Assessing environmental efficiency of buildings

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1. Introduction

Buildings shall serve certain functions without jeopardizing health and well-being of its users. Further the goal ought to be fulfilling these wishes with the least possible impact on the external environment.

Today there are a number of simplistic tools used for environmental assessment of buildings, for example BREEAM[1], LEED[2], and MILJÖSTATUS[3] within the building sector. They are normally focussing on a number of selected issues and don't give a comprehensive picture of the environmental impact of an assessed building. In order to get a more profound understanding of the environmental causes and effects we want to introduce the term *environmental efficiency* of a building as a means to minimize negative impact on people in a building and on

[1] Building Research Establishment Environmental Assessment Method.
[2] Leadership in Energy and Environmental Design.
[3] Miljöstatus för byggnader.

the external environment including people elesewhere, figure 1. Impact on the internal environment means here low negative impact on health and well-being of the users.

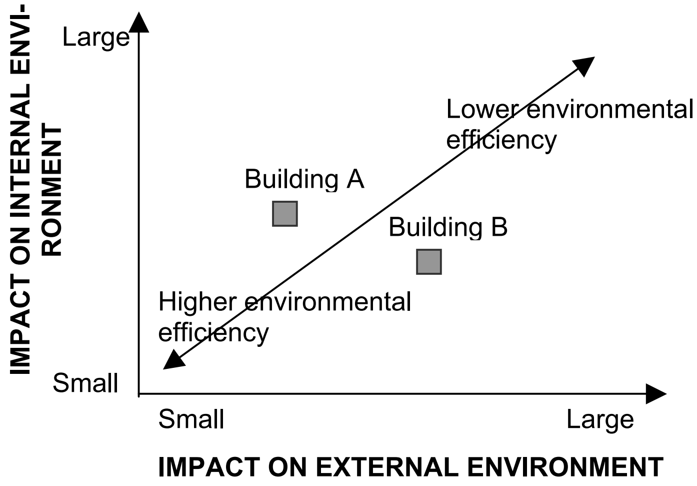

Figure 1. Illustration of how environmental efficiency of a building can be presented.

If we calculate a comprehensive *internal impact index*, ***I***, representing impact on people in a building or on a property, and an *external impact index*, ***E***, representing the potential impact on the external environment caused by using the building, any building could be plotted in this diagram. The buildings may then be compared and improved regarding their environmental efficiency. The environmental efficiency will increase if the internal impact is decreased to the same external impact. The environmental efficiency will also increase if a certain level of internal impact is reached with less external impact. Note that there is no clear relation between internal and external impacts for buildings. For example, a certain level of thermal comfort can be met in different ways, either with focus on mechanical means or on passive means (insulation, solar shading devices, thermal mass etc), which causes very different impact on the external environment.

The main question is if it is possible to create these indexes comprehensive enough to be meaningful and clear enough to be comprehensible and easy to resolve for finding causes for bad scores. To explore the possibility to develop such indexes is a part of a larger project called EcoEffect[4] aiming at developing a general method for environmental assessments of buildings and building properties.

In this paper we propose a method to calculate the internal impact index, for an existing building, I_e. Procedures for calculating an internal impact index for a building at the design stage, I_d, has also been developed within the EcoEffect project as well as the external environmental index, ***E***, based on life cycle assessment (LCA). The included impact categories in these indexes can be found in the summary at www.ecoeffect.tk.

However, it is a problem that some properties of buildings are difficult or even impossible to measure or describe objectively. Choices that will lead to bias or incompleteness have to be made. We, nonetheless, follow the hypothesis that it is possible to find enough measurable impacts to calculate environmental efficiency in a way that is both credible and practicable. Even if this goal is not fully achieved, the review of impacts related to health, well-being and

[4] Glaumann M. (1999)

environmental impact from buildings still serves as a starting-point for further research and conceptualisations within this field.

