#4964

BUILDING PERFORMANCE SPECIFICATIONS

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INTRODUCTION

Most people spent a great deal of their time (and life) in an indoor environment, residential and/or occupational. In their environment more and more skylines are changing by towering high-rise buildings, creating windy streets and blocking the sun. Many of them tall and thin or low and wide, mirrored in silver or bronze. The buildings we see, live and work in are an important part of our total environment. However we tend to take them for granted, they are just there. We tend to take whatever we get. While fighting for the quality of our natural environment in protecting trees, the quality of water, wildlife etc., we rarely act on buildings.
The quality of the buildings we occupy however is just as important as the quality of the natural environment. But when we look at modern (most office-) buildings it seems that they are made for the outside and not for people to live in: most building interiors are not as glamorous and colorfull as the outside.
As we know from several building investigations (1) some 20-30 % of the existing building stock may be characterized as problem buildings. Many people are likely to be exposed to either a sick home or a sick commercial building (30-70 % in the U.S.). Consequences are health effects (2), high sickness absence rates (3), low worker moral and reduced employee performance and organizational productivity (4,5). So it is a social responsibility and certainly a responsibility of all building professionals (not only the architect) to ensure that standards of quality are maintained in the buildings we use and live in. Regulations and guidlines for the indoor air quality are a contribution to that.

REGULATIONS

The development of each and every new policy area knows a certain amount of phases (policy cycle). The first phase consists of the observation and inventarisation of problems (effect on health, kind and bulk of problems). The second phase is marked by research in mechanisms, cause and consequence relations: parameter studies. In the third phase dosis-effect relations of the different relevant aspects in the problem area are being pinned down. In the fourth phase all aspects are weighted, translation into regulations takes place (laws, norms, guidelines). The last phase sees an evaluation of regulations and feedback from practical experience. Regulatory measures take an essential and central place and formulate the translation of science into the building practise. Implementation of knowlegde. This policy cycle is also relevant to the sick building problems. In actual fact this policy-cycle is risk assessement (hazard indentification, dose-response assessement, exposure assessement, risk characterization) followed by risk management, political decission (regulations) and evaluation of regulations.

Occurance of health problems related to buildings stem from the seventies. In the eighties several large scale investigations into the subject have been executed (a.o.1 and 6) indicating the kind and seize of the problem area. Then (as well as now) a lot of research into health effects, cause-consequences mechanism and dosis-effect relations has been executed. Taken the proceedings of past Indoor-Air conferences one can conclude that until the mid-eighties efforts largely concentrated on the first three phases. In previous years attempts were made to move some aspects of the complex matter into phase four. Gradually more attention is given at international conferences to the necessity of and possibilities of policy making and regulations.

In Berlin (1987) Ken Sexton (EPA) concludes that up until that moment research efforts have focused on the relevant scientific and technical questions. Consequently, relatively little attention has been paid to identifying and resolving the key policy questions (7). Key words: risk assessment, risk management as an essential part in societies efforts to attain healthy and comfortable indoor environments (also 8). For the first time the necessity to translate available knowledge to suit the practical needs of the architects comes to the fore ground.
The main object of the CIB Conference Healthy Buildings '88 (Stockholm) was to give recommendations to architects, consultants and real-estate owners. Several lectures look into the matter of translation (the importance, possibilities and limitation) into the practise of building (a.o. 10, 11 and 12). Ferahian (12) concludes 'All findings about indoor air quality are of little use to the avarage citizen, if they are not applied and translated into rules incorporated in our building codes for design, construction and, last but certainly not least, maintenance of our buildings'. Key words: healthy building design, regulation, standards, codes, quality assurance, policy and regulatory science. Certain lectures stress the point that more is necessary than just regulations to ensure healthy buildings, cooperation with the world of construction and implementation in the building proces by quality assurances.
During Indoor Air '90 in Toronto several lectures were held which dealt with the (possible) development of policy and regulation (a.o.Seifert, Dionne, Rajhans, Stolwijk, Berglund, Fanger). Attention was given as well to the (necessity) development in research: programs of EPA (Berry), WHO (Suess), NATO (Marconi).
It must be apparent that to ensure a healthy indoor-climate, regulations are necessary but an insufficient condition.

