SPI - AN INDICATOR FOR ASSESSING TOTAL NOISE IMPACT

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ABSTRACT
Norwegian authorities have introduced a new indicator to quantify the annoying impact of different environmental noise sources. The indicator is based on the total noise dose from separate sources, the number of residents that are exposed to these doses, and dose-response relationships that describes the annoying properties of different sources (road traffic, rail, aircraft, etc.).

INTRODUCTION

The Norwegian parliament has decided that the annoyance caused by environmental sources must be substantially reduced. In order to quantify this reduction it was necessary to establish an indicator that would fulfill the following requirements:

- the indicator should give a good description of the noise problem
- the indicator should include the number of people exposed at different levels
- the indicator should simplify comparisons between different noise sources
- the indicator should have an internationally accepted basis

Another issue that was considered important when searching for a new indicator, was the fact that a large number of people were exposed to moderate noise levels with corresponding moderate annoyance. However it was necessary that also these groups were included in the new indicator, and that the emphasis was not concentrated only on the relative small group that was highly annoyed.

ANNOYANCE SCORE

The annoyance score is a rating of the annoyance on a scale zero to one, were the end points of the scale are designated "*no annoyance at all*" and "*the most severe annoyance*". In a survey or lab experiment the rating can be done by picking a number, between for instance zero and ten (or hundred), or by choosing a carefully selected modifier on the annoyance scale (a word that describes the annoyance), the value of which has been established in another experiment. The annoyance score functions are source specific.

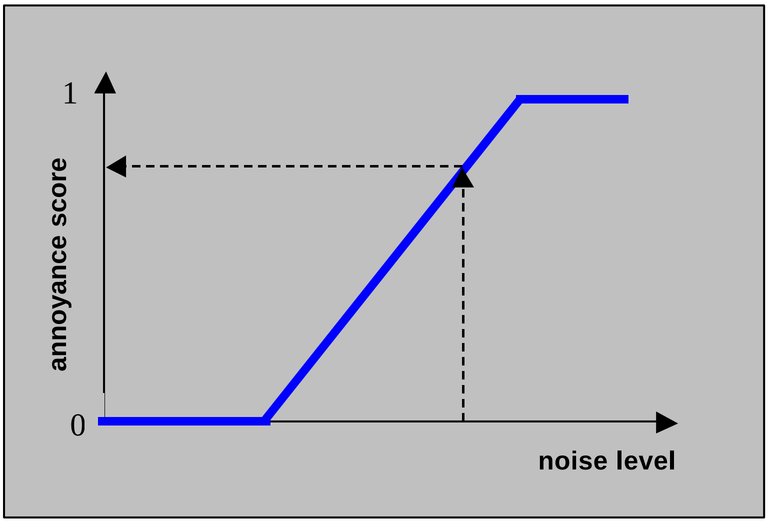
The modifiers that are recommended for the English language for a 5-point scale are as follows [1]:

annoyance score	modifier
0.0 – 0.2	not at all annoyed
0.2 – 0.4	slightly annoyed
0.4 - 0.6	moderately annoyed
0.6 – 0.8	very annoyed
0.8 – 1.0	extremely annoyed

Dose-response functions (annoyance score versus noise level) for different noise sources can be found from the results of social surveys [2] [3].
By definition a psychometric function that describes the relationship between a stimulus and the corresponding reaction on a finite scale (with finite end points) will approach these end points asymptotically. In relation to noise annoyance this can be explained as follows: In a random sample of the population there will always be someone that express a certain degree of annoyance, no matter how low the noise level, and there will always be someone that are not "absolutely annoyed" no matter how much the noise level increases.

Analysis of existing survey data has shown that the annoyance score functions can be approximated by straight lines [3] [4]. The upper extreme, annoyance score equal to one, will be outside the range for normally occurring community noise levels. At the lower end of the scale it is necessary to introduce a threshold level, below which the annoyance score is set to zero.