2. Weighting – prerequisite for indexes

To arrive into single internal and external impact indexes the included impact categories need to be weighted according to their significance. In the EcoEffect method the proposed weighting system is based both on the *probability* of an environmental impact to occur and the potential harm it may cause if it occurs, denoted *severity*. The impact indexes are meant to include most measurable potential impacts on people today and in the future. They are calculated as the sum of the product of these two variables for each impact category taken into account, shown in Eq. 1.

$$\boldsymbol{I} \text{ or } \boldsymbol{E} = \Sigma\,(p_i * s_i) \qquad \text{(Eq. 1)}$$

p_i = probability that the impact *i* will occur
s_i = severity if the impact *i* occurs

The probability that something will occur depends on a pressure. The larger this pressure is, for example, the noise level or the amount of CO_2 emitted due to heating of a building, the larger is the probability that it will harm people immediately or in the future. The harm caused by an impact might be either physical as disease symptoms, e.g. pain, decreased mobility, etc. or psychological, e.g. anxiety, irritation or depression. Both kind of harms will lead to restrictions in what activities (functions) we may perform. In social medicine the term *disability* is used to describe the harm of an impact on people.

The probability factor, *p*, is associated with the properties of the assessed building while the severity factor, *s*, is related to the potential degree of harm each kind of impact may cause. The latter acts as a weight based on the size of each environmental problem. Probability multiplied by severity shows a *risk.* In the case of internal impacts it reflects the risk for a user of a building to be affected by an impact caused by the building, while in the case of external impacts it reflects the risk for any person, anywhere and any time to be affected by an impact caused by producing, use and demolishing the building.

The severity of a specific impact can be measured in the unit DALY[5], (Disability Adjusted Life Years) - for an individual as DALYs per person and for a society as the sum of all individual DALYs. It is a unit developed with support from WHO and the World Bank for measuring the total burden of different diseases. The background is the need for means to support decisions concerning resource allocation in the field of health care. The DALYs for a specific disease is calculated as the number of years a person normally is sick multiplied by a *disability weight* for the disease. For mortal diseases the number of *lost healthy years* due to premature death is also included, figure 2. The *disability weight*, has a scale where 0 means no impact and 1 mortal impact. It corresponds to the degree of disability an affected person experience. The average convalescence time and the years lost for different diseases are received from health statistics.

[5] Murray C J L, Lopez A D (1996).

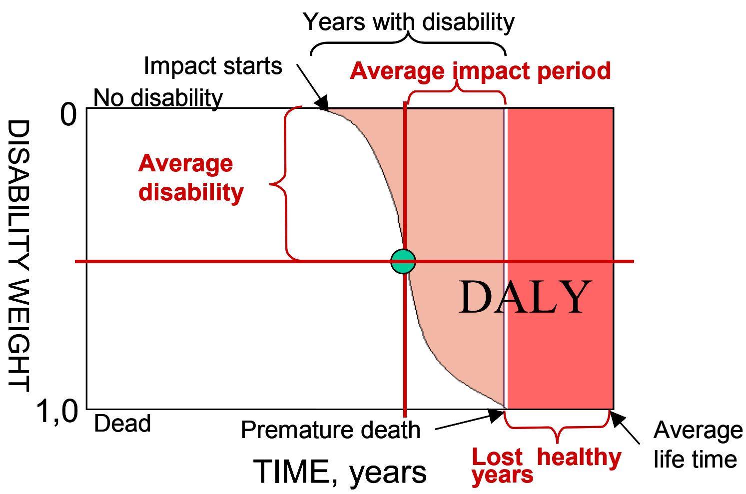

Figure 2. Illustration of the DALY concept. The shaded area represents the number of DALYs for a specific disease expressed in the unit years.

