inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 3.2

NEW WAYS (AND OLD THEORY) FOR ABATING AIRPORT NOISE ANNOYANCE

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Keywords:
NOISE-INDUCED ANNOYANCE, AIRPORTS, NON-ACOUSTIC DETERMINANTS, SOCIAL THEORY

ABSTRACT
In this paper noise annoyance is conceived as a stress-response (i.e., the resultant of perceived disturbance and perceived control) determined primarily by two variables: sound and sound control. The basically dual nature of noise annoyance clarifies why annoyance by exposure to aviation noise can only be understood in social and political terms. By distinguishing carefully between levels of the acoustic load (e.g., as measured by Ke or L_{den}) and 'levels' of exposure-management, ways to abate noise annoyance around Amsterdam Airport Schiphol have been developed that are psychologically and politically more effective. In particular, the indispensable role of both administrative and private parties in the region is highlighted. Various institutional arrangements are discussed that enable the public expression of preferences regarding local noise environments, and that offer opportunities to act accordingly. Such (long term) investments in exposure control are most likely to reduce noise annoyance significantly.

1 - INTRODUCTION

Exposure to environmental noise, including aviation noise, at levels below L_{den}=70 dB(A) may lead to annoyance and sleep disturbance. Somatic health effects have not been observed below these levels [1], [2], [3], [4] and [5]. This article will deal with annoyance only, which may be regarded as a health effect if health is defined in the broader sense of 'well-being'. Annoyance is considered generally as the adverse effect during day-periods. Typically, when summarized on doses (sound), surveys reveal quite a scattered plot of responses (annoyance). Notwithstanding recommendations by the earliest investigators already not to direct policy attention only to the crude acoustical predictors of noise acceptability, e.g. [6], that very bias did develop.
Following the pioneering work of Schultz [7] much effort has been devoted to establish the unique quantitative relationship between dose and response for various transportation modes [3], although generally with not much more theoretical draught than the model of figure 1 (a similar observation was made by Fidell a decade ago: "The view that the fundamental problems in predicting the effects of noise on individuals and communities are problems of theory, not of measurement, has slowly gained recognition" [8, p.19]).

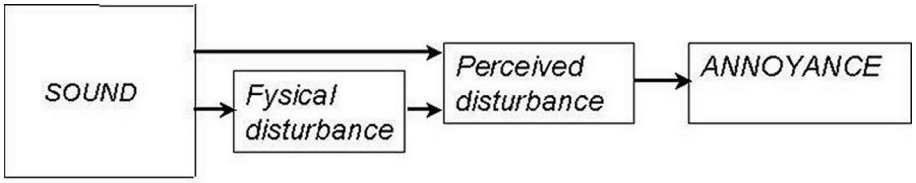

Figure 1: Psycho-physical model of annoyance by environmental noise.

The major reason for this fitting of response to dose is the wish of noise regulators - much less so of the public - to be informed about expected reductions of community averaged annoyance following a

given decrease of the dose. However, this information reinforces the simplistic belief that the major determinant of annoyance is acoustic. Also, non-acoustical factors (see below) are believed to be too variable or person-specific, virtually impossible to quantify them and, as a consequence, not amenable for regulatory control. Unfortunately, as a consequence of this erroneous line of argument the significance for annoyance (and noise) reduction of creating opportunities for local and regional parties to shape their own (noise) environment is underestimated seriously (moreover, the usefulness of the dose-response curves is overestimated as they have been constructed on data from steady-state situations, which may not be equated with non-steady states −active public interest in changes of exposure−). This leads to the paradox that where controversy over noise is most acute, that is, where residents have had enough or fear a significant change of noise exposure and stand up for a different distribution of risks, costs and benefits, the dose-response information is least useful (see also [9]). I will discuss such opportunities for annoyance reduction in Section 3.