The need for regulations

Before we speak about building requirements, we have to consider the possibilities for regulations. Because the demands are intended to be incorporated into the regulations. Regulations are more than a collection of loose demands and recommendations. These days regulations are part of a much encompassing (building) quality policy. Regulations regarding construction are moving along, strongly influenced by Europe '92. Building products have to meet Essential Requirements (Council directive on the approximation of law, regulations and administrative provisions of Member States relating to construction products). One of the essential demands which is very important in this context is "hygiene, health and the environment". This will be elaborated by a Technical Committee TC3) into a foundation document. Harmonised European standards will eventually form the ground for an EC-mark.

Demands regarding policy regulations:

- requirements should be unambiguous, measurable (simple) and controllable (refering to CEN standards)
- there has to be a relationship between the prescription and the intended effect (here: prevention or reduction of health effects)
- requirements should not be a barrier for innovation (non-material bound specifications).

In connection with past developments it is important to demand performance specifications of relevant features and characteristics of buildings or building parts.

Form of regulations

Regulations can be devided into:

- legislation: bans, standards (IAQ, emission, ventilation)
- standards: IAQ, emission, ventilation
- guidelines: operation and maintenance, building- and HVAC-design.

Guidelines and standards (unless they are mentioned in a building code or other legislation) do not have the force of law; compliance with them is voluntary. Their principal value is that development is not as cumbersom as legislation procedures.
Dionne (14) does mention in the regulatory approach: prohibitive bans (of products), emission standards (applied to sources), air quality standards (intervention guide for labor inspectors), application standards and warnings (manufacturers' responsability in case of hazardous product). He concludes that providing and maintaining healthy air quality is more than just scientific information alone.

To people who need to make practical decisions it is of little value. In the non regulatory approach he mentions: health guidelines, ventilation guidelines and public information/education.
Rajhans adds to this (15) the possibility of a release of operation and maintenance guides for all buildings, for most IAQ problems arise not because a building has a below capacity ventilation system, but because this system is not properly maintained.
Finally Seifert concludes (16) that, although setting air quality standards has been instrumental in reducing the pollution of outdoor air, guideline values, rather than standards, should be developed for indoor air: one value should be an action level, one level would define a target concentration.

Goal of regulations

The goal of regulations (functionally described) is the prevention or reduction of health symptoms to an acceptable level in buildings. Or positively formulated: to assure an indoor environment that respect health, comfort, well being and productivity with acceptable social costs. That's why it is important to stop and consider the source (mechanisms) of health symptoms in buildings; fig 1 shows a simple model.
It is known that the development of symptoms are not solely dependent on the building and building environment factors (fysical, chemical and biological factors) and the usage (management and maintenance) of the building but also psycho social and other factors (the work experience and personality). The first two do determine the physical environment in buildings. This physical environment lents itselfs for building regulation. The following story points to these factors.

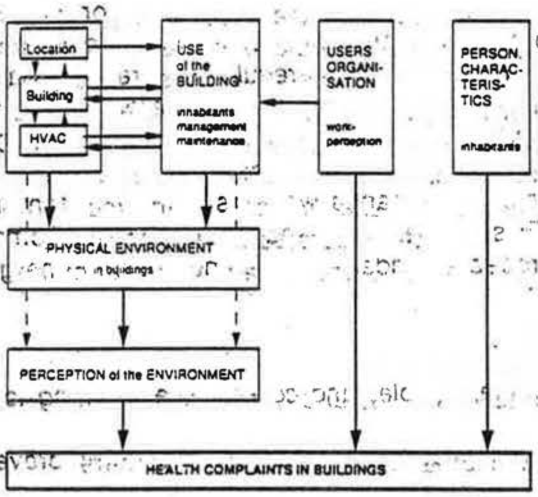

Fig. 1: Simple model for health complaints in buildings.

