A SIMPLIFIED METHOD TO GENERATE WEIGHTS FOR APPLICATION IN ENVIRONMENTAL ASSESSMENT OF BUILDINGS

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Key words: environmental assessment, LCA, disability weights, buildings, weighting, DALY, EcoEffect

Summary

Aggregation of results is generally a prerequisite for practical application of environmental assessments. Since there is no consensus about how this should be done researchers and tool developers apply different approaches, which are often customized to each tool or method. Due to this lack of generality it is difficult to transfer weighting systems between methods or models.

In this paper a framework of a general method for weighting is presented. It is based on the consequences for man caused by different kinds of environmental impact. This concept is inspired by the DALY (Disability Adjusted Life Years) system. It has two major components namely the degree and time of suffering. The average degree of suffering, measured as a disability weight, has to be found for problems addressed in the environmental assessment. A way to set preliminary disability weights by a problem classification procedure is demonstrated. These disability weights together with estimated duration times can be of immediate practical use in the weighting of building related problems. The accuracy can successively be improved by questionnaires.

One of the advantages with this method is that building problems can be quantitatively compared with a wide range of other problems in society because of the connection to the DALY system and a method for classifying quality of life within social medicine.

1. Introduction

Environmental assessment of buildings generally comprises evaluation of a number of different aspects. To make these results practicable throughout a design, construction or operation process aggregating of results is needed, which means that some form of weighting process has to be applied. The credibility of the result is strongly linked to the weighting methodology used and its transparency, reliability, intelligibility etc.

To obtain quantitative assessment results, measures have to be found for all aspects, which are to be evaluated. Furthermore, to make an aggregation these measures have to be dimensionless and a way to measure the relative significance of each measured aspect (problem) has to be found, i.e. weights. The impact measure can be made dimensionless through normalization. Thus, a weighted impact can be calculated as:

$$I_i = (L_i / N_i) * s_i \quad (1)$$

I_i = Weighted impact for the aspect *i* in a building
L_i = Load, the measure of *i* in a building
N_i = normalisation value for the aspect *i*
s_i = relative significance of aspect *i*

In Sweden a holistic method to make environmental assessment of buildings or properties called EcoEffect has been developed (Assefa et al 2005). In this method we needed a weighting method preferably applicable for assessment of both internal and external impacts. A review of existing environmental assessment methods for buildings showed that there is no consensus about how weighting should be performed, and a wide range of different approaches has been used. A closer look at some of them showed that they either were not systematic enough, lacked transparency or were too tailored or complex to adopt. Andresen 1999 has reviewed general possibilities to weight and we have tried some of them, specifically Analytic Hierarchy Process (Saaty 1980). Since weighting is the most crucial issue for practical use of environmental assessment and what we had seen was not ideally suited for our purpose, a general systematic method for weighting was developed. This paper presents the basis for this system, i.e. how to measure the relative significance of each endpoint problem addressed.

2. Method development

The first step in development of the weighting method was to decide the basis for the system. The second step was to find a measure for the significance and third was to calculate the weights, which should be possible to do by us.

2.1 Basis for weighting

The development of an environmental assessment method for buildings includes identifying direct or potential problems related to a building and finding measures and weights for those problems. The problem identification is made with reference to stated safeguard objects, which for example could be human health, natural resources and biodiversity. The first two objects are clearly related to human quality of life today and in the future. Saving biodiversity is not as clearly related to human wellbeing. However, depletion of biodiversity indirectly hurt man in the end. To simplify the environmental assessment and to apply the precautionary principle, human health (physically and psychologically) was chosen as the only safeguard object. Depletion of natural resources and biodiversity then had to be interpreted in terms of harm or damage to humans. The relative significance of each endpoint problem could thus be measured as its potential harm to man.

