# Weighting health risks in buildings and outdoor environment


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## INTRODUCTION

Eco Effect is a system for environmental assessment of buildings, (Glaumann 2000). Health risks outdoors and indoors are assessed, (Hult 2000). These health risks range from cancer, infections, and poisoning to SBS, allergy and various comfort problems. The risk assessments are made on individual scales based on limit values related to what is considered normal and socially accepted according to norms and praxis and what is considered as no risk. The advantage of individual scales is that they refer to established values. Since the assessed health problems are all different the same score representing "acceptable" or "not acceptable" for different problems have different meanings in terms of health risk. To be able to understand and compare the risks the individual scales must be transformed to a common scale, i.e. they must be weighted according to the same concept of risk.

Risk means probability that something bad happens. Risk assessments usually include the negative consequences of the happening. In terms of risk this means that a low probability that something terrible will happen may be equal to a high probability of a less terrible happening. We define health risks accordingly, i.e. as the product of the probability of getting ill and the severity of the illness (or comfort problem). This is the basis for a common scale that facilitates the comparison of mild problems with severe problems, e.g. the risk of being disturbed by noise indoors and the risk of getting lung cancer.

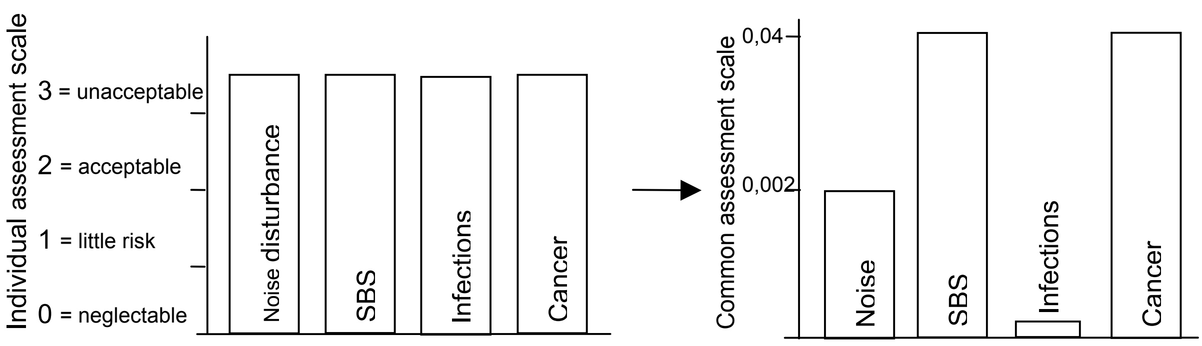


Figure 1. Unacceptable risk for health problems assessed on individual interval scales to the left and transformed to a common quotient scale to the right.

A common scale for risk assessment of different kinds of health problems is proposed in this paper. The weighting processes to adjust the individual assessments to this scale, briefly outlined by a few examples, will continosly be developed according to the knowledge and experience gained not least through the use of the method.

## A COMMON SCALE FOR RISK ASSESSMENTS

The individual scoring is the starting point for the systematic weighting. All scales in EcoEffect have a score 0 = “no risk” in common. They are interval scales. Score 2 means twice the risk of score 1. Score 2 = “acceptable risk”, i.e. the limit between 2 and 3, is the point of comparison. Since the scales are linear it is sufficient to compare just one point on each scale.