The figure shows that a different category of buildings needs different demands (probably different strategies) for a good IAQ (schools, hospitals, offices, residential dwellings etc.)

BUILDING PERFORMANCE SPECIFICATIONS

It's a known phenomenon that there are buildings which comply with every known demand and still remain problem buildings. One of the reasons for this could be that the set of requirements is incomplete or worse that demands are made on non-relevant aspects, which seem to suggest a certain quality (like detergent advertisements). Its of the utmost importance to pinpoint all relevant building factors before specifing requirements. When regulations are implemented one has to separate building factors (design demands) and user-factors (user demands). In the following, especially building factors will be dicussed .

Relevant factors
To determine systematically all the relevant health-related building factors two methods can be used (generally not specifically IAQ).

- On the basis of expert opinions (building factor)
  * Yes/no relevant (Delphi-method)
  * calculation of risk factor per aspect
- On the basis of judgement of occupants (Post Occupancy Evaluation)
  * assessement of (Building in Use)dimensions of Environmental Quality
  * data analysis of building investigations: relative risks out of building and symptoms c orrelations.

Expert opinions
The first rough way to determine relevant quality factors is to give experts a list of all known building quality factors. They are requested to translate relevant health factors (including comfort and well-being) on humans in buildings on a scale of 1 (utmost important) to 5 (not important). In Holland in 1989 this research took place by GBA among the Dutch participants of the Healthy Building congress in Stockholm (16 respondants). In this investigation an adapted list of quality factors for buildings was used, which the GBA uses for cost-quality policy (see appendix 1). The quality factors are subdivided into spacial visible aspects, functional and technical factors. It appeared that spacial visible factors got the lowest-score. Of the functional aspects the floorspace per person gets a reasonable score. A reasonable score is also given tot part of the technical aspects (outdoor air quality, used materials, noise and vibration, natural light and humidity). A very high score was preserved for thermal comfort, lighting and the quality of indoor air.
It won't surprise anyone that in a similar investigation held among architects, spacial visible aspects got a higher score, principally the use of colour and spacial perception.

The second method is based on the same list, but more specified and extensive, accentuating a healthy building quality. An example of the extended list is given in appendex 2. The opinion of the expert will be more or less guided to calculate the risk factor per aspect in terms of chance x consequences. We will use the following equation:

$$Risk = [P * C * I] * E/10$$

Risk	=	health risk of observed aspects [1-100]
P	=	prevalence in buildings (exposure of population) [1-5]
C	=	characteristic of exposure of the aspect [1-5]
I	=	measure of individual influence [1-4]
E	=	health effect [1-10C], in which C is raised cancer risk or death risk.

This project has been executed just as a pilot project with 4 experts. The method, which in its larger structure is the same as allready in use in Holland on several chemical agentia in residential dwellings, when adapted, it can be used for this air as well.

Post Occupancy Evaluation
A different approach is, instead of using the experts opinions, to use the perception of the occupants. In 19 office buildings research has been carried out about environmantal quality (17) with the help of a questionnaire. Each questionnaire contained a number of rating scales from 1 (bad or uncomfortable) to 5 (good or comfortable). The rating scales were submitted to a factor analysis. Ten factors emerged consistently, using a variety of different factor-analysis procedures. These factors are: privacy, indoor air quality, thermal comfort (warm), thermal comfort (cold), spatial comfort (furnishing), dust, spatial comfort (fittings), individual control, external noise and lighting.
These factors (dimensions) represent sets of environmental ratings, wich can be averaged to produce a score for each dimension. These scores are indicative of how people judge environmental quality (and do take psychological factors in consideration). They do not necessary correspond to instrument measurements of human comfort.