2.2 Measuring harm to man

Health and wellbeing can be defined inversely, i.e. as lack of physical or psychological suffering. Within social medicine measures of this have been developed for instance as a means for resource allocation within medical and health care. A well-known and widely applied method of this kind is called DALY (Disability Adjusted Life Years), the development of which was supported by WHO (Murray and Lopez 1996). This approach has also been used successfully within LCA (Hofstetter 1998). The basic concept of DALY is that a mild suffering during a long time is assessed as equal to a harsh suffering during a short period. This is expressed, as a ***disability weight*** multiplied by a ***duration time***, which expresses the degree of harm an individual experiences due to a specific impact.

$$H = dw * dt \qquad (2)$$

H = harm to a person
dw = disability weight
dt = duration time

This approach inspired us to use a similar concept for problems associated with buildings. Then the potential harm to a person from an environmental impact would be measured as the average harm it is expected to exert on an individual. The relative significance of impacts that would hurt many people could be taken as the expected number of affected persons multiplied by the average suffering of the individuals.

A number of people and a duration time are easily understood concepts and the way to estimate them is straightforward. The concept of a disability weight and how to find it, however, is more complex.

3. Obtaining disability weights

If disability weights for comfort problems would be comparable to disability weights used for DALY calculations building problems could be comparable to a vast number of diseases, accidents and psychological problems for which disability weights have been elaborated for use in DALY calculations (Int. Burden Of Disease Network 1999). Since building related problems may last for a comparably long time, even low impacts, like for instance discomfort due to overheating, might be comparable to more severe suffering caused by a disease.

If a large number of persons with a specific disease are asked to indicate how disabled they feel on a visual scale from 0 to 1 a disability weight could be calculated as the mean value. This procedure is called setting a value after a Visual Analogue Scale (VAS). The DALY disability weights, however, are set according to another procedure involving a group of physicians, who make a “trade off” between groups of people who are affected and unaffected of diseases (Person Trade Off – PTO). This was too complicated for our purpose. Further more, physicians are hardly more fitted to describe everyday problems, like discomfort, than other people.

For comparison of comfort problems it seems to be relevant to relate a disability weight to a load level, for instance a noise level, that is clearly perceived by most people, i.e. a load that is neither very high, which might be unusual, nor so low that it is hardly detectable. It is thus crucial to describe this load level and what harm it causes when a person is exposed to it. To conclude, there are at least three issues to take into account when setting disability weights for comfort problems.

1. description of the load level that is clearly perceived for each problem and which the disability weights should represent
2. description of the consequence to man when exposed to these impact levels
3. setting disability weights with reference to the consequences to man

People’s opinions are the yardstick for setting disability weights according to the VAS method. To get consistent answers from a questionnaire about discomfort problems, the questions has to formulated according to step 1 above and how to set the weight according to step 2 and 3 must be explained. At description of the load both intensity and duration has to be stated. The importance of incorporation of these three steps was not clear to us in the beginning of the work. To find disability weights two approaches were tried out. First we made a general pilot questionnaire in order to find out if disability weights could be set directly this way. After the difficulties with this approach had been revealed we tried to arrive at disability weights directly from a thorough description of consequences of different impacts. This seemed to work in principle but one can’t be sure that the consequences described correspond to the clearly perceived level of impact, which is wanted. These correlations have to be further investigated with questionnaires. The two approaches and our experiences of these will be described in the following sections.

3.1 Test with a questionnaire

With the aim to find general differences in valuation of common building-related problems such as noise, draught, chilliness, etc. a pilot questionnaire was designed. The respondents were required to imagine a situation where he/she had the opportunity to freely choose an apartment in a multi-family building and a work place in an office. They were asked to rank and weight predefined problems/shortcomings related to housing and office environments and some building-related health problems according to an inconvenience scale, figure 1.

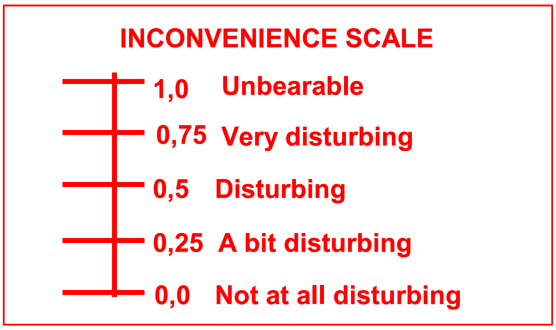

Figure 1 The inconvenience scale used in the questionnaire

Since it was a pilot study, no randomised sample was collected. The sample was based on two different collection procedures. 50 % were gathered from questionnaires sent out to friends and colleagues of the research group and 50% were collected from students. In total, around 200 questionnaires have been analysed. Table 1 shows an extract of the result.