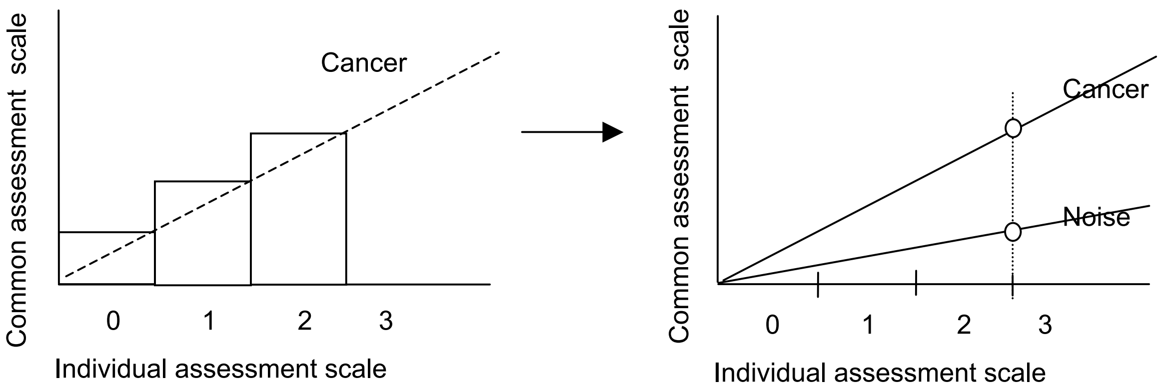


Figure 2. Individual risk scales compared on a common scale: to the left an individual interval scale for lung cancer; to the right it is transformed to a linear quotient scale and compared with disturbance form noise on the same scale. The weight of the individual risk scale is indicated by the inclination of the line.

We use the DALY method for estimating the severity of health problems, (Murray et al, 1996). According to this methodology the damage or suffering due to a disease is quantified as the number of years lived with disability multiplied by a disability weight. The disability weight varies from 0 = “healthy” to 1 = “dead”. For mortal diseases the years that may be lost due to premature death are multiplied by the disability weight 1 and added.

DALY = YLD + YLL

DALY (Disability Adjusted Life Years)

YLD (Years Lived with Disability) = duration of disability x disability weight;

YLL (Years of Life Lost) = reduced life years due to the disease

The DALY method has been used to calculate the burden of disease on global and national levels for use in health policy, (Murray et al, 1996). We apply the same methodology on an average individual level to measure the severity of each assessed building related health problem including disturbance from noise, odour, etc. Expressed as a procuct of disability and duration the severity of all health problems can be measured and compared. Multiplied by the probability of occurrence they can all be compared on a common risk scale:

Assessed risk = probability x duration x disability

The probability of being affected by a health problem, the typical duration of the health problem, and the typical disability, (intensity in the disturbance,) are the three weighting factors that will be defined for each assessed and weighted risk.

Cancer develops over a long time whereas infections hit instantly. Comparing the risks of different building related health problems it is important that the probability is calculated for a reasonable long time ahead. A fourth factor, time discounting, may be used to differentiate between instant and future health risks and make up for the fact that people and environment change and that future risks are considered to be much less severe.

The weighting is carried out as comparisons 1) between groups of similar health problems choosing one representative from each group, 2) within groups of similar health problems.

## COMPARING RISKS FOR DIFFERENT KINDS OF HEALTH PROBLEMS

Table 1. Health risks in residential buildings compared on a common scale. Disability weights and typical duration for severe upper respiratory infection, allergy, pneumonia and lung cancer are taken from Peterson et al (1998). Other data are estimated.

| Type of health problem | Probability | Disability weight | Duration weight | Assessed risk | Time discounting | Discounted risk |
|---|---|---|---|---|---|---|
| For comparison:<br>Severe upper respiratory infection | 0,35 | 0,07 | 0,02 | 0,005 | 0,5 | 0,0025 |
| Outdoor comfort problems<br>Example: Noise | 0,2 | 0,05 -0,01<br>0,01 | 0,02 | 0,0004 | 0,5 | 0,0002 |
| Indoor comfort problems<br>Example: Noise | 0,2 | 0,05 -0,01<br>0,01 | 0,2 | 0,004 | 0,5 | 0,002 |
| SBS, aggravated allergy, etc.<br>Example: Allergic rhinit | 0,1 | 0,05 -0,01<br>0,012 | 0,66 | 0,008 | 0,5 | 0,004 |
| Infections, poisoning<br>Pneumonia (legionella) | 0,01 | 0,1 - 0,5<br>0,028 | 0,02 | 0,0004 | 0,5 | 0,0002 |
| Cancers<br>Example: lung cancer | 0,0012 | 1 | 0,2 | 0,024 | 0,17 | 0,004 |
| Theoretical maximum risk:<br>Instantly mortal disease | 1 | 1 | 1 | 1 | 1 | 1 |