Remaining aspects (questions) after factor analyses are:

For the dimension *Air Quality*:
- Air Freshness (stale air - fresh air)
- Odours (unpleasent - not noticeable)
- Nuisance unpleasant odours (often - never)

For the *Thermal Comfort (warm)* these are:
- Heat nuisance (often - never)
- Summer temperature (uncomfortable - comfortable)
- Temperature-shifts (often - never)

For *Thermal Comfort (cold)* these are:
- Affected by cold (often - never)
- Cold feet (often - never)
- Winter temperature (uncomfortable - comfortable)
- Draughts (often - never)

For *Dust*:
- Dust (dusty - free from dust)
- Cleaning (discontent - content)
- Rel. humidity (too dry - good).

Although this method is very interesting when determing the environmental quality (fig. 2 gives an example), these scores do not lend themselves for regulations in terms of building performance specifications. For these one needs to find the correlation between these aspects and building and installation characteristics. These analysis are being carried out at the moment.

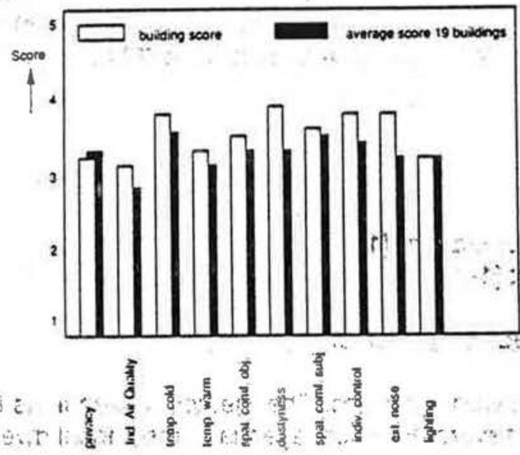

Fig. 2: Example of a building score with the Healthy Building Quality Method.

Research in 61 Dutch office buildings (18) shows groupings of complaints related to building features, translated into a relative risk. On the bases of these its aparent that the following aspects (no individual characteristics like gender) are relevant: the possibility to manually change the temperature, treatment of occupants complaints, the work experience, mechanical ventilation, recirculation, air humidification, number of persons per room and working with screens. It boils down to the following installation characteristics.

- installation types:
  - natural versus mechanical ventilation
  - existence of himidifiers
  - existence of recirculation
- manually/individually controled temperature.

IAQ-factors

The following aspects for Indoor Air Quality are destilled from previously mentioned research.

Air Quality

- freshness
- odours
- pollutions (chemical, biological, dust)
- individual control of ventilation
- dust
- cleaning

Thermal Comfort

- temperature (warm, cold)
- temperature shifts
- draughts
- humidity
- individual control of temperature, sunshades

Type of HVAC system

- natural versus mechanical ventilation
- existence of humidifiers
- existence of recirculation.

One can translate these to the following building/installation characteristics:

Functional Quality
- amount of person per workplace

Architectural Quality
- used materials (emission, sources of dust, growth of fungae, odour)
- ways of construction and application of detail (damp, growth of fungae)

Urban Planning Quality
- Outdoor air quality

Building Fysical Quality
- thermal comfort

Technical HVAC Quality

- amounts of ventilated air
- manual control of temperature, ventilation, sunshades (lighting)
- amount of recirculation
- nature of air humidity systems.

Next to these the following users aspects are relevant:
- emissions caused by used appliances
- cleaning (dust)
- amount of persons per m2
- treatment of complaints
- enjoyment of work.

STATE OF THE ART

This chapter will deal with previously mentioned relevant aspects. The state of the art of every aspect is mentioned and elaborated.

Amount of persons per workspace

The amount of space per person is, provided enough ventilation per person is present, not very relevant for the IAQ, although it is important for privacy and spatial comfort. National standards appear in several countries (a.o. Holland, France). In the context of individually controled ventilation, temperature, light and sunshades, the amount of persons per jobspot is important. It's known from practical experience that many persons per workspace give rise to comfort complaints. What some consider fresh air, others feel as draught. A comfortable temperature for the one, is chilly to another. Landscape-offices are notorious for this, it will be better to avoid them. Standards or guidelins in this area are yet unknown.

