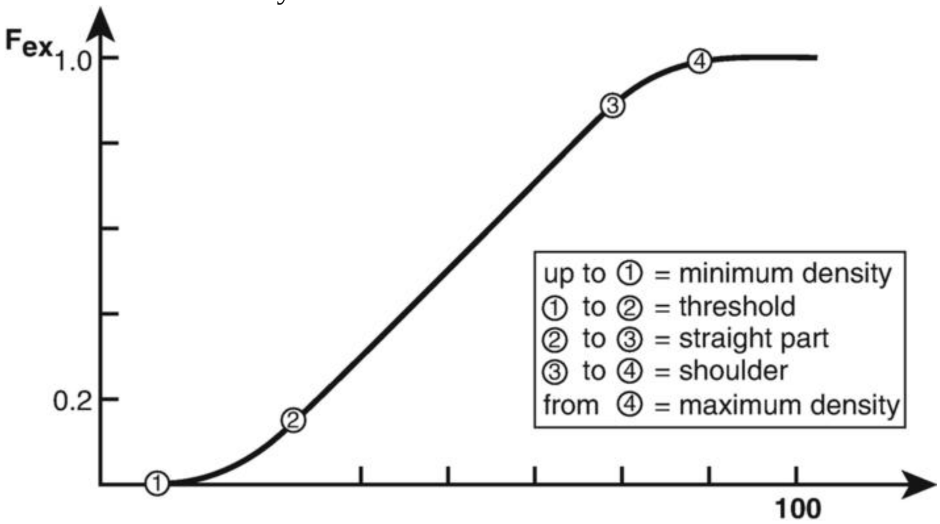

Fig. 2. Factor of expectation (expectation factor F_{ex} = [0,1]) in dependence with rate of expectation R_{ex} = [0,100]: any deviation from the expected level in the direction of growth causes the growth F_{ex}.

A form of the factor of expectation may be different for different vulnerability aspects, but expected to be similar with one of dose-effect curves for various types of response to hazard (Fig. 3), usually used for quantal response of the recipient to dose of toxicant (reflecting a given exposure of chemical or biological stressor).

Further step is a "normalization" procedure for noise level used in noise impact assessment:

$$L_{DN\,\text{norm}} = L_{DN\,cal/meas} + \Delta L_{s\,\Sigma} \quad (3)$$

where calculated or measured value $L_{DN\ cal/meas}$ is correspondent with case of noise event under consideration, and vulnerability shift $\Delta L_{s\Sigma}$ may include additively a number of factors influencing on vulnerability of the receptor to noise in this case.

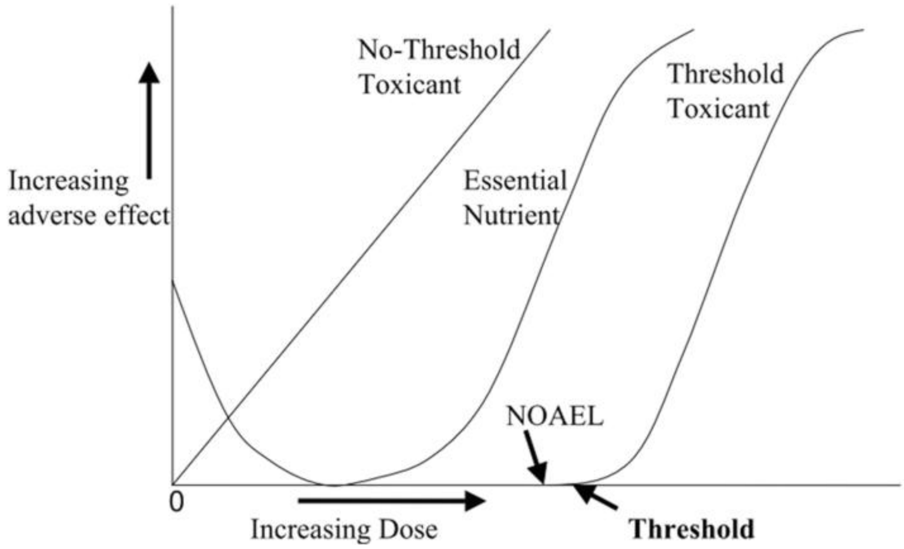

Fig. 3. Dose-effect curves for various types of response to hazard: NOAEL, no-observed-adverse-effect level

3.NOISE EXPOSURE AND NOISE IMPACT FOR BALANCED APPROACH TO NOISE CONTROL

Till now all the existing BA elements are subjects to identify and assess the noise exposure [22], mostly via noise contour modelling, in some cases via monitoring, which allows to evaluate noise control measures and to determine the most cost-effective and efficient for environment protection set of them [3]. In best known solutions, the process is continuing with public notification and consultation procedures and even being a mechanism for dispute resolution. This important approach is implemented in the European Environmental Noise Directive. According to it, noise action plans will be developed with the participation of the public. The claim of the citizens in participation has steadily grown, especially if their residential area or essential environmental aspects are concerned.

With this context of public involvement it is appropriate to begin with new vision on ICAO BA to aircraft noise control (namely, to add to the existing elements of noise reduction: at source, by noise zoning and land use planning, with operational procedure and mitigation measures) the newish element – the reduction of the noise effects via novel concept, approaches and efforts to reduce aviation noise annoyance, or more directly – to reduce vulnerability effects for the receptors affected by noise, and accordingly a number of affected people by noise. The protection of the residents is understood as a dynamic process, meaning that the evaluation criteria must be repeatedly tested and – if necessary – adapted to new scientific findings. The only significant determinant of perceived disturbance is the level of noise exposure. Comparing with traditional ICAO balanced approach elements, which are defined by physical effects of sound generation and propagation, an annoyance is a psychological phenomenon (in nature of effect on humans, the noise is a psychological phenomenon too!). The type of information collected and the way in which it is analyzed and reported will differ according to the objective of the programme of noise control.

4.CONCLUSIONS

It should be a primary objective of future research into environmental noise impact to investigate the interplay of sound level control and perceived control. New and additional (political) measures to mitigate noise impact may result from the redirection of attention from sound to noise and to noise annoyance. Strategies that reduce noise annoyance, as opposed to noise, may be more effective in terms of protecting public health from the adverse impacts of noise and its interdependency with other environmental, operational, economic and organizational issues of airport and airlines operation and maintenance.

The reviewed and proposed models provide a good model fit and support to the toolboxes of noise annoyance management, currently under the design. It can be concluded that the concern about the negative health effects of noise and pollution, other environmental issues, are still the subjects of scientific and societal attention, their newish deliverables may improve the approach to build the fifth element of ICAO balanced approach to aircraft noise control around the airports, which cover the measures to reach the final goal of aircraft noise management – to reduce the number of people living in vicinity of the airports and affected by noise.

5. ACKNOWLEDGEMENTS

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