In EcoEffect the severity, $s_{i,}$, for each impact as mentioned is based on the DALY concept but we have modified slightly through normalisation with life time, eq. 2. The latter vary from country to country. The unit of the severity factor then becomes persons, i.e. the weighting factor is proportional to the potential number of disabled persons and the average degree of disability for each impact.

$$s_i = (nd_i * dw_i * d_i + nl_i * l_i)/lt \qquad \text{(Eq. 2)}$$

dw_i = disability weight for impact i
nd_i = potential number of persons disabled by impact i
d_i = average duration for impact i, years
nl_i = potential number of persons subjected to premature death due to impact i
l_i = average years lost due to premature death by impact i, years
lt = life time, years

In the case of internal impacts, the risk for an individual to suffer, the potential number of other persons suffering from the same impact is irrelevant and the *nd* and *nl* terms disappear. Furthermore the internal impacts are rarely mortal. For those impacts which are not mortal the severity factor s_i is simplified to only $dw_i * d_i/lt$.

The disability weights used for calculating DALYs have been assessed by panels of physicians, mainly through PTO[6]-technique (Person Trade Off). These disability weights do not only show the harm of a specific disease. They also reflect the outcome of allocations of resources to cure it so as to serve as a basis for health policies. Disability weights used for DALY calculations have been made for hundreds of diseases and other health problems. A compilation of them has been done in Australia[7]. Thus, if disability weights can be used for building related problems comparable with the DALY weights we are able to compare building problems with a wide range of other human health problems.

3. Calculating the internal impact index for existing buildings, I_e

Dissatisfaction regarding a condition in a building can also be said to have two dimensions, magnitude and duration. Disturbance by noise, for instance, may mean either low noise levels

[6] Murray C J L, Lopez A D (1996).
[7] International Burden of Disease Network (1999).

occurring frequently, or high noise levels occurring occasionally. In a pilot study we wanted to find out general differences in valuation of different common building problems as noise, draft, coldness etc. meant to take care of. A questionnaire was used where the respondents were expected to make comparisons with reference to clearly disturbing intensities and common durations. Most building related problems are not mortal. They often occur regularly, e.g. noise varies throughout the day and heat and cold vary by season. This means that in these cases the duration factor can be measured as a fraction of time

Probability for internal impacts

To find the probability factor for an existing building, the users' judgements are used through a standardised questionnaire. In EcoEffect we use a questionnaire which is a further developed version of the "Stockholm questionnaire"[8] that has been used in over 10 000 dwellings in Stockholm. Complementary technical measurements are carried out to measure impacts that usually cannot be perceived, for instance occurrence of radon gas. The questionnaire includes for example questions like if the users of the building are satisfied or dissatisfied with the thermal comfort, air quality and light conditions.

Severity of internal impacts

Disability weights and the opposite quality of life indicators have been developed within social medicine for persons with different kinds of diseases, for example the QALY-system[9] (Quality Adjusted Life Years). In Europe, this system has been further developed into a classification system for diseases called EuroQol[10], which facilitates assessment of the degree of disability related to both physical and psychological effects.

A problem, when setting disability weights for a disease, is to define the health state that shall represent it, since the health state vary during the convalescence period and different people are affected differently. For this reason several disability weights can be set for the same disease representing different ages, sexes etc. Thus, thorough description of the health state is crucial for arriving at a representative disability weight.

Disability weights derived from PTO-technique will not be the same as those set without considering the effects of interventions. Using a VAS scale (Visual Analogue Scale) the problems are just ranked and then the weights set on a linear scale. For our purpose disability weights according to a VAS scale are more appropriate than a PTO assessment since we want our weights to represent the average harm experienced by effected people. Data from a Dutch study [11] however gives us possibility to convert PTO-weights to VAS-weights and therefore a large number of disability weights used for DALY calculations may also be useful for our purpose.

To conclude, with access to questionnaire results from a building we also need disability weights and common duration times for the considered impacts to be able to calculate ***I*** for it. How these disability weights can be found is thereby also the focus for the rest part of this paper.