Use of materials

Materials used for construction, finishing and installation of a building can be responsible for emissions of toxic or dangerous gases and particles (formaldehyde, VOC's, fibres etc.), dangerous radiation (radon), odours, pollution of water and presence of damp on surfaces. For many substances advers health effects are known and guideline values are available and published (ex.: 19, 20). Some different (regulatory or non regulatory) strategies are previously brought to the foreground.
With regard to emissions two ways to approach the problem are possible for building regulations.

- Prohibitive bans
  This tactic can be applied to products that may cause significant indoor air contamination and health risk (ex.: asbestos, PCP). Most governments are very careful with bans while one has to proof the detrimental effect and there has to be an acceptable substitutional product.
- Emission standards
  Contaminants can be controled by appling emission standards to sources in a source category irrespective of existing air quality. One can start from a acceptable indoor concentration level and calculate the emission rate, assuming the average conditions under which the product is used in practice. Although the necessary work has been done, like guidelines for test chamber measurements (21) and the Council Directive on construction products (22), much work remains to be done to establish harmonised standards for products (16).

Standards and guideline values for indoor air quality are unsuitable instruments for building regulations but are important and usable for problem solving in existing buildings. They can be used as an instrument by the labor inspection. A very promising new approach for IAQ (i.c. future ventilation standard) is presented by Fanger, in which all pollution sources are acknowledged, so too of building materials and installation. Emissions outof building materials can become a major design tool and probably can be considered in the near future for conversion into regulations.

It is known that dust as a reservoir of microbic pollution, can lead to complaints (mucosal and general symptoms). Correlated parameters are a.o. amount of floor dust, fleece-index, shelf-index and floor-covering (24). For the time being there is no substantiated performance requirement.

Various studies have demonstrated health effects on inhalation when exposure to *fungi* in indoor air was present. Depending on factors such as the degree of humidity, temperature, the presence of oxygen, pH, nutrients etc., a microbial flora can grow in/on building materials (chipboard, mineral wool etc.). Some building materials may already from the production line be contaminated with micro-organisms (corck sheeting).
Regarding the dependancy of humidity (ventilation) and temperature and the probability of organisms to become airborne it seems that regulation concerning material application is not obvious. An investigation into the presence of micro-organisms in building materials and constructions (25) in both healthy and sick buildings, did not show any correlation of airborn microorganisms and the presence of microorganisms in/on building constructions.
Recommendations which are independent of used materials should be included into guidelines (sealing in tight constructions).

Construction design and details

The relation of the ways of construction and application of detail with IAQ lays in the possible occurence of (internal) condensation. This creates favorable conditions for the development of fungi Internationally as well as nationally a lot of research is carried out in de context of IEA Annex XIV (26). In several countries the results are already incorporated into the building codes.

Outdoor Air Quality

It is obvious that a good indoor air quality starts with a good outdoor air quality. In many countries there are ambient air quality standards which limit the emission of pollutants into outdoor air.

Research into this area, from the viewpoint of indoor climate, is usually restricted to the influences of temperature, humidity and wind. In several research projects the indoor as well as the outdoor concentrations of suspended particles and VOC's are measured, concluding that the majority of the VOC's have infiltrated from outdoors. In (28) some guidelines concentrations are given for some outdoor pollutants (good air) and supply air quality (half of the contaminant concentration indoors). Also in (19) guideline values for certain substances in the outdoor air are given.

Since polutants in the building will be added to the outdoor air, it seems relevant that building regulations make demands on the quality of supply air, inclusive the effect of filters (comparable with the regulations with regard to noise (maximum noise level outdoors, sound insulation, acceptable noise level indoors).

