Assessment and Assurance of Indoor Environment Qualities in Buildings
during Program, Design and Management phases

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Summary

Background

Unhealthy buildings are unfortunately not a passed phenomenon. Buildings with moisture damage, for example, "are a never ending story". This raises some initial questions with regard to this thesis:

1. How can property-holders, designers and building constructors work systematically to *assure* Indoor Environment Qualities (IEQ)? How can the different phases of the building process - and the completed building - be assessed?
2. How can a better correspondence between *planned* Indoor Environment (IE) and the indoor environment *perceived* by users of the building – and to health hazards not directly perceived by them - be obtained?

There is a need to emphasise the possibilities to communicate IEQ questions during the building and management process.

The aim of the study

This thesis presents and evaluate a methodology to *assess* and *ensure* IEQ in buildings, during program, design and management phases. Different tools are proposed to collect data for the assessment and to structure the decision making with focus on IEQ in planning process.

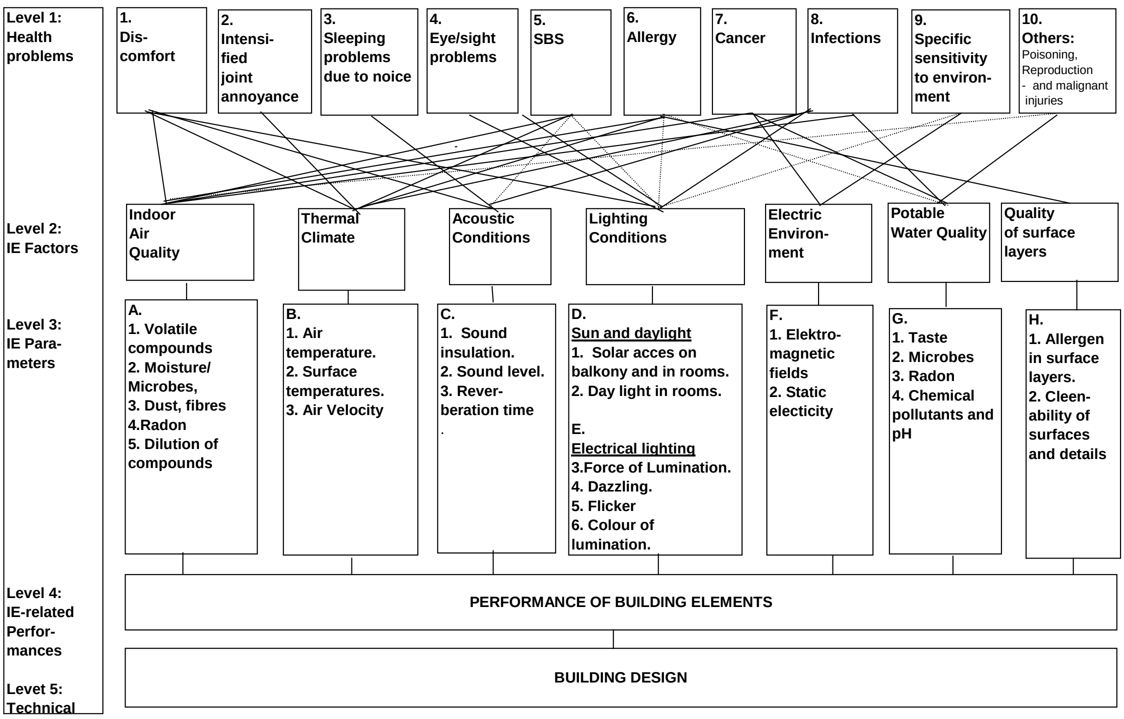

Figure 1: The causal structure, developed to schematically describe the physical connections between health and building design

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Method

The methodology to *assess* IEQ has been developed as part of the development of a broader, computer based environmental assessment method for real estates, EcoEffect (Glaumann et al, 1998). To fit into this tool, the assessment method of IEQ should be designed to sum up the result in two different ways. One reflecting an estimated risk of getting health problems, (level 1 in Figure 1) from the building, the other giving an assessment value of IE Factors (level 2 in Figure 1), e. g. as *health problems* and as *indoor environment factors*.