Table 1 Means and standard deviations for some comfort problems in housing sorted by degree of inconvenience – total sample. 0 = no impact, 1 = unbearable.

Problem/deficit	Mean	St. dev.
Indoor problems		
Ventilation – you can often feel smoke and the smell of cooking from your neighbours	0,78	0,21
Thermal comfort – the residence is unusually cold in wintertime	0,68	0,22
Ventilation – the indoor air is often stuffy	0,66	0,22
Noise – you can easily hear your neighbours' voices, and noise from the staircase	0,64	0,22
Light – the residence is dark (little daylight)	0,61	0,25
Noise – sounds from installations are evident (for instance ventilation, fridge, pipes)	0,60	0,21
Thermal comfort – the residence is unusually warm in summertime	0,59	0,25
Noise – sounds from traffic are apparent	0,58	0,24
Light – the sun seldom reach the kitchen and the living room	0,53	0,25
Outdoor problems		
Smells often enter the balcony or private yard (for instance from industry or restaurants)	0,60	0,24
Noise enters the balcony or private yard (for instance traffic or industry)	0,58	0,24
The balcony or private patio is usually shady	0,55	0,24
The balcony or private patio is windy	0,51	0,26
The balcony or private patio becomes dirty (for instance by traffic dust)	0,49	0,24

The mean values give a general idea of how these problems are valued. Consequently, they can be used as a basis for setting disability weights (the scales have to be adjusted first). The standard deviation is large throughout. For some problems the answers differ a lot while they are more consistent for others, figure 2 and 3.

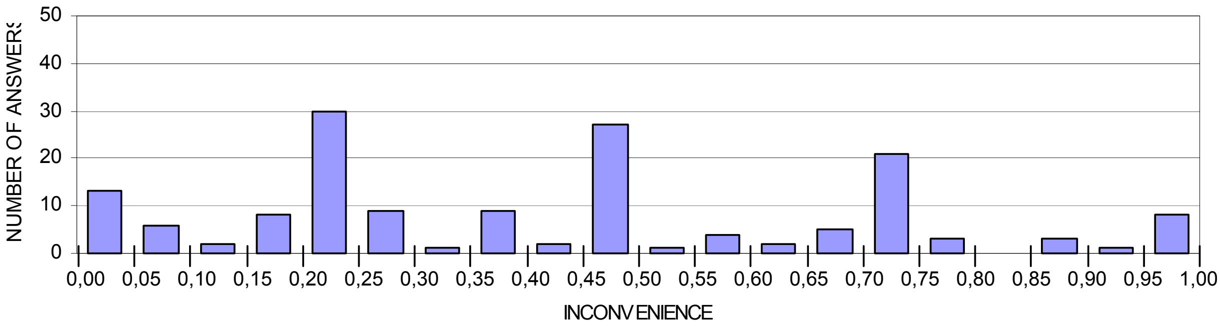

Figure 2. Number of respondents giving different weights to the problem "The patio is windy" (Office environment)

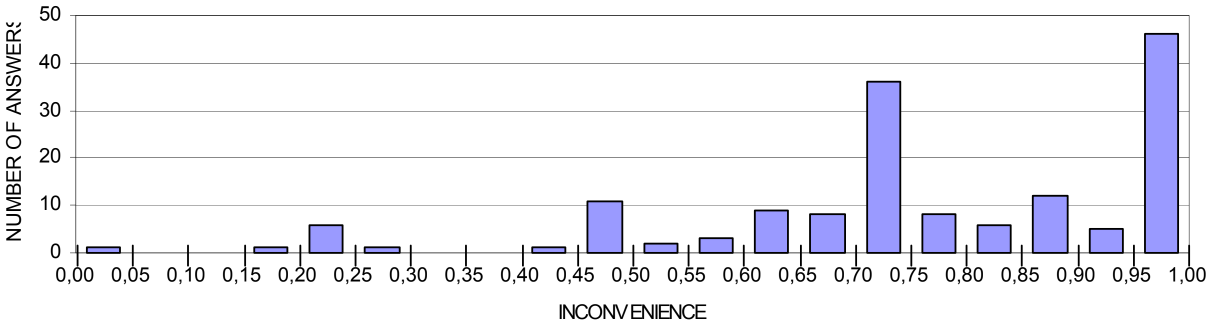

Figure 3. Number of respondents giving different weights to the problem "you can often feel smoke and the smell of cooking from your neighbours " (Residential building)