Thermal comfort

Requirements to the thermal environment, i.e. air temperature, thermal radiation, air velocity, humidity, are specified in the international standard ISO 7730 (29). It is possible at the design stage to predict the thermal parameters. There is, however, a need for better methods to predict the air temperatures and air velocity in a room (30).

Ventilation

There are several national standards for ventialtion, the most well known are the ASRAE standard 62-1989 and the German DIN 1946. For the state of the art with regard to ventilation one is refered to "The new principles for a future ventilation standard" by Fanger (23).

A minimum of fresh air (35 m3/h p.p.) can be incorporated in building codes or occupational regulations.

For the building codes it might be necessary to make this demand independent of number of occupants, because in practise this is determined by the the use of the building. While translating one can use the standard with regard to the minimal space per occupant (8 m2) in offices or an average occupancy per room for dwellings.

Individually controled temperature, ventilation, sunshades, lighting

It is apparent from research that individual controle of temperature, ventilation and sunshades are important aspects in relation with the development of complaints. Is it difficult to express this aspect into a performance specification, it does not lend itself for building regulation (building code). It can be included in guidelines and standards in the form of a functional discription: (aspect) must be individually controlable. The amount of occupants per workspace can be a problem.

Type of installation

A lot of research shows (a.o. 2,31) that the amount of complaints increase as more air treatment technics are applied. Buildings with natural ventilation have the lowest complaints percentage, buildings with airconditioning the highest.

Explanations up till now have been largely hypothetical although suspicions are raised by microbic pollutions in ventilation and AC systems.

The given facts are useless for incorporation into regulations, but suitable for guidelines.

Amount of recirculation

Recirculation of indoor air is often used as an energy saving measure. Pollutants will be spread through out the whole building. Filters can not remove all pollutants (tabacco smoke, VOC's, biological contaminants). Correlation between (the amount of) recirculation and certain health symptoms are not unambiguous. Calculations show that whith 50% recirculation twice as many concentrations occur as without. When 30% recirculation the factor is 1.5. One is advised either to stop recirculation or restrict to 30%. In any case the amount of fresh outdoor air of 35 m3/h p.p. must be guaranteed. Prohibition of recirculation seems premature.

Nature of air humidity installation

When air humidity installations are present spraying results in more complaints than steaming (18). Here also only hypothetical explanations are given. The accessibility of this aspect into regulations is limited.

There are some recommendations for maximal allowed micro biological pollutants (water, air) during the usage of the installations.

CONCLUSIONS

From the previous we can conclude that certain aspects of IAQ at this moment can be included (or have already been included) into building regulations in the shape of building performance specifications: ban of certain products, demands imposed upon the way of construction in connection with condensation, thermal comfort, ventilation quantities. Other aspects lend themselves in a lesser degree, but can be incorporated into guide lines: IAQ standards, use of materials involving growth of microbial flora, individual controlability, amount of recirculation.

Several aspects need further research. For building regulations: absent emission standards, relation between building features and dust in connection with microbial pollution, quality of suplpy air, amount of recirculation. For guidelines: olf catalogue of building materials, individually controlled systems and amount of persons per workspace.

Lastly it's stressed that we cannot achieve anything with only scientifically justified standards and regulations. Implementation into the building proces is vital. Perhaps more can be achieved now with implementation of existing knowledge into the building proces than to remain in search of even more refined rules (concerning new buildings). This applies to a lesser degree to the amelioration of the existing building stock.