The 6 assessment requirements shown in Figure 2 are based upon the three phases for assessment and assurance and the two ways of presenting the assessment results

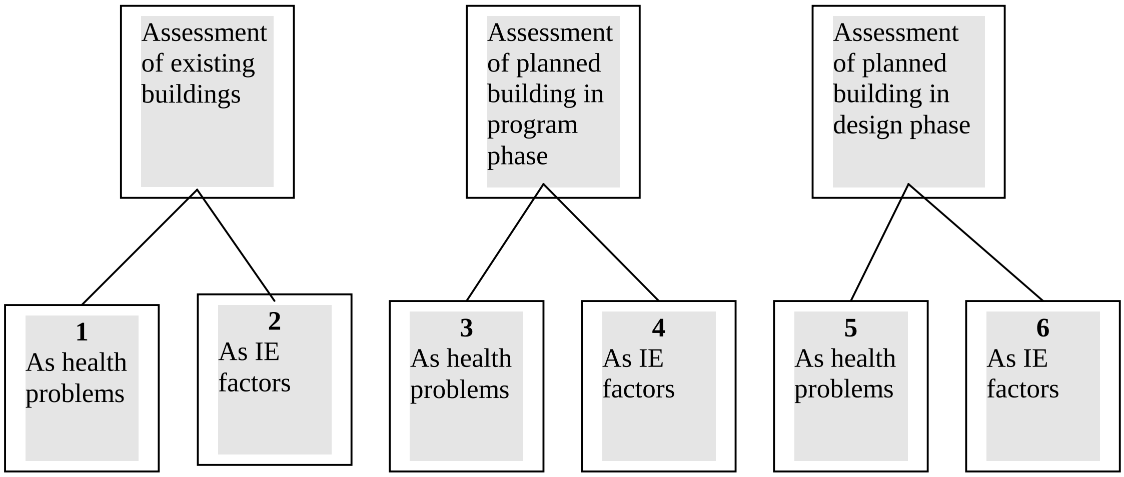

Figure 2: The 6 assessment requirements.

The requirements, shown in Figure 2, are the basis for deciding the criteria of assessment. The method used to organise the criteria is multi-criteria analyse, development of different hierarchies for different assessment situations and simple additive weighting of criteria (Saaty, 1979, Andresen, 2000).

Assessment of 3 different situations of 10 health problems and 8 IE factors gives a total of 54 hierarchies, or tree structures. To keep the number of variations limited, it is important to find as many common parts as possible between the hierarchies.

One important goal when forming hierarchies is to promote the input of experience from tenants in existing buildings to the planning process, or, between tenants perceived IEQ and IE targets and performances. This is also a reason why as many common parts as possible of the hierarchies should be found. Only necessary differences, caused by the different nature of the criteria used in the different assessment situations, is regarded as relevant.

In 1998-1999 the methodology to assess IEQ in existing buildings was developed and tested in three groups of multi-family houses. In 2000-2001 the method was developed and tested during the program and design phases in three multi-family building projects, planned for the exhibition Bo01 in Malmö, Sweden.

Results

Ten main groups of health problems are taken into account (level 1 in Figure 1). Even discomfort is defined as a health problem according to the WHO definition of health as both well being and absence of disease. The causality between some health problems, indoor environment and building performance is complex. This is specially the case with SBS (Sick Building Syndrome) and Indoor Air Quality, because most of the dose-response relations of specific compounds are unknown – at leased at the low levels they occur indoors. As a consequence, a questionnaire (Engvall, 2002) to obtain tenants perception of health impacts, is used when assessing existing buildings. Technical measurements are used when necessary, e.g. when estimating the risk of lung cancer due to radon in indoor air. Criteria, used to assess existing buildings, consist of frequencies of health annoyance of IE perceptions and values from physical measurements.