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[8] Engvall K et al. (2002).
[9] Hayward Medical Communications.
[10] Stouthard E A et al. (1997).
[11] ibid

4. Disability weights derived from a questionnaire

Initially, we carried out a pilot study in order to learn more about how people in general value building related problems. Our problem, to rank and weight internal impacts, has relation to valuation of housing quality in general which have been studied extensively with questionnaires in Sweden. We found, however, that there is a great difference between studying qualities and problems. Further the questions in quality studies did not cover more than a few of the housing problems that we are interested in. Thus, we decided to make a customised questionnaire to serve our special intentions.

The questionnaire

The respondents were demanded to imagine a situation where he/she had the opportunity to freely choose an apartment in a multi family house and a working 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. The problems were presented in groups as shown in table 1. The weights were set according to an inconvenience scale, figure 3. It was possible to choose weights between 0,0 to 1,0 with intervals of 0,05. The weights set by the respondents were expected to reflect a general judgement of an evident disturbing level of each problem.

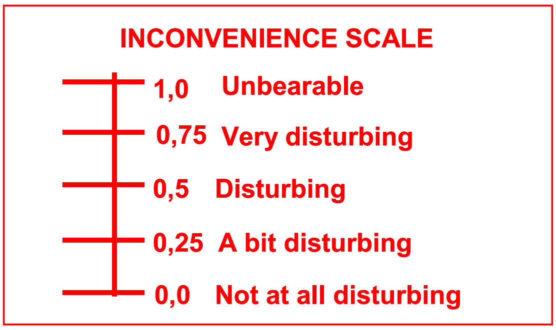

Figure 3. The inconvenience scale used in the questionnaire of the pilot study

It should be noted that since the inconvenience scale includes expressed end and mid points, respondents tend to choose these values more frequently than others.

Sample

The questionnaire was designed to be answered in an excel-document. In total, around 200 questionnaires have been used. Because of the character of a pilot study, no randomised sample has been collected. The sample is based on two different collection procedures. 50 % relates from questionnaires sent out to friends and colleagues to the research group in January 2003. These persons were asked to answer the questionnaire and forward it to other people preferably differing in age and profession. In May 2003 two groups of students at The University of Gävle collected nearly 100 additional questionnaires. Besides a direct falling off of around 15 %, quite a few replies in the Gävle sample were sorted out due to incomplete or inconsistent answers. In the end, around 150 replies were used as the total sample. Distribution of age and type of living in the sample is shown in figure 4 and 5. There was an even distribution between women and men. The most important distortion in the sample is age distribution, which depends on students collecting many replies and the fact that the questionnaire had to be answered digitally.

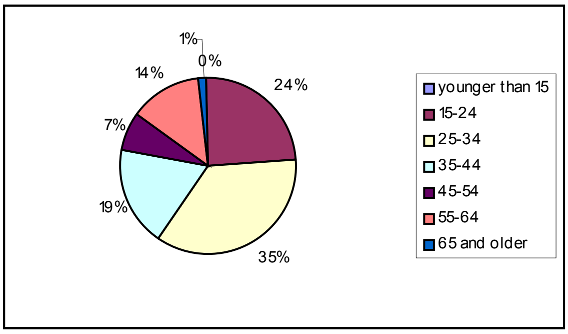

Figure 4. Age distribution of the sample

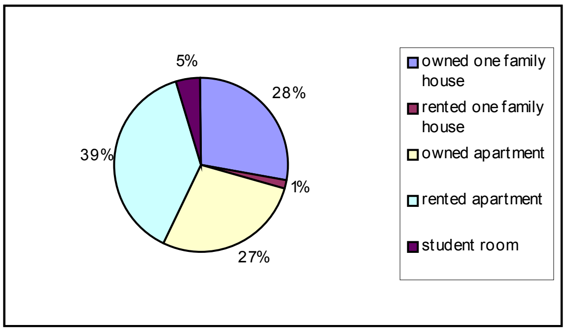

Figure 5. Distribution of type of living

Results of the pilot study

Means, standard deviations and confidence intervals were calculated. Results for the problems discussed in this paper are shown in table 1. The results indicate that preferences can be discerned even though the spread is quite large.