Since the result does not show a normal distribution, mean values may be irrelevant. The spread of the answers might reflect a real spread in perceptions but the result might also show a distorted picture due to a poor definition of the problem resulting in answers to slightly different issues. During the analysis we realised that the load level was not sufficiently described. It most probably has to be defined both with regard to load level and duration time to avoid different interpretations of the size of a problem by different respondents. Furthermore, in this case the problems were grouped according to areas in order to reduce the number of issues that was to be ranked at the same time. In many cases this lead to an inconsistent use of the inconvenience scale for different areas although a specific procedure to avoid this was included.

The pilot questionnaire clearly showed that there are a number of problems associated with trying to find disability weights by a questionnaire. However, it also indicated that there are common opinions about some building related problems. To trace them reliably there is a need for a more appropriate questionnaire than the one that was used in this case.

A general drawback with questionnaires used for this purpose is that a large sample is needed, which demand quite a lot of work. For this reason it is complicated to obtain disability weights for “new” problems that one may want to assess.

3.2 Test with a classification system

Referring to the general procedure mentioned earlier disability weights might be set from a thorough description of the consequences (harm) the problems give to man. So the next step in the work was to look for ways to describe quality of life or its opposite in a systematic way.

A system to classify health status that looked promising is called EuroQol (Brooks 1996). It facilitates classification of problems with regard to both physical and psychological effects. In one variant, the EQ-5D+ system, problems are classified in three levels (1, 2, 3) according to their consequences regarding six different aspects of life quality. In Stouthard et al (1997) an attempt was made to calculate disability weights directly from the means of the classification scores with fairly good results. However, a conclusion in this study was that the scale was too rough and that the results would probably improve with a finer scale. Since building-related problems generally are of a less serious character and thus only appear in a small part of a disability scale running from no impact to death, a finer scale is preferable also for this reason. Consequently, we proposed an extension of the EQ-5D+ disability levels, Table 2.

Table 2. Proposed extension of scale and descriptions of the EQ-5D+ system. Class 1 and 3 are new. Class 0 corresponds to former 1 and class 4 to former 3. (Plain text from Stouthard et al, 1997, text in italics is the extended proposal).). Numbers in brackets indicate original classes.

ASPECTS OF QUALITY OF LIFE	DISABILITY CLASS/SCORES				
	0 (1)	*1*	*2* (2)	*3*	*4* (3)
	No problem	Small problems	Some problems	Large problems	Very large problems
Mobility e.g. *stand up*, move around, *climb a staircase, fine motor ability*	No problems in walking about. *Can write without difficulty.*	Some problem with staircases. Some problems with writing.	Some problems in walking about	Can walk short distances with support.	Confined to bed
Self-care e.g. manage personal care, *cooking,* dressing, washing,	No problems with washing or dressing self	Small problems with some clothes	Some problems with washing or dressing self	Need help with washing and dressing	Unable to wash or dress self
Usual activities e.g. work, study, housework, family and leisure activities. *Take into account other activities that are not performed due to the impact.*	No problems with performing usual activities	A few less important usual activities are not performed due to the impact.	Some problems with performing usual activities. *Some usual activities are not performed due to the impact*	Most usual activities are not performed due to the impact	Unable to perform usual activities
Pain/discomfort *Physical impact*	No pain or discomfort	Occasionally little pain, feeling cold or warm	Moderate pain or discomfort	Permanent pain or other physical problem	Extreme pain or discomfort
Anxiety/depression/ *Irritation* *Psychological impact*	Not anxious, depressed or *irritated*	Occasionally anxious or touchy	Moderately anxious, depressed or *irritated*	Often very anxious, depressed, touchy or irritated	Extremely anxious, depressed or *irritated*
Cognition e.g. memory, concentration, coherence, IQ	No problems in cognitive functioning	Occasionally distrait and some difficulty to concentrate	Some problems in cognitive functioning *Often difficulties to concentrate.*	Often forget and have problems to communicate	Extreme problems in cognitive functioning *Can hardly communicate*

We kept the original classification description and only put in intermediate class levels. Hence results derived from use of the original scale can still be compared with results from use of the extended scale. For our purpose we also needed to clarify some of the original descriptions of the aspects of quality of life shown in table 2.

