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Risk methodology as a tool for aircraft noise assessment and control

Aircraft noise is one of the subjects of environmental or community noise, which is a kind of physical stressor on environment/community, which may produce a number of negative effects, including health impacts, as for humans as for environmental systems/objects (nonhuman impacts on environment). Among them are the following mostly recognized outcomes for humans: annoyance by noise (noise annoyance), sleep disturbance, direct health impacts, hearing loss (more important for occupational health protection), etc. Risk methodology is proposed to be used for assessment and control of aircraft noise impact on population located in airport vicinity.

Aircraft noise annoyance.

Noise is an environmental nuisance that has the potential to degrade health and negatively impact the relationship between humans and their environment. Aircraft noise annoyance is a still increasing problem, especially in the densely-populated areas and without reducing population's annoyance, it will become more and more difficult to increase the number of aircraft movements, or to build new runways or other airport infrastructure. People are driven to complain when some nuisance factor (or stressor) in the environment gives rise to their annoyance and when this stressor reaches a threshold of tolerance. In this context the stressor is an aircraft noise, which is described by exposure metrics usually. The actual situation is rather more complex. Exposure can lead to more than one effect and community impacts depend on multiple effects (Fig. 1). While sleep disturbance during night time and annoyance during composite day time are the primary–recognized health consequences of community noise exposure, cardiovascular disease and cognitive impairment in children also contribute [1].

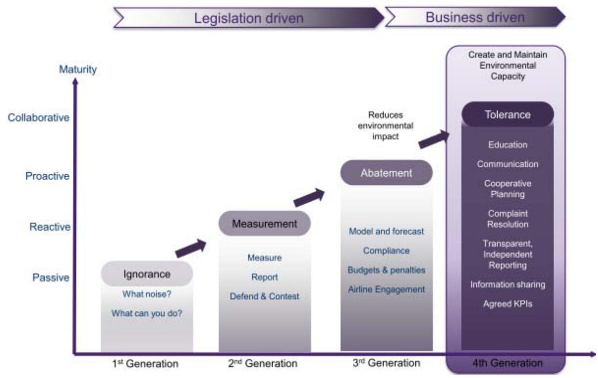

Fig. 1. An airports noise management typically evolves over time

WHO indicates also that positive wellbeing and quality of life can be compromised by noise annoyance and sleep disturbance first of all. Both of them are estimated for grounding the noise zoning and land use planning around the airports, using Critical Limits, Protection Guides and Threshold Values for sleep disturbance and annoyance [3] to control the aircraft noise impact in usual way. To control annoyance the effective adequate model should be designed. In a same manner as the appropriate models were designed to control all other elements of ICAO Balanced Approach to aircraft noise management, for example like US models ANOPP and INM are used for that, or their Ukrainian analogues: BELTRA (combines two large modules: BELTAS - for noise assessment at points of interest around the source and hence derivation of the directivity pattern of a noise event, and TRANOI - which indicates the need for noise control under the flight paths) and IsoBella (full analogue of INM) soft tools, both used for decision-making procedures concerning aircraft noise problems. Models and methods used for assessing environmental noise problems must be based on measured or/and calculated noise exposure indices, which are used by relevant national and international noise control regulations and standards [9].

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 [10]. The only significant determinant of perceived disturbance is the level of noise exposure. Thus through the effective management and control of aircraft noise, best practice – through ICAO BA, it must be possible to minimize adverse impacts of aircraft noise on health and quality of life.

Besides noise level, non-acoustical factors are associated with current aircraft noise annoyance: e.g. individual noise sensitivity (Pearson correlation r = 0.324 for relation of the sensitivity to annoyance, from [5] it is varying between 0.15 and 0.48); in [4] it is cited the found correlations between source evaluation and noise annoyance in the order of (-0.25), this covariation is higher with annoyance by private airplanes; trust in authorities responsible for noise level reduction (-0.307), expected changes in residential situation due to airport extension. The effects of noise annoyance on perceived disturbance and perceived control and coping capacity are equal to 0.90 and 0.94 respectively.

The significant determinants of the perceived level of control and coping capacity (Tab. 1 [7]) are the negative attitude toward noise source authorities and the noise policy −0.22, the negative expectations related to noise development −0.42, the concern about negative health effects of noise and pollution −1.15, and the concern about property devaluation −0.15. Especially, the concern about negative health effects has a large effect on the capacity of people to handle the noise situation. The most important determinant of this factor is the positive social evaluation of noise source −0.40 and the belief that noise can be prevented 0.24.

Risk methodology for aircraft noise impact assessment and control.

Under the standard [6] the definition of "risk" is no longer "chance or probability of loss", but "effect of uncertainty on objectives". The purpose of risk assessment is to provide evidence-based information and analysis to make informed decisions on how to treat particular risks and how to select between options.

Principal benefits of a performing risk assessment includes a wide set of positive outcomes for person, group or/and community [11].

Table 1. Standardized total effects of each variable on noise annoyance [7]

Variable	**Effect**
Concern about negative health effects of noise and pollution	0.59
Perceived disturbance	0.56
Perceived control and coping capacity	−0.51
Negative expectations toward noise development	0.26
Negative attitude toward source authorities	0.11
Concern about property devaluation	0.08
Positive social evaluation of the noise source	−0.05
Belief noise can be prevented	0.03
Noise annoyance	0.02
Noise exposure *DENL*	0.02
Annoyance non-noise effects	0.01

Risk is defined as the probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions [12].