When assessing IEQ in planned buildings during the program phase, criteria consist of indoor parameters (level 3 in Figure 1), and when assessing IEQ during the design phase criteria consist of IE related performances of building elements (level 4 in Figure 1).

Indoor Environment Factors (IEF)		**Subheadings to IEF**		**Indoor Environment Problems (IEP)**
Indoor Air Quality	→	**Volatile pollutants and smells**	→	"Pungent smell" and "Dry air"
			→	"Smells traffic fumes"
			→	"Smells effluent"
			→	"Smells neighbours cooking fumes"
			→	"Smells own cooking fumes"
			→	"Smells waste"
			→	"Smells smoke from outdoors"
	→	**Moisture/ Micro-organisms**	→	"Moisture in bathroom"
			→	"Smells mould "
			→	"Smells musty"
			→	"Risk for spreading legionella bacteria to room air"
	→	**Dust/Fibers**	→	"Dusty air"
			→	"Presence of asbest"
	→	**Ionising radiation**	→	"Unhealthy rate of radon gas in room air"
			→	"Unhealthy rate of gamma radiation in room air"
	→	**Dilution of pollutants**	→	"Stuffy air"
			→	"Possibilities to influence air quality"

Figure 3: The common part of the hierarchies used when assessing IE factors in existing and planned buildings.

Detailed questions about perceived environment, designed and used in the questionnaire, are appointed to have a central position (as standardised *indoor problems*, like "Smells mould", "Draught from windows") also when formulating and structuring criteria for assessing planned buildings. They are used as common categories when arranging connections between the hierarchies of the different assessment situations, Figure 3. In the program phase they are used to organise the indoor environment parameters and in the design phase they are used to organise the indoor environment performance of building parts and products. Going from the assessment of IE factors to the assessment of health problems *indoor problems* are reorganised in a different pattern. This method is used to communicate experiences from the management phase to the planning phase.

Figure 4 shows the suggested way to present results of the assessment. Values from technical measurements and frequencies of annoyance from the questionnaire are transferred into **load values** on an interval scale between 0 and 3. In the left diagram in Figure 4, load values reflect the risk for health problems, where 0=negligible risk, 1=little risk, 2= normal risk and 3= higher than normal risk. In the right diagram load values are as 0=much better than praxis, 1= better than praxis, 2= as praxis and 3= not so good as praxis. The score has been developed using two "anchors" to correlate the values for the different criteria to the scale of load values 0-3. One is 0, which corresponds to values without any health risks. The other one is 2, which corresponds to praxis or benchmark.

Figure 4 shoes the results from the assessment of the test buildings, consisting of three groups, A, B and C, of existing multi-family houses in the suburbs of Stockholm. A was built in 1997. The other two groups of buildings,B and C, were both built at the end of the 1960s. It is obvious that the modern building in this case has a much better indoor environment and there is less risk for tenants to get health problems from the building.