This means that a reduction of the noise level by a certain number of decibels, will yield the same reduction in the annoyance score regardless of the absolute noise level where the reduction is introduced (provided it is above the threshold). The effect of one noise mitigation measure will therefore have full effect regardless of other mitigation measures. The planning of noise reduction strategies will thus be facilitated.



Dose-response function, noise level versus annoyance score for a typical transportation noise source

NOISE ANNOYANCE INDEX

The noise annoyance index of a community (in Norwegian: *støyplageindeks*: SPI) is a quantity equal to the sum of the annoyance scores for all residents within that community. This quantity expresses the magnitude of the noise annoyance impact. One SPI is equivalent to one person exposed to noise that yields an annoyance score of 1.0, or two persons with an annoyance score of 0.5 each, etc.

Until now the magnitude or severity of the noise annoyance impact, especially in connection with transportation noise, has usually been described by the percentage (or the number) of people annoyed to a certain extent, for instance *percentage highly annoyed (% HA)* [5]. Noise mitigation measures aimed at reducing % HA have therefore normally been concentrated towards people or places with the highest noise levels. Such measures will often have little or no effect on places with moderately or low levels. If SPI is used to quantify the noise annoyance, any noise mitigation measure, even at low exposure levels, will have an impact. The authors consider this as an improvement.

PRACTICAL CALCULATION OF SPI

For practical calculations of SPI caused by a certain type of noise source in a community, one possibility is to establish noise contours in, say, 5 dB or smaller intervals, and then count the number of persons within each contour interval. This number is multiplied by the mean annoyance score for the relevant interval, which then yields the SPI per interval. Finally these SPIs are added in order to get the total SPI caused by that particular type of noise source for the community.

The concept of SPI can only be applied to a group of people with the same relevant characteristics as the group that was surveyed to get the annoyance score function. The SPI concept can not be used on an individual basis.

EXPOSURE TO DIFFERENT SOURCES

Norwegian authorities have estimated the magnitude of the total impact of noise annoyance in Norway. This has been accomplished by calculating the noise from all major sources, and by combining the information about noise levels with the number of residents exposed to those levels. As a first approximation this has been done separately for each major source (road traffic, air, rail, industry, etc.), and the SPI for each source has been added together.

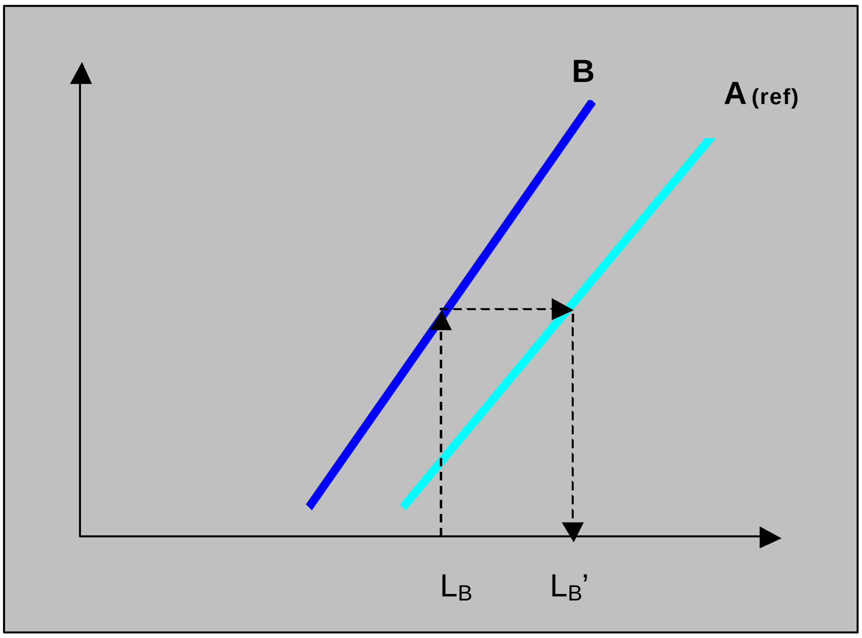
The total SPI for all of Norway has been estimated to about 600.000, in other words equivalent to 600.000 people being *extremely* annoyed by noise [6].