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

Problem/deficit	**Mean, w_q**	**St. dev.**
Indoor problems		
Ventilation – you can often feel smoke and 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 ventilations, 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
Health problems		
You have a head ache (migraine)	0,82	0,21
You have problems with breathing (asthmatic symptoms)	0,76	0,23
You have aching ears (ear inflammation)	0,70	0,23
You have itching, red or irritated eyes	0,64	0,23
You have a fierce cold	0,57	0,23
You have pain in muscles and joints	0,57	0,23
You have itching rashes	0,52	0,25
You have an irritated, stopped-up or running nose	0,46	0,25

The means give a general idea of how these problems are valued by the 150 people in the survey. Consequently, these means could be used for weighting internal impacts, i.e. serve the same purpose as the disability weights used in DALY. From now on the questionnaire weights will be referred to as $\mathbf{w_q}$.

It can be concluded that the spread in data is relatively prominent and the credibility of data can be discussed. Two important sources of errors can be pointed out, which may be possible to reduce in a new study. Firstly, an insufficient definition of the magnitude and duration of problems has most likely caused different interpretations of the size of each problem. Secondly, the problem with using the scale consistently for all groups of problems could possibly be reduced by improvements of the questionnaire.

A natural spread in responses due to different experiences of the problems certainly will influences our values and the weights set. Although deficiencies, an important finding is that in spite of these differences common values can be traced from the questionnaire. Some significance tests have been pursued for the data, indicating that when subsequent means differ around 0,08 or more, the ranking of the problems may be enough reliable.

5. Weights derived from classification

Using the EuroQol classification

Questionnaires like the pilot study could serve as a basis for general conclusions about qualities and deficits in housing environments. Nevertheless, we wanted to find a system for getting disability weights for new and more precisely defined problems, without having to pursue a new survey every time. For this reason we wanted to find out if an updated EuroQol classification called EuroQol5D+ could be applicable on building related problems.

In the EuroQol5D+ systems problems are divided into six different impact categories. In the Dutch study, mentioned before[12] an attempt was made to calculate disability weights directly from the classification with fairly good results. However, one conclusion was the scale was to rough and that the result would probably improve with a finer scale. Since building related problems generally are of a less severe character when compared to the range from no impact to mortal impact, we also needed a finer scale to distinguish between our problems. Subsequently we have proposed an extension of the EuroQol5D+ shown in table 2.

[12] Stouthard E A et al. (1997).

Table 2. Proposed extension of scale and descriptions the EuroQol5D+ system. Class 1 and 3 are new. Class 0 corresponds to former 1 and class 4 to former 3.

	Disability class				
Impact category	**0**	***1***	**2**	***3***	**4**
	No problem	***Small problems***	**Some problems**	***Large problems***	**Very large problems**
Mobility *function, 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, dressing, cooking*	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 have 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 *Forget immediately and can hardly communicate*

Plain text from Stouthard et al 1997, Italic text are new proposals

It can be discussed whether the EuroQol categories designed for measuring quality of life are appropriate for characterising building related problems. Never the less, we found it possible although some categories seemed to be overlapping. For instance, the category self-care depends on mobility, which in turn can be affected if you have pain when you move.

To investigate if it was possible to arrive at comparable results when calculating disability weights from a standardised classification and the weights derived from the questionnaire we classified the internal problems shown in table 1 several times and compared the calculated weights (the mean value normalised) from the classification with those from the questionnaire. Since the sizes of the problems in table 1 are not very well defined the classification could be done differently and still meet the description of the problems. The repeated classification in order to match questionnaire results can be resembled as way to find a proper description in quality of life terms to what the respondents had expressed in their answers. During the classification procedure we took notes about how we were reasoning and how the problem would be described to limit options of interpretations. We can conclude that a detailed description is a prerequisite when making such classifications or when designing questionnaires about these issues.