Furthermore, the class numbers have been changed in order to simplify the transformation from classification values to weights. The original class numbers were 1,2 and 3 but we let the scale run from 0 to 4 since the scale for disability weights also starts on 0. In the disability weight scale 1,0 corresponds to the utmost suffering, i.e. dead. This is more severe than “very large problems” which is the upper end of the scale in table 2. When calculating a disability weight from scores set according to table 2 we suggest it should be done through adding all the scores and divide the sum by 27. If doing so the smallest disability weight becomes 0,0 and the highest (score 4 on all aspects) approximately 0,9 which seems reasonable.

According to the proposed classification system, six numbers, one score for each aspect of quality of life, can characterize the consequences for man of any problem and a corresponding disability weight can be. The great advantage with this approach is that load level is clearly stated and that it can handle both physical and psychological problems. Building related problems, as discomfort or suffering from noise, do not generally lead to physical problems or diseases but rather to annoyance, which can be interpreted as psychological impact on individuals.

The disadvantage is that the impact categories of the system originally were designed to suit a description of diseases. If the system should be designed to suit building related problems the aspects of quality of life would most certainly have been different. Now, building problems only may give scores in a few of the aspects of quality of life. The building problems give very low disability weights in this system and the full scale is poorly utilized. However, the advantage to facilitate comparison with other human problems in the society outweighs.

It must also be noted that the gap between the thorough description through classification and how people react on each defined problem can be more accurately evaluated through a questionnaire, which include the precise aspect descriptions. Nevertheless, setting preliminary disability weights through classification facilitates aggregation immediately, although on a lower accuracy level. Further these preliminary disability weights are never “wrong”, they just describe a specific disability level.

4. Need for higher resolution at comparison

In many cases it might be interesting to more obtain a more accurate comparison between for example comfort problems. This can easily be done through the same methodology. Take for instance different aspects of air quality, which affects us differently depending on which activity we perform. The different problems and activities can be listed and a detailed classification according to the descriptions in table 2 can be made, table 3.

Table 3. Example of preliminary classification of problems related to indoor air quality. Classification scores were set according to table 2. Italic text refers to questions in the EcoEffect questionnaire.

USUAL ACTIVITIES	INDOOR AIR QUALITY RELATED PROBLEMS											
	Volatile compounds, smells								Moisture, microbes		Dust, particles	Dilution of compounds
	"Pungent smell"	*"Dry air"*	*"Smells exhaust gases"*	*"Smells sewer"*	*"Smell from others cooking"*	*"Smell from own cooking"*	*"Smells garbage"*	*"Smells smoke from outside"*	*"Smells mould"*	*"Smells musty"*	*"Dusty air"*	*"Stuffy air"*
Falling asleep	2	1	3	2	1	0	2	1	3	2	1	1
Relaxing	2	1	3	3	1	1	2	2	3	2	1	1
Cooking, eating	2	0	3	3	1	0	2	1	3	2	1	0
Being with guests	2	0	3	3	2	0	3	2	3	2	2	2
Read, concentrate	2	0	2	2	1	0	2	1	3	2	0	1
Washing, cleaning	1	0	1	1	1	0	1	0	3	1	0	0
Mean value	1,83	0,33	2,50	2,33	1,17	0,17	2,00	1,17	3,00	1,83	0,83	0,83
Relative importance	0,10	0,02	0,14	0,13	0,06	0,01	0,11	0,06	0,17	0,10	0,05	0,05
	0,64								0,27		0,05	0,05

The mean classification score of each problem shows a description of the relative severity for an exposed person according to the person doing the classification. Of course different people can have different opinions about the scores. For this reason it is preferable that a group of persons perform the classification in dialogue and arrive at a consensus scoring. This procedure is not critical for the use of the method. Each set of scoring describes the consequences of a chosen load level for each problem.

Finally all the detailed classification problems under air quality can be interpreted as a part of "usual activities" in table 2. For determining a final disability weight these mean values must be put in under "usual activities" as shown in table 4.

Table 4. Calculating the final disability weights for detailed problems related to Indoor Air Quality. The values for "Usual activities" are taken from table 3.