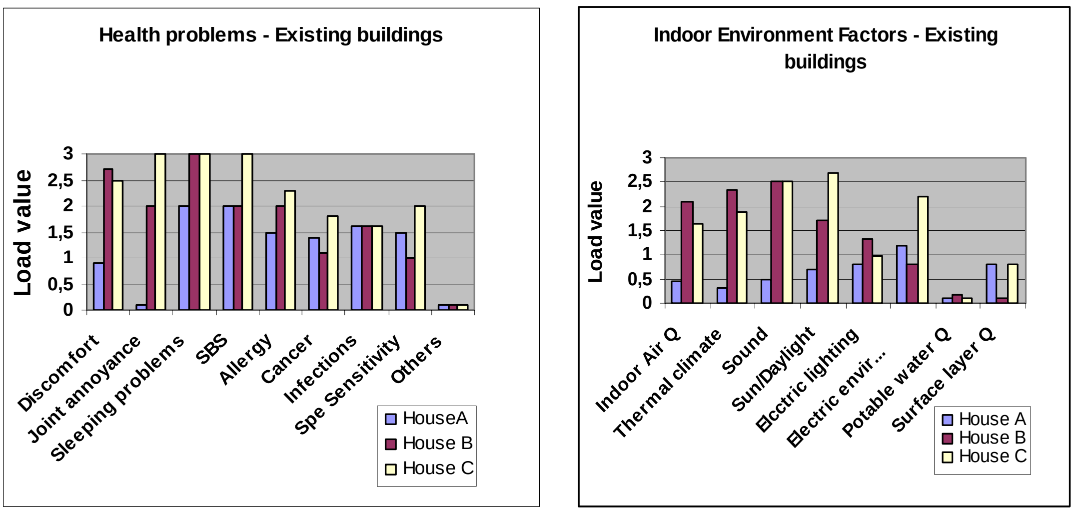

Figure 4: Two different forms of presenting the assessment results.

The different hierarchies needed for the 6 requirements shown in Figure 2, are used to create **tools** to collect input to assessment and to sum up results as load values, shown in Figure 4.

All inputs in the assessment will be open to users of the assessment method and it is possible to use results without any weighting.

For existing buildings the input for assessment is the frequencies of different annoyances of health problems and results from physical measurements. One assessment tool for IE factors and one for health problems in existing buildings has been developed. A specially designed questionnaire is developed and used as main *input tool*. The questionnaire is based on the widely used Stockholm questionnaire, but adjusted to fit the assessment methodology. When estimating the risk of SBS (Sick Building Syndrome) in an existing building, a model based on logistic regression analyse is used (Engvall et al, 2000, Hult et al 1999). It accounts for individual probabilities of different categories of tenants (allergic/non allergic, man/woman, age 18-65/age 65 and older), to get each of five SBS-symptoms found in the model to be the most building related: nasal-, eye-, throat irritation, cough and skin irritation. The model also takes into account whether the building is private or public owned. Probabilities are compared with actual frequencies of symptoms in the building investigated, using the questionnaire. The difference between the expected frequencies and the actual determines the estimated risk of SBS for tenants in the building.

For the program phase a *target tool* is developed and used to assess functional IEQ demands set up by the client in his program document. The target tool lists IE parameters. These are compared with functional demands for indoor environment set up by the client. The tool contains four ambition levels, which determine load values 0, 1, 2 or 3. The same tool can be used to create a program document. Complemented with weights, it is used to sum up the result from IE factor assessment. When the result from health problem assessment is summed up, a tool with reorganised indoor problems is used.

For the design phase a *performance tool* is developed and used to predict if functional demands of the indoor environment set up in the program will be fulfilled. The performance tool lists criteria, or indoor environment relevant performances of building elements. They are arranged under the same IE factors and IE problems as in the *Target Tool*. This tool contains four ambition levels as well. The same tool can be used to create a plan document in order to assure IEQ. Complemented with weights, it is used to sum up the result from IE factor assessment. When the result from health problem assessment is summed up, a tool with reorganised indoor problems is used.

The tool is used to control performance standards set up in tender documents by the architect and the consultants of construction, ventilation, heating and electricity. Special attention is paid to avoid moisture problems, emissions from building materials and to get quality assurance of the ventilation system.

Discussion and conclusions

Judging from tests carried out the method to assess existing buildings is easy to carry out. Some restrictions must be applied. There must be as least 12 tenants answering the questionnaire and the questionnaire should be distributed in wintertime, when people spend more time indoors.

The method to assess planned buildings is quite easy to for clients as well as consultants and tenants to understand, since focus is on **indoor problems**. It clarifies that the aim of assessment is to predict building users perception of the indoor environment in future buildings. This also makes it possible to follow up results with a new assessment based on the questionnaire in the completed building. A simplification of the system that makes assessment procedure faster is also an aim for the future.

The tool used in the design phase is quite extensive in its present form, which makes it a bit complicated. A possible way to simplify the tool is to create links to other computer based programs used for detailed IE calculation and dimensioning.

Acknowledgements

Grants from the Swedish Council of Building Research (now FORMAS), and the Foundation of Architectural Research (connected to White arkitekter AB) mainly supported this study.

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