Some conclusions from this exercise are. The respondents answering the questionnaire might not have used the scale consistently. This is likely to be the reason why health problems had to be revised downwards and indoor problems had to be revised upwards. A general question is how temporary health problems are valued compared to more prevailing ones, i.e. what influence duration have on the valuation. Consequently, less use of outdoor spaces compared to indoor spaces could be the explanation why outdoor problems were systematically revised downwards in the adapted classification.

Finally, the appropriateness of the categories in the classification may be questioned for indoor and outdoor problems. For instance, air quality was ranked high by the respondents of the questionnaire but with the categories used, the scores cannot be increased that much for air quality.

6. Comparing disability weights from different sources

Classification weights versus weights from the questionnaire

The question if our general appreciation of a building related problem could be described in an acceptable way by the classification still remained.

Since we know that the regression curve ought to pass through the points (0;0) and (1;1) we forced it to approach that by completing the sample with three points of each (1;1) and (0,01;0) (the logarithm is not defined for 0). The logarithmic curve shown in figure 6 fitted the new sample best. The fit to the original data is of course not improved and the relation for high and low disability weights are still unknown.

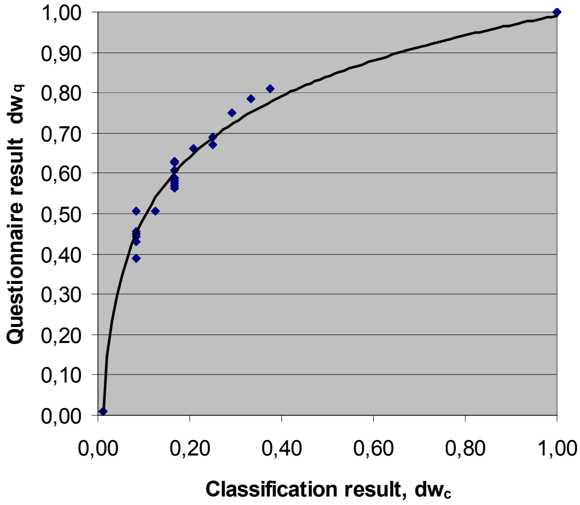

Figure 6. Classification weights versus questionnaire weights

Thus, the correlation equation became:

$$dw_q = 0{,}22 \ln dw_c + 1{,}0 \qquad \text{(Eq. 5)}$$

This relation seems to give a fairly good prediction of questionnaire weights within the interval 0,4-0,8 and possibly also outside it.

DALY weights versus classification and questionnaire weights

Finally, we also wanted to examine the relation between the disability weights of PTO-type used for calculation of DALYs and the classification and questionnaire weights. As mentioned before the PTO-weights have been developed for hundreds of diseases and disability states. A correlation between PTO weights and classifications weights performed on the Dutch data mentioned before[13] gave a R2 value of 0,84. Since we basically use the same scale (EuroQol5D+) but with a slightly higher resolution (5 steps contra 3) we can anticipate a cor-

[13] Stouthard et al. (1997).

responding or likely better fit between classification weights from our proposed scale and PTO weights.

In our pilot questionnaire we also asked the respondents to rank and weight a few health states. Although few and not well defined, some problems for which we could find some corresponding PTO weights are gathered in table 4.

Table 4. Examples of disability weights with classifications transformed to our proposed system where available.

Health state Classification	Disability weight, PTO	Source	Disability weight, classification, dw_c	Disability weight, VAS*	Questionnaire weight, w_q
Eczema	0,06	Victorian Burden of Disease Study 199		0,12	
Influenza	0,05	Estimated using EQ-5D+ regression model		0,10	
Mild asthma, 0/0/0,5/0/0,1/0	0,03	Stouthard et al 1997	0,025	0,07	
Asthma	0,07	Sjukdomsbördan I Sverige (Peterson et al 1998)		0,14	
Severe asthma	0,23	Victorian Burden of Disease Study 199		0,30	0,76
Severe asthma	0,36	Stouthard et al 1997		0,36	
Ordniary cold 0/0/0,3/0,3/0/0	0,02	Victorian Burden of Disease Study 199	0,025	0,05	
Fierce cold	0,07	Sjukdomsbördan I Sverige (Peterson et al 1998)		0,14	0,57
Fierce cold, 0/0/0,4/2/0/0 akut sinusit	0,10	Victorian Burden of Disease Study 199	0,10	0,18	
Reumatism mild, 0/2/2/2/0/0	0,21	Stouthard et al 1997	0,25	0,29	0,57