In many cases people will be exposed to more than one type of noise source, for instance a combination of rail and road traffic. If a person is exposed to rail traffic noise equivalent to 0.5 on the annoyance score scale, and has a similar response, 0.5, due to road traffic, the result would be SPI = 1.0 according to the present calculation procedure. This "imaginary person" will thus be regarded *extremely* annoyed. In reality this, of course, is not the case.

Imagine a community of 1000 residents where every person is exposed to a certain level of noise from source A, equivalent to an annoyance score of 0.4, and the same residents are exposed to noise from a source B, also equivalent to an annoyance score of 0.4. The total noise impact would be expressed as SPI = 800 if the sources are considered separately. If one of the sources was removed completely, the remaining impact would be SPI = 400. This would indicate that the total noise annoyance was reduced to one half of the original. If we assume that the annoyance score functions for sources A and B are quite similar (but not necessary identical) the contributions to the noise level from these sources must be almost the same. If one of the sources was removed, the residents, therefore, would experience a reduction of the total noise level of only a few decibels, and the reduction in the annoyance would be correspondingly small.

In order to estimate the total SPI for a community, the combined annoyance score per person should be calculated and then added, instead of adding the annoyance scores for all sources and all persons. This can be done by using the annoyance score functions to transform the noise from each source into an *equally annoying* contribution from a reference source. The procedure is explained in a technical addendum to the standard ISO 1996 that is currently being revised [7]. After the transformation the different contributions (expressed in terms of the reference source) can be added on an energy basis to form the total noise level, and the corresponding total annoyance score can be found:

> A source **SB** is characterized by its annoyance score function **B**. A noise from this source, L_B, can be transformed into an equally annoying noise from source **SA,** L_B'**,** (reference source), characterized by its annoyance score function **A**, as shown in the diagram.



Transformation of a noise from source SB in to an equally annoying noise from the reference source SA

THE COST OF ANNOYANCE

In order to be able to choose the most cost effective noise mitigation measures, it is necessary to put a “price” on the annoyance. The annoyance score and the SPI concept is very useful for this type of considerations. The value of a reduction of the noise annoyance, should ideally reflect the amount of money people are willing to spend in order to achieve this reduction. We have assumed that the annoyance score function, and thus the SPI function, can be approximated by straight lines. In other words, a reduction of the noise by a certain number of decibels will have the same effect on the annoyance score regardless of the absolute value. This implies that the “cost of the annoyance” or “the value of a noise reduction” will be a constant sum of money per decibel. This is an important observation. It is therefore possible to optimize the effect of an investment in noise reduction. The money should ideally be spent in order to produce the largest decibel reduction for as many people as possible, in other word to produce the maximum reduction in SPI (annoyance score reduction times number of residents). It should be noted, however, that even if the “value” of a decibel reduction is the same regardless of absolute noise level (above the threshold), the cost of achieving this reduction may be something completely different. In most cases one will observe that the cost per decibel of noise reduction increases with increasing numbers of dB reduction: ‘the last decibels are always the most expensive’.

Several attempts have been made to quantify the value of noise reduction. Different studies yield very different results. The value, of course, will vary between different regions and different countries, and will depend, among other things, on standard of living and average income per household. ECMT (European Conference of Ministers of Transport), a permanent body affiliated with OECD in 1998 published a report giving "best estimate" values for different countries [8]. For Norway the value of noise reduction is stipulated to about 25 Euro per decibel per person per year. Considering the extent of the annoyance problems, the total cost of reducing the noise to an acceptable level may be very high, but substantial savings can be reached through proper mitigation measures.

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