ASPECTS OF QUALITY OF LIFE	INDOOR AIR QUALITY RELATED PROBLEMS											
	Volatile compounds, smells								Moisture, microbes		Dust, particles	Dilution of compounds
	"Pungent smell"	*"Dry air"*	*"Smells exhaust gases"*	*"Smells sewer"*	*"Smell from others cooking"*	*"Smell from own cooking"*	*"Smells garbage"*	*"Smells smoke from outside"*	*"Smells mould"*	*"Smells musty"*	*"Dusty air"*	*"Stuffy air"*
Mobility	0	0	0	0	0	0	0	0	0	0	0	0
Self-care	0	0	0	0	0	0	0	0	0	0	0	0
Usual activities	1,83	0,33	2,50	2,33	1,17	0,17	2,00	1,17	3,00	1,83	0,83	0,83
Pain, discomfort	2	1	2	0	1	0	1	2	3	3	1	0
Anxiety, depression	3	1	3	3	2	1	2	2	3	2	2	1
Cognition	0	0	0	0	0	0	0	0	0	0	0	0
Disability weight, VAS	0,25	0,09	0,28	0,20	0,15	0,04	0,19	0,19	0,33	0,25	0,14	0,07

5. Disability weights according to VAS versus DALY

Disability weights used for DALY-calculations are, as mentioned earlier, set through a PTO "Person Trade Off" (PTO) process. This does not give exactly the same weights as when people are asked to set disability weights according to a visual analogue scale (VAS), fig 4.

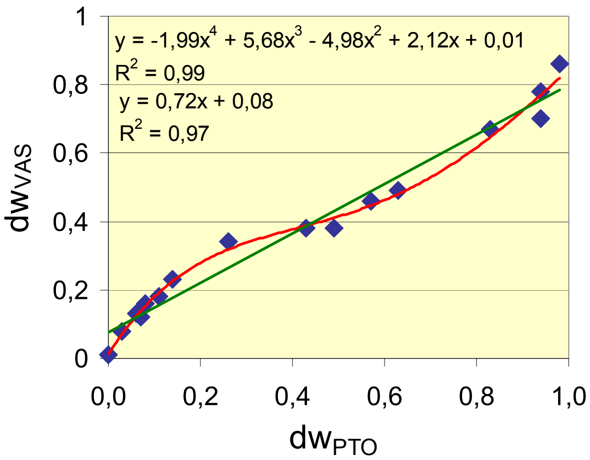

Figure 4. Disability weights, dw, derived from VAS respectively PTO processes. Mean values from three groups of physicians. Data from Stouthard et al 1997.

A straight line according to equation (3) on next page gives a fairly good approximation of the relation between disability weights arrived at in the two different ways apart from at high values.

$$dw_{VAS} = 0,72\ dw_{PTO} + 0,08 \qquad (3)$$

6. Discussion

There is a need for a measure to compare different kinds of harm to man when prioritizing between counteractions. Since suffering includes two dimensions, namely the degree of suffering (intensity) and the duration of it, both these aspects should be included in such a measure. The duration is an easy measure to understand but the degree of suffering might be understood in different ways.

The perceived degree of suffering (disturbance) from a specific exposure varies individually for different reasons such as experience, activity, age etc. To describe the consequences of a disturbance with reference to different aspects of quality of life, like the EQ-5D+ system, seems relevant for building related problems even though these usually give very low scores. It can be questioned whether the EQ-5D+ categories designed for measuring quality of life are appropriate for characterizing building-related problems. Some categories may overlap. For instance, the category of self-care depends on mobility, which in turn can be affected if one has pain when one moves. This scale, however, is verified and widely used, which is a reason for keeping it.

To describe a level of suffering in terms of a load level (intensity) and duration, which matches the classification scores or vice versa is not easily done. Since the problems concern human experience the answers can only be obtained by asking many people about their opinions. However, we judge the methodology outlined here as good enough, appreciating the fact that tentative values can be used in the start. Hopefully further improvement will be gained successively through results from questionnaires or full-scale experiments. It should be noted that one has to distinguish between immediate responses to a disturbance and the average experience of the same load occurring intermittently during a long time. The experience of the physical environment is of the latter kind and can not always be captured by experiments.

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