Table 1 shows a comparison of some health risks representing the range of health problems assessed in EcoEffect. Severe upper respiratory infection is added for comparison. According to a Swedish DALY calculation a person gets an infection 3,5 times yearly of which 10 % are supposed to be severe and lasting a week (Peterson et al, 1998). The intensity of the suffering is estimated to 0.07 on the DALY scale. Allergic rhinit and pneumonia are added to represent two different groups of similar building related health problems. 100 % risk to die immediately is the theoretical maximum risk = 1.

**Probability**

In EcoEffect the probability of a building related health problem is defined as the probability that an average user of the building is affected by the health problem.

In an existing building questionnaire responses directly measure the risk for some of the health problems in terms of probability. For residential buildings there is a data bank of questionnaire survey results to refer to, and frequences are age- and gender-weighted, (Engvall et al 2000). More than 20 % of the users disturbed or affected is generally assessed as “unacceptable” for most comfort problems. For other selfreported problems like SBS and aggravated allergy it varies and is lower. The questionnaire method requires a minimum of 12 responders and a response rate of 75 % to give reliable results.

A few health risks in existing buildings are assessed by measurements. The scoring is based on limits for pollution in air and drinking water. These limits are more or less explicitly linked to probabilities to fall ill. ”Unacceptable” when it comes to radon emission, for instance, corresponds to a probability of 0,12 % of getting lung cancer after long term exposure to more than 200 $Bq/m^3$ (Mjönes et al 2001).

Assessments based on design features are linked to the probability that they influence emissions, concentrations, etc that have a detrimental impact on the users’ health and comfort. This is the only available method to assess planned buildings. The risk of being disturbed by traffic noise, for instance, is assessed from information on sound insulation, distance to roads and number of cars estimated from traffic models.

The assessments vary in validity and reliability, e.g. assessments based on questionnaires are more valid than measurements, but measurements are more reliable. Validity and reliability influence the probability and must be accounted for though it is not discussed here.

**Severity**

The DALY calculations are based on health statistics on the incidence and prevalence of different diseases and the average number of years lost due to the disease. Panels of medically trained persons have determined the disability weights in procedures similar to that of health budget discussions. Only a few of the building related health problems assessed in EcoEffect are included in the weighting procedures carried through so far. Disability weights and durations in table 1 have been estimated by comparisons with similar DALY- weighted diseases. The disability weight of ”unacceptable” noise, for instance, is assumed to be less than that for a severe upper respiratory infection and in the same range as SBS and allergies.

Comfort problems and some of the building related illnesses ceases after exposure to the environmental load, e.g. disturbance from noise or windiness outdoors, thermal or visual problems indoors. As an average for all the users of a residential building 2/3 of the time is supposed to be spent at home, of which 90 % indoors and 10 % outdoors. (There are no statistics to verify these assumptions. 90 – 95 % indoors, however, is a frequently used figure to underline the importance of the indoor climate.) The environmental load may also vary in time. Noise for instance can be continuous or intermittent, and the duration of ”unacceptable” disturbance may be short and intensive or long and less intensive. Here we assume ”unacceptable” disturbance from an almost continuous traffic noise at a frequency corresponding to 1/3 of the time at home, i.e. 0,9 * 1/3 * 2/3 = 0,2 of all time.

The long duration of comfort problems and some building related and aggravated illnesses makes up for their low disability weights. For mortal diseases like lung cancer the years of life lost dominate the severity, and the years lived with disability can be neglected in the severity comparison. Some infections and poisoning have high disability weights but they are assumed to be of short duration and they are rare and therefore cannot compete in either severity or probability with the other health problems.