* calculated from relation between PTO and VAS

It is obvious that setting disability weights is no exact science and results depend on differences in health states, values and used methodology. The weights from our pilot questionnaire are 2-3 times higher than the VAS weights. This is not that strange since the EcoEffect questions were different and the respondents didn't have to take several kinds of effects into consideration. The EcoEffect health states were further not defined very well and the respondents may have understood them differently. It is clear that if one wants to compare disability weights derived from questionnaires, the problems have to be defined and formulated in another way than we have done. Further, it is not evident that general opinions coincide with values derived from a certain set of classification categories, although they intend to reflect general qualities of life. The relevance of the categories has to be discussed further. To get a better understanding of these issues a questionnaire better designed to serve the purpose should be performed.

7. Application

To give an example on how an internal impact index for existing buildings, I_e, can be calculated the residential building "Oskar" in Örebro has been chosen as an example. An EcoEffect questionnaire investigation was made in 2002. In EcoEffect, I_e includes both indoor and outdoor environment on a property. In this example we choose to include only the indoor part $I_{e,indoor}$. The calculation proceeded according to Eq. 3.

First the disability weights for the included impacts were calculated through classification, see table 4. The duration factors were estimated. For thermal comfort the fraction of estimated time people are awake in their homes in may-august and november-march for summer respective winter conditions was used as duration factor, $\mathbf{d_i}$. For ventilation and noise the fraction of estimated time people are awake in their homes is used. For daylight, the fraction of estimated time people spend in their homes is used and for daylight and sunlight the fraction of time with average sunshine is used. The result is shown in table 5 together with a summary by problem area.

Table 5. Indoor impact index for the building "Oskar" based on our extended EuroCol5D+ classification and a user questionnaire in the house.

	Classification category												Using dw_c		Using w_q, tab 1	
	Mobility	Self-care	Usual activities	Pain/discomfort	Anxiety/depression	Cognition	**Fraction of dissatisfied in the building, p_i**	**Disability weight through classification, dw_c**	**Duration factor, d_i**	**$I_{e\,i} = p_i * dw_i * d_i$ - detailed**	**$I_{e\,i} = p_i * dw_i * d_i$ - by problem area**	**Problem area**	**Rank**	**Relative impact**	**Rank**	**Relative impact**
Indoor problems																
Thermal comfort - the residence is unusually warm in summertime	0	0	0	1	2	1	**0,05**	**0,17**	**0,09**	**0,0008**	**0,004**	**Thermal comfort**	**3**	**0,08**	**3**	**0,16**
Thermal comfort - the residence is unusually cold in wintertime	1	0	0	2	2	0	**0,15**	**0,21**	**0,12**	**0,0036**						
Ventilation - the indoor air often is stuffy	0	0	0	0	3	1	**0,05**	**0,17**	**0,25**	**0,0021**	**0,019**	**Air quality**	**2**	**0,34**	**2**	**0,36**
Ventilation - Smell of cooking or cigarette are frequent	0	0	1	2	3	2	**0,2**	**0,33**	**0,25**	**0,0165**						
Noise - sounds from traffic are apparent	0	0	1	0	3	1	**0,1**	**0,21**	**0,25**	**0,0052**	**0,030**	**Noise**	**1**	**0,55**	**1**	**0,45**
Noise - sounds from installations are apperent (for instance ventilation, fridge, pipes)	0	0	0	0	3	1	**0,45**	**0,17**	**0,25**	**0,0186**						
Noise - you can easily hear your neighbours and noise from the staircase	0	0	0	0	3	1	**0,15**	**0,17**	**0,25**	**0,0062**						
Daylight - the residence is dark	0	0	0	1	3	0	**0,05**	**0,17**	**0,13**	**0,0011**	**0,001**	**Natural light**	**4**	**0,02**	**4**	**0,03**
Sunlight - the sun seldom reach the kitchen and the living room	0	0	1	0	2	0	**0,00**	**0,13**	**0,13**	**0,0000**						
Sum =Indoor Impact Index = $I_{e,\,indoor}$										**0,054**						