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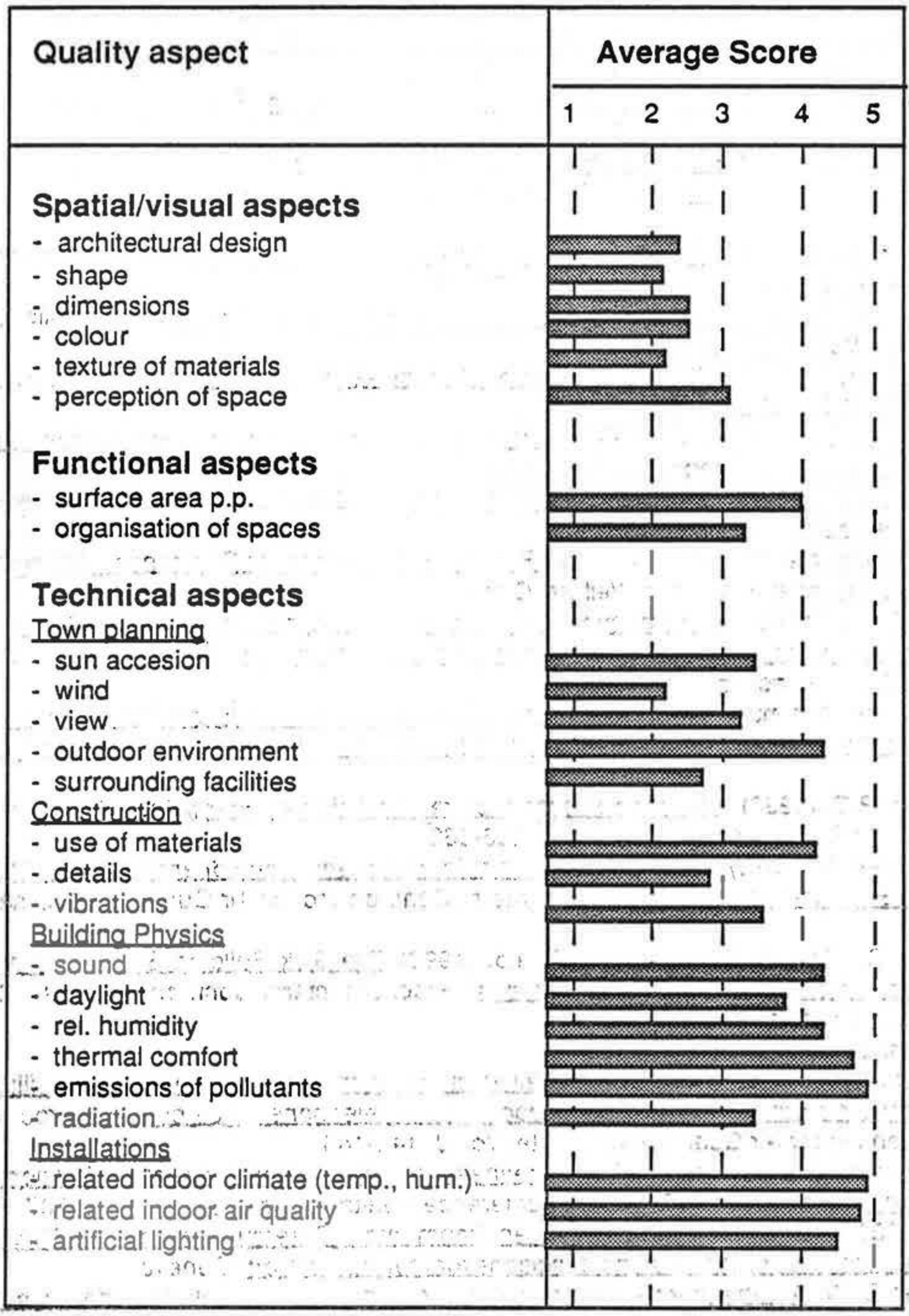
APPENDIX 1: Average scores of expert opinions of quality aspects related to health complaints.



1 = not important
5 = very important

APPENDIX 2: Extended checklist of Healthy Building Quality aspects. Example: construction.

Quality aspect

Technical aspects
 	
<u>Construction</u>
- Use of materials
  * source of dust
  * source of emissions (formaldehyde, asbestos, radon, benzene etc.)
  * source of biological material
  * fibres
  * apsorption/desorption characteristices
- Details/design
  * source of dust (easy to clean, maintain)
  * cold bridges
  * internal condensation
  * air tightness
  * water leakages
- Vibrations