Broader studies of noise annoyance have shown repeatedly that roughly about as much variance of annoyance is explained by acoustical measures of sound as by so-called non-acoustical factors [10], [11], [12]. At a special workshop devoted to the role of these factors with respect to aviation noise annoyance the following predictors were listed (no theoretical order): perceived predictability, perceived control, trust and recognition, voice, understanding and general attitudes, personal benefits, compensation, sensitivity to noise, home ownership, accessibility to information [13]. Of these, the generic 'perceived control' is theoretically most important, with behavioral/decisional control (e.g., being able to move or not) and cognitive control (e.g., being able to gain trustworthy information about future developments or not) as specific manifestations. Perceived threat - which, after all, is what perceived disturbance is about (the negativity of noise-annoyance is rooted in the fact that exposure to noise may make it difficult or impossible to attain or maintain something valued, e.g. playing music, enjoying a house in a quiet quarter, etc...) − and perceived control are the two pillars of psychological stress theories (e.g. [14], [15]). Only when a disturbance begins to tax a persons resources, it may become annoying or, with a generic term, stressful. Thus, non-acoustical and acoustical variables together must determine noise annoyance [16]. The comprehensive model of figure 2 shows this.

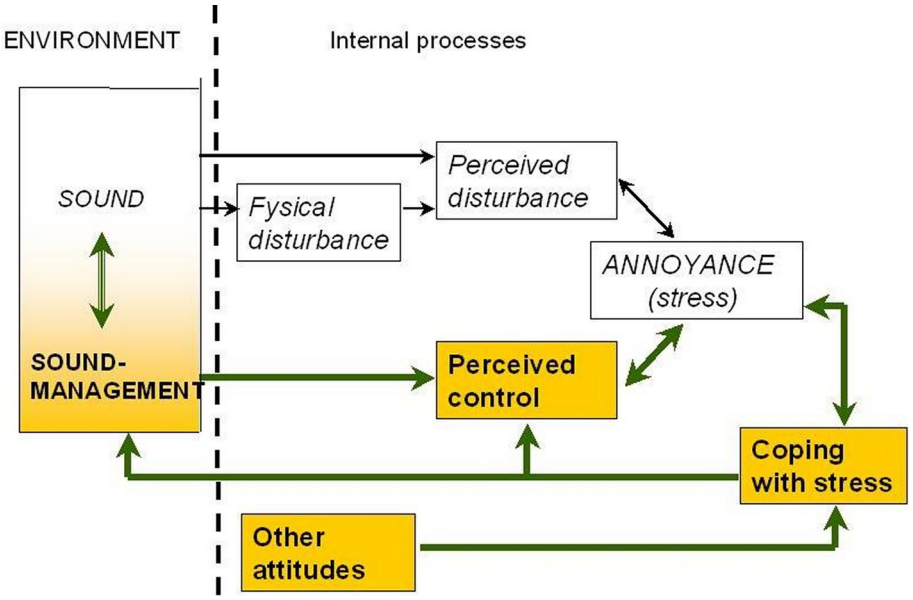

Figure 2: Psycho-social model of annoyance by environmental noise.

The difference with the traditional model of figure 1 is clear. Most notable of figure 2 is that it expressly points at external determinants other than sound. First of all, the very way in which sounds are controlled, at the source as well as −indirectly- at the regulators desk, is as important and immediate a stimulus as the sound itself. Exposure to sounds never is impersonal business. It is always a matter of 'you' expose 'me', too (including the reciprocal: 'I' (as I do not see reasons for further protective action) expose myself to 'your' sound). Second, other attitudes regarding non-noise aspects of the source and its environment inevitably play a role as well. If my neighbor always parks his car in front of my windows despite my complaints, I will get upset more quickly by his afternoon trumpet exercises. Etc. Thus, annoyance by environmental noise is an intrinsically social phenomenon, just as much as any measure

to prevent it. Not only noise but also noise control determines noise annoyance, and airing annoyance is a means to gain influence on both. Annoyance policies tell us something about how we wish to address such relationships. Therefore, it is informative to describe shortly the fundamentals of the actual Dutch aviation noise policy (Section 2). In the final Section 3, I will discuss new policy measures that have been proposed from the point of view of figure 2 (these proposals were the result of research commissioned first by Amsterdam Airport Schiphol and continued by the Dutch Department for Aviation RLD; P.W.M. Smit and this author in close cooperation with representatives from the major parties at state, regional and local level conducted this research).

2 - PRESENT POLICY REGARDING ANNOYANCE FROM AMSTERDAM AIRPORT

Dutch aviation noise policy contains airside and landside restrictions. The latter entered political discussion in the mid seventies, but they gained political weight and, in the case of restrictions on housing development, formal status in the last 10 years. Airside restrictions have been longer in effect, ranging from flight path management to differential levies on noisy aircraft. The effectiveness of both types of restrictions is assessed by how they impact on the level of Kosteneenheid (Ke), with Ke being the expected year-averaged noise exposure at a given location as measured by number, level and time of day of exposure events. Possibilities of further sweeping regulations such as noise-based slot allocation or the imposition of a noise cap on total aviation are playing have surfaced in the political debates only in recent years.