The same procedure was also performed with the weights obtained from the pilot questionnaire study (coloured area). The ranking became the same but the relative impact differed slightly by problem area and aspects valued.

Note that if you want to use the indoor impact index for comparison with other buildings you need to use exactly the same disability weights.

8. Conclusions

The aim of the paper was to introduce the concept of environmental efficiency of buildings and show a principle for how to calculate one of the needed indexes, the internal impact index $\boldsymbol{I_e}$ for existing buildings. It is natural to oppose to such an extensive aggregation of complex problems. Nevertheless, a lot of practitioners take decisions about maintenance and changes of buildings every day without any comprehensive goals containing both environmental building performance and user satisfaction. Knowledge about the proposed indexes and what they contain could increase the awareness of which environmental impacts different decisions might give. Decision makers ask for simple advices, like environmental labels, without questioning the assumptions and criteria lying behind. This is reasonable, since they normally have no time and/or ability to penetrate problems in detail. They have to rely on professionals and experts. We believe that aggregated indexes can help a lot in certain decision processes if trustworthy, which they only can be if they are clear and transparent in a way that make them open for dispute and change. This is the reason for proposing internal and external impact indexes. However, to be able to reach that point it has been necessary to move into the controversial field of weighting. However we feel relatively comfortable with making the weights problem based.

How to define and find disability weights is a key question dealt with in this paper. We believe that there is an obvious need for a systematic system to define, preferably by classification, the health states, physically and psychologically, for which disability weights shall be set. If we had started from scratch and tried to design such a system for building related problems it would probably have looked very different from the one we have tested here, the well-established EuroQol5D+ system.. By adapting to this system a wide range of possibilities for comparing building related problems with all kinds of impacts on man are opened. In our case it is especially valuable that psychological aspects are dealt with, which we have been able to apply also for calculating the external impact index, ***E.*** However, we are not yet sure that the EuroQol system meets our needs, although extended as proposed in table 2.

The advantage with starting from the classification seems to be large. This method makes it easy to review exactly what a disability weight is based on. It is easy to change classification scores and get new disability weights or make a sensitivity analysis on what certain scores mean. If some classification categories seem to be overlapping or are less appropriate for a specific application, it can be handled by weighting them in relation to each other. However, the greatest advantage will be that it is easy to obtain disability weights for different kinds of problems, even outside the environmental field, and discuss them on the basis of comparison.

Finally, we feel quite confident that a classification system can be used for calculating disability weights mechanically from classification. Although low resolution the Dutch study[15] referred to show a reasonable correlation between disability weights calculated from classification and disability weights set by panels of experts for comparing burdens of diseases.

The relation between weights derived by experts who have taken a number of aspects into account and the spontaneous valuation of the same problem made by a general public, is not clear. The pilot questionnaire study contained health questions but they were few and the health state too poorly described to give any real guidance for the respondents. Further research on the relation between disability weights used for different purposes and arrived at in different ways would broaden the exchange and understanding between disciplines.

At last, it is important to bear in mind that disability weights and environmental indexes calculated from them are highly approximate. There is a natural deviation in health states caused by the same impact and in opinions about building problems and qualities. Although calculations might give an impression of a high accuracy, this is false. The results can never be anything else than a general guidance that, however, is an important matter in itself.

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