Risk can presented conceptually in relation to **H**azard, **V**ulnerability and **A**mount of elements-at-risk with the following basic equation:

$$\mathbf{R = H * V * A_{elements\text{-}at\text{-}risk}}$$

or taking into account the **C**apacity (opposite characteristic to vulnerability) to cope the hazard consequences [2]:

$$\mathbf{R = H * V / C}$$

The equations given above are not only a conceptual one, but can also be actually calculated (for example, with spatial data in a GIS to quantify risk from geo-distributed hazards).

Mathematically **R**isk is proportional to a measure for the **P**robability of an event (frequency, likelihood) and the **C**onsequences of an event (impact, effect on objectives):

$$\mathbf{R = P * C}.$$

For individual risk this basic condition may be expressed by the formula [8]:

$$\mathbf{R = P_f * P_{d/f}},$$

where P_f – the probability of harmful event (eg, aircraft accident); $P_{d/f}$ – the likelihood of the consequences (effect or damage), particularly the fatal consequences caused to individuals in the absence of protection from (or resistance to) a danger.

In more general form probability of accident P_f may be divided to the probability of scenario p_{Sc} and the probability of hazard exposure p_{Ex}:

$$\mathbf{P_f} = p_{Sc}\, p_{Ex}.$$

The effects are usually described in terms of various type damage *k* (eg, fatality, injury, physical damage, environmental losses, loss of income, etc. depending what are the elements-at-risk) and their vulnerability v_k (for example, a person's vulnerability can be defined as mortality):

$$\mathbf{P_{d/f} = k^{*}v_k}$$

Vulnerability is determined by physical, social, economic and environmental factors (or simply conditions or processes), which increase the susceptibility of a community to the impact of hazards. Vulnerability can be classified as shown in Tab. 2. Risk assessment is concerned with determining those factors which are especially dangerous and determining the likelihood of unacceptable harmful exposure. Among vulnerability properties of the population under the risk of noise impact is a number of acoustic factors (fleet composition, their respective distribution over given time period of observation) and non-acoustic factors (personal noise sensitivity, attitude towards the noise source, performed activities at the moment, etc.).

Table 2. General classification of vulnerability [13]

	Human - social	Physical	Economic	Cultural Environmental
Direct losses	• Fatalities • Injuries • Loss of income or employment • Homelessness	• Structural damage or collapse to buildings • Non-structural damage and damage to contents • Structural damage infrastructure	• Interruption of business due to damage to buildings and infrastructure • Loss of productive workforce through fatalities, injuries and relief efforts • Capital costs of response and relief	• Sedimentation • Pollution • Endangered species • Destruction of ecological zones • Destruction of cultural heritage
Indirect losses	• Diseases • Permanent disability • Psychological impact • Loss of social cohesion due to disruption of community • Political unrest	• Progressive deterioration of damaged buildings and infrastructure which are not repaired	• Economic losses due to short term disruption of activities • Long term economic losses • Insurance losses weaken-ing the insurance market • Less investments • Capital costs of repair • Reduction in tourism	• Loss of biodiversity • Loss of cultural diversity

Risk assessment needs to be used in framework of its regulation. To investigate the effects of hazards there are important factors of vulnerability - physical, social, economic and environmental conditions and processes that tend to increase the damage from the effects of the hazards impact on the person or society as a whole. There is necessary a covering *capacity* - capabilities of a human, system, society, nature to confront the consequences of dangers and threats, ie resources are needed that may reduce the negative effects.

Risk assessment for other environmental factors inside and around airport

The main objective of environmental safety management systems (EnvSMS) is the creation and maintenance of a necessary level of protection of vital interests to guarantee favorable conditions for the safe and sustainable development of individuals, society, and environment. The main element of modern EnvSMS evaluation is an assessment of risk and of the probability of negative impacts of various anthropogenic factors and their consequences. Therefore, in aviation context the primary objective of environmental safety study is identification of anthropogenic factors that can lead to the violation of environmental safety, particularly for the population in the vicinity of airports.

Sustainable management is critical. Currently in aviation sector it covers more safety and environmental issues as before. For example, safety may include more deeply the occupational conditions and operational safety training for staff/personnel and aspects of aircraft airworthiness like removed parts from end-of-life aircraft will go back into service for newish ones. Any recyclables should profit for environmental issues of aircraft manufacturing and operation, ensuring aviation stakeholders environmental stewardship continues at end of service. A number of other factors of impact on environment [14] needs to be evaluated in a same way – with risk approach:

- There are a multitude of sources of emission and air pollution concentrated inside airport territory.
- There are a multitude of sources of EM radiation that are in use today, and they all have a probability of affecting electronic components in their vicinity in some way.
- The aircraft are subject of flight accidents, mostly close to airport (around 70% of total accidents), and they are subject of risk for population living in airport vicinity [2,8], etc.

Conclusions

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.

Noise annoyance as a form of psychological stress is determined by the extent to which a person perceives a threat, i.e. perceived disturbance and the possibilities or resources that a person has with which to face this threat. Risk assessment and management methodology is proposed to be used for noise impact assessment and management. It provides necessary tools to include in consideration *vulnerability & capacity* values, both very important for management of the impact first of all. New communication technologies must provide better understanding of the problem to the community, to every individual living around the airports, providing their more positive response to aircraft operation and noise in consequence.

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 loving in vicinity of the airports and affected by noise.

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