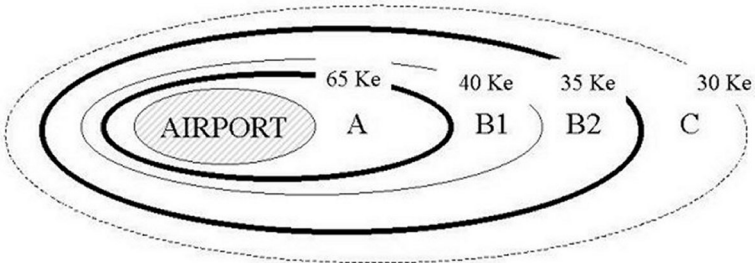

Figure 3: Spatial planning zones around Amsterdam Airport (simplified drawing).

The present configuration of 4 runways carries three Ke-zones A, B $_1$/B$_2$ and C, as shown simplistically by figure 3. Zone A is the area within 65 Ke: no housing is allowed here, and existing houses must be removed (60 Ke is of the same order of magnitude as 70 L_{den}). Within the so-called safeguarding zone B, with 35< B<65 Ke, no new houses may be built (the number of houses has been frozen at the 1990 level of 15,100). In addition, the ca. 5,000 houses within the stricter zone B_2= 40 Ke should get insulation of its major living space. No State-issued restrictions apply to zone C. However, the regional authority has used its statutory freedom to define a wider safeguarding zone (C_1) at the level of 30 Ke. After 2003 a 5th runway should be operational, which will increase capacity considerably (in any case, up tot 500.000 landings & take-offs a year) while affecting less residential area. When the 5th runway becomes operative in 2003 zone B may not contain more houses than 10,000.

The political debates on the 5th runway reached its height in 1996. Environmental concerns about uncontrollable growth of the airport caused the parliament to restrict explicitly the yearly total of aircraft movements to 440,000 (and, "to be sure", the numbers of passengers to 44 million). This predominant 'cap-on-growth' attitude stimulated strongly the investigation of the development of an entirely new international airport out at the North Sea. By the end of 1999 the government concluded that this was not a feasible option for the foreseeable future: "Growth should be accommodated at the existing location Schiphol within strict environmental standards". For the long term future a redesign of the existing runways should be considered.

The new environmental standards (here, I will discuss the noise and annoyance standards only; the second and equally important environmental standard concerns residential safeguarding against crashes, 3rd party safety) will be measured in L_{den} (the equivalent dose calculated with special weights for day, evening and night periods; also, other than the Ke, the L $_{den}$ will take into account noise-events with loads below 65 dB(A); thus, 35 Ke can only be about 58 L_{den}) instead of Ke units, although it is stated expressly that "the spatial consequences of the new standards should not be much different" [17, p.4] from the existing ones (but there is no technical answer to the question 'how different is too different?', as the transformation from Ke to L_{den} cannot be a sheer mathematical transformation (like, e.g., from degrees 0F to 0C); the two units show a significantly different sensitivity to various technical input

characteristics, and they have different time-of-day penalties [cf. 18]; therefore, the adoption of either one system requires value judgments by technical experts, but - because of that - not by them only). Therefore, as stated before, with the 5th runway there may not be more than 10,000 houses within the (35 Ke equivalent) L_{den} zone. On average, the (35 Ke equivalent) L_{den} must not be exceeded, otherwise closure of runways will follow. This will be measured by monitoring some 30 points along the contour. In addition, for a subset of these monitoring points where they are close to residential areas that L_{den} figure will have the status of absolute threshold value, i.e., no averaging out. Within the five-runway zone B (see figure 3) the restrictions to new housing and other development will be virtually the same as in the present safeguarding zone for four runways. Finally, new also is the introduction of the notion of 'avoidable annoyance'. This refers to any (policy) measure that the local/regional parties and the aviation industry can agree upon to reduce annoyance further than defined by the new environmental standards. The government has announced legislation that will make it mandatory upon the industry and the local communities to reach such agreements. At the time of this writing the parliamentary debate on the government proposal has not yet taken place.
Whereas the old policy was strongly hierarchical, that is, with all noise and annoyance measures being essentially the exclusive domain of the State-authority, the recent proposal offers (cautious strokes of) a somewhat different picture. The clearest is the initiative to have the airport and its neighboring communities reach agreement (the term is: 'a contract') about measures to control noise and prevent annoyance. This is in line with the philosophy of Section I, and with the results of research conducted with that point of view (see footnote 5). However, for this agreement to be viable two important conditions must be met:

- A different political and practical meaning than the present one (see above) must be attached to the subset of threshold points near residential areas. The exceeding of the yearly maximum exposure at any of these places *per se* is presented now as a sufficient reason to pass on to harsh volume constraints, such as the closing of a runway for the remaining part of the year. Although marginal flexibility of the contour is allowed explicitly, it apparently does not apply to the subset of places near residential areas. Why not? The proposal is not explicit about it. Noise exposure over levels of (35 Ke equivalent) L_{den} is certainly not generally unacceptable to residents. For people living within the contour (10.000 houses!) exposure levels even up to (65 Ke equivalent) L_{den} are deemed tolerable. Another possible argument that there ought to be legal security for the communities near the subset of points is equally untenable. If the year averaged noise exposure is tightly fixed at those points, then, towards the end of the year, this may cause transgressions of expected yearly noise loads at other places within (and outside) the contour. Would this greater insecurity about noise-loads of, say, 40 or 50 Ke not be a greater problem? A third possible argument might be that a subset of strict thresholds is needed as a means to fall back upon when the airport grows more than permitted. However, the purpose of limiting maximum growth (and living up to the maximum 'footprint' of 10,000 houses) is served effectively by sound and practicable rules for averaging out the year-averages along the contour. Legal security should be based upon the transparency and enforceability of these rules, which both define the margins of flexibility and guarantee that the noise load will − in the long run − stay stable and that the 'footprint' will not enlarge. Therefore, short term 'breathing' of the contour as a result of changes of fleet composition, developments in operational techniques, technology and the weather should nowhere along the contour be a problem. On the contrary, rigidities at the threshold points near residential areas will make interactions between the airport and its environment a matter of no substance (see further Section 3). Ironically, what should be a means of public protection may then come to be the reason for the industry to continue window-dressing PR, and further ineffective fights over details of acoustic calculations.

- This leads to the general topic of 'self control' by residents. Experiments on reaching agreement between sector and residents, e.g. on ways of compensation, are most useful in areas with relatively high noise loads, and they may need State-involvement to get the negotiations started and keep them going. At this point, the present government proposal is ambiguous. On the one hand, there is the initiative to have private parties conclude a contract. On the other hand, the suggestion is given that this should apply first and foremost to possible measures outside the (35 Ke equivalent) L_{den} because at the 'inside' annoyance prevention is adequately taken care of by the noise load restrictions. In the same vein, the State-role of facilitator is defined in a minimal way (let us take the insulation program as example; at present, it is fully State-regulated; there is no room for individual preferences on this insulation issue, and also hardly any opportunity for the airport/airlines to cut

on the very costly insulation costs; here, home owners/tenants and the sector together could benefit from flexibility).

3 - NON-ACOUSTICAL MEASURES TO PREVENT ANNOYANCE

If annoyance by environmental noise from aviation is the primary concern - that is, when noise loads are generally below 70 dB(A) (see Section 1) - then political arrangements for noise control are as important as acoustic measures. This is the main thesis defended above. When looking up-stream of the causal chain (see figure 2), different levels of control should be distinguished. Returning to the specific case of major airports, the following three types of political arrangements all frame annoyance, each in its own way:

- Opportunities (or lack thereof) for noise annoyance control at the State-level. These opportunities are determined by the typical statutory power of States to take decisions about the optimal location of national airports, that is, the best possible configuration and use of runways according to several macro-criteria.
- Opportunities (or lack thereof) for noise annoyance control by local and/or regional authority. Typically, as they are closest to their communities, they are the competent authorities, and they are charged with the responsibility for the quality of life and work in their region.
- Opportunities (or lack thereof) for noise annoyance control at the level of private parties. 'Private parties' could be individuals as well as (governmental, industrial etc.) organizations.