**Time discounting**

Health risks with immediate effects are generally considered to be more threatening than future health risks. Smoking is a striking example of this. In table 1 the probability and the alternative logarithmic time discounting refer to 50 years, i.e. risks are given continuously less weight until they are neglected after 50 years. The discounted risks are calculated as a yearly average over 50 years. Lung cancer, for example, is assumed to be diagnosed after 25 years of exposure to radon, which corresponds to a discount rate of 0,17. Other health risks, like disturbance from noise, do not change with time and the discount rate is assumed to be 0,5 as an average over the calculation period.

## WEIGHTING COMFORT RISKS WITH RESPECT TO SEVERITY

The following example concerns indoor comfort problems in residential buildings. The same strategy, however, could be applied to outdoor problems and office buildings. The same probability factor is used in the individual scales for all comfort problems, but the severity may differ and therefore need weighting. The comparison is made with respect to how disturbing the ”unacceptble” levels of the problems are for typical home activities. This means that the disability weight for each comfort problem varies with activity. The severity can be estimated as the summarised products of disability weight and duration for each combination of comfort problem and activity:

$$\text{severity} = \Sigma \text{ (duration weight for each activity * disability weight for each activity)}$$

There are no data on the average duration of typical home activities, and the comparison will have to be based on estimated duration. (Duration is chosen as a quantifiable and objective measure of importance, but subjectively estimated they would be about the same.) Sleeping and relaxing are assumed to take up most of the time, housework the least. When sleeping noise is supposed to be more disturbing than thermal “discomfort” and light is not needed at all. Light, however, is important for houseworking whereas noise would be less of a problem than for most other activities.

Table 2 shows a systematic weighting procedure for residential buildings. It starts by listing important home activities whith varying demands on comfort. The comparisons start vertically: How long time is spent on sleeping compared to other home activities, etc.? They continue horisontally for each activity: How disturbing is bad air quality compared to noise, etc.? A simple weighting technique is used that starts with ranking to facilitate a distribution of 100 points according to relative weight. Only the points are shown i table 2. After this a horisontal matrix multiplication is made, i.e. the number of points for the duration of each activity is multiplied by the number of points for the intensity of disturbance. The products for each of these multiplications are added vertically for each comfort problem. Only the result of the matrix multiplication in terms of relative weights is shown in table 2.

Table 2. Comparison with reference to duration (vertically) and disability/intensity (horisontally) of different comfort problems in a residential building.

| Activity | | Unacceptable comfort conditions concerning………. Air quality | Thermal comfort | Noise | Sun- and daylighting | Artificial light kitchen, bath |
|---|---|---|---|---|---|---|
| Vertical distribution of 100 points with reference to duration ↓ | | Horisontal distribution of 100 points with reference to how disturbing different comfort problems are → | | | | |
| Sleeping | 25 | 25 | 15 | 60 | 0 | 0 |
| Relaxing, TV | 20 | 20 | 20 | 40 | 20 | 0 |
| Eating, cooking | 15 | 25 | 20 | 20 | 20 | 15 |
| Studies, reading | 15 | 20 | 20 | 40 | 20 | 0 |
| Social activities | 10 | 25 | 25 | 30 | 20 | 0 |
| Personal hygiene | 10 | 30 | 30 | 10 | 10 | 20 |
| Houseworking | 5 | 15 | 10 | 5 | 30 | 20 |
| Summary | | 2325 | 1975 | 3625 | 1450 | 525 |
| Relative weight | 1 | 0,2 | 0,2 | 0,4 | 0,15 | 0,05 |
| Discounted risk | 0,005 | 0,001 | 0,001 | 0,002 | 0,00075 | 0,00025 |

According to table 2 unacceptable noise is twice as severe a problem as unacceptable air quality, thermal comfort or sun-and daylighting and artificial lighting together. The time discounted risk for noise is 0,002, according table 1. Time discounted risks for other comfort problems are estimated in relation to this in table 2.

## CONCLUDING REMARKS

A weighting strategy has been briefly outlined and exemplified by data, which to some extent are tentative. We are just in the beginning. As the weighting work proceeds data will be improved and the arguments more elaborated. When data and arguments are clearly presented in the assessment system they will contribute to a more consistent and concordant view on environmental risks.

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