In most general terms, measures at level I follow from the rating of various (inter)national interests. Measures at level II are primarily concerned with safeguarding the rights of airport and neighboring population as a whole. These two largely administrative measures ought to respect the possibility of private relationships as their natural complement: there should be room for individual actors to choose the quality of life and relationships that they desire. The three levels are interdependent: arrangements at one level may facilitate the proper working of measures at another, and *vice versa*.

The opportunities for annoyance prevention at level I are both direct and indirect. Direct influence is exerted by the development and enforcement of measures to minimize the aggregate emission over longer time periods, which is related to the total volume of flight movements (more precisely, it always is aggregate emission with a particular geographical distribution; dose-response curves help to decide about optimal allocations of resources, as they express how aggregate (community averaged) annoyance relates to aggregate noise loads (read: to areas of land for a particular use)). Important inputs to the process of standard setting at this level of annoyance control are the state of art of aircraft technology and air traffic management. Strong but indirect influence should be exerted by the creations of optimal conditions for other public and private parties to play their roles, that is, by the development of legal and financial frameworks that enable them to interact responsibly. If this combination of a direct and indirect approach is sustained, and if the implied administrative division of tasks is given form energetically (see below), it will generate less dissatisfaction with and more trust in government noise control policy, and less annoyance will be the result.

Like other industrial developments, operating a major airport in the vicinity of communities affects the quality of life and work in several ways, physically as well as socially. For example, exposure to the emissions of aircraft (and to the car exhaust of the airport traffic) may impair community health. There also is a substantial positive but less direct health effect: just having a job and material prosperity in general increase life expectancy (the job and prosperity effect, although hardly noticed in public discussions and media attention, seems to be by far the largest [19]). Policy makers in the region (level II) pre-eminently are used to integrate such diverse assessments of risks, costs and benefits. Their traditional instruments to prevent a deteriorating local environment are (1) spatial planning and (2) the development of special projects to improve the quality of life. Typically, spatial planning has a long time horizon of 10 or more years. Special projects, which aim to balance benefits and costs for communities as such, offer flexibility within shorter time frames. Examples of projects to reduce local annoyance are the development of airside operating regimes [20], the creation of new recreation areas, subsidies for communities with vanishing public services (due to housing restrictions), financial compensation for incidental exposure above normal noise loads. A number of these projects may be entered into contracts between the industry and affected communities, as both have a legitimate claim on the 'commons' of airspace and, thus, have something to negotiate. A pioneering study by Fidell *et al.* [21] suggests that residents would place acoustic measures (e.g., fewer airplanes per day; time periods free of aircraft) highest on the agenda for contract talks, with means of financial compensation ranking second.

Finally, there are opportunities for annoyance prevention at the level of private parties (level III): individuals exposed to the same noise load will still differ considerably in terms of annoyance for a number of person-situation specific reasons. E.g., some people seem to be sensitive to loud noises, whereas others typically respond strongly to quieter noises [22]; for some, homeownership matters, for others not; *et cetera* [12], [13]. It is not possible for policy makers to address all these factors directly, but it is not necessary either. At the State-level only the initial conditions should be created for bringing the respective parties together. In situations of 'you expose me' it is always better to arrange for a meeting of 'you' and 'me'. Doing so would put parties in control of their situation, and, on the long term, tlaks, agreements and sticking to them breed thrust. As discussed in Section I, increasing the level of perceived control means decreasing the degree of annoyance. The subject matter of such agreements are, e.g., noise complaints arrangements, informing incoming residents on noise and average annoyance, public reward *bonus/malus* systems for airlines that behave extra-ordinarily good or bad. Parties might agree on the role of an arbitrator, etc. In the 'compensation for noise' area much is possible: types and degrees of home insulation offered, with varying levels of residents' financial participation; community projects, and 'blunt' individual financial compensation. As a last example, specific arrangements could be created that would make it possible for individuals within specific areas of exposure to move to quieter places. The mere existence of a guarantee already that one can leave for a quieter place without incurring extra financial costs will reduce noise-induced annoyance.
Especially the above-described private arrangements represent a potential for annoyance reduction that is currently not exploited at most airports. They should be part of a comprehensive policy, together with the appropriate level I and II measures. It has been the objective of this article to show that there is quite some scientific evidence that strongly favors such an integrative approach [cf. also 5].

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