A framework for performance criteria of healthy and energy-efficient buildings

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ABSTRACT

A framework for performance criteria for healthy and energy-efficient buildings was developed within the context of two European funded Projects: PeBBu and HOPE.

PeBBu, Performance-Based Building, is a Thematic network under the Competitive and Sustainable Growth programme, which started 1 September 2001 and will run for 4 years. The 3-year project HOPE (Health Optimization Protocol for Energy-efficient buildings) started in January 2002, with 14 participants from nine European countries.

Structuring of the performance criteria and of all the available information with respect to the performance approach is an important task in order to avoid conflicting criteria and evaluation procedures. Therefore, a framework has been developed that allows for a logical structuring of the information. This framework is applied in both projects. The paper will discuss the development of the framework and explain its use for the performance-based building approach. An example will be given.

INDEX TERMS

Performance; Indoor environment; Quality

INTRODUCTION

Performance is a very popular topic today. Finance or cost is the most important performance parameter of the parties who make the decisions. This financial performance evaluation is mainly based on the cost aspects of a building: buying land, building, exploitation and maintenance, rarely on the (indirect) turnover, such as productivity gains or potential savings from sickness rate reduction.

Environmental complaints indoors are related to sickness absence rates of office workers (Fisk, 2000). This, together with losses in productivity and in working efficiency, means a large financial loss. In domestic buildings, asthma and allergy related illnesses lead to increased health care costs. Besides that, investigations on costs related to repair and damages show an enormous potential as well. It is therefore important that indoor environmental complaints and illnesses are prevented by creating a healthy and comfortable indoor environment. Performance criteria for healthy and comfortable buildings are required.

TWO EUROPEAN PROJECTS

At this moment, TNO Building and Construction Research is involved in two European projects on performance criteria for healthy buildings: HOPE and PeBBu. The health of buildings in this context relates to air quality, ventilation, thermal comfort, noise and light.

HOPE, Health Optimization Protocol for Energy-efficient Buildings: Pre-normative and socio-economic research to create healthy and energy-efficient buildings, is a 3-year European research project under the programme ENERGIE. The outcome will comprise of a methodology for assessing the performance of buildings according to a set of health–energy

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integrated defined criteria, to improve unhealthy or low energy efficient buildings (http://hope.epfl.ch).

PeBBu, Performance-Based Building, is a Thematic network under the Competitive and Sustainable Growth programme and will run for 4 years. TNO is the leader of the domain 'Indoor Environment', one of the nine domains in the network. In this domain, special emphasis is put on performance criteria for healthy buildings and on methods, guidelines, protocols and tools to evaluate/measure the health status of buildings or designs for buildings (www.pebbu.nl).

Both projects look for performance criteria for healthy buildings. In the PeBBu project, the focus is on gathering all available information (literature and research) on this topic in order to come up with a state-of-the-art. In the project HOPE, health and energy efficiency are the main performance criteria and need to be quantified in order to allow assessment of these parameters in current and future office and apartment buildings.

THINKING IN ENDS RATHER THAN MEANS (PBB APPROACH)

Behind both projects lies a higher target that propagates to start thinking in ends rather than means: the so-called performance-based building (PBB) approach.

Performance according to Merriam-Webster is defined as: The fulfilment of a claim, promise, or request (implementation), the manner in which a mechanism performs (efficiency) and a manner of reacting to stimuli (behaviour). This definition of performance is valid under all circumstances, however, the performance of something is always context based. The stakeholder, the building phase or a building object, are examples of a context: the user will have different performance requirements than the contractor. The user wants to live comfortably in the building, whereas the contractor is interested in the performance of individual building objects.

PBB has been introduced to oppose the deficits of the prescriptive approach (CIB, 1982). The major difference is that a performance-based approach indicates expected outcomes whereas prescriptive regulations provide a single or a limited choice of solutions. Furthermore, the PBB approach makes it possible for all stakeholders to speak their own (understandable) language. This means that the initiator does not have to deal with the indoor air temperature, or the insulation thickness. He just can identify that he would like it to be comfortable under given specific conditions and/or that he wants the building to be energy efficient and healthy. Given these positive aspects of the PBB approach it is expected that in the future the PBB approach will replace the current prescriptive approach. However, there is still a lot of work to be done before that will be fully possible. The work described here seeks to contribute to that process.

A FRAMEWORK

As Cain (2002) describes, health and comfort are complicated performance parameters as they include a large number of variables that affect the health and comfort. But this is only one part of the puzzle. Besides a qualification/quantification of health and comfort there is also a need to include these parameters in the design, construction and user process. After all, health and comfort of a building is not just a resultant, instead it can be pursued. To facilitate the latter, a conceptual framework has been developed. This framework also has a close relation with the facilitation of the PBB approach. As such the framework thus should be able to combine these two topics.

The framework has been developed from the assumption that the number of performance definitions and the different contexts in which they can be applied make it difficult to keep track of all the building performance information that are available. This also accounts for all the translation rules that are required to translate subjective performance information at one

stage, e.g., the design phase, into, e.g., specific quantitative information for the construction phase. Therefore, a system is required that allows for a logical ordering of all the information related to PBB in order to improve the applicability of the PBB approach.

Stakeholders, building phases and building objects are regarded important components of the PBB approach. Interrelations between the building phase and the type of stakeholder are obvious, as is the case for building objects and building phases. Each specific performance criterion therefore can be related to the individual contexts. By presenting these contexts on axes in a three-dimensional format, a matrix is developed that facilitates the performance-based matrix. The concept for this matrix or framework was developed within the two European projects mentioned and is shown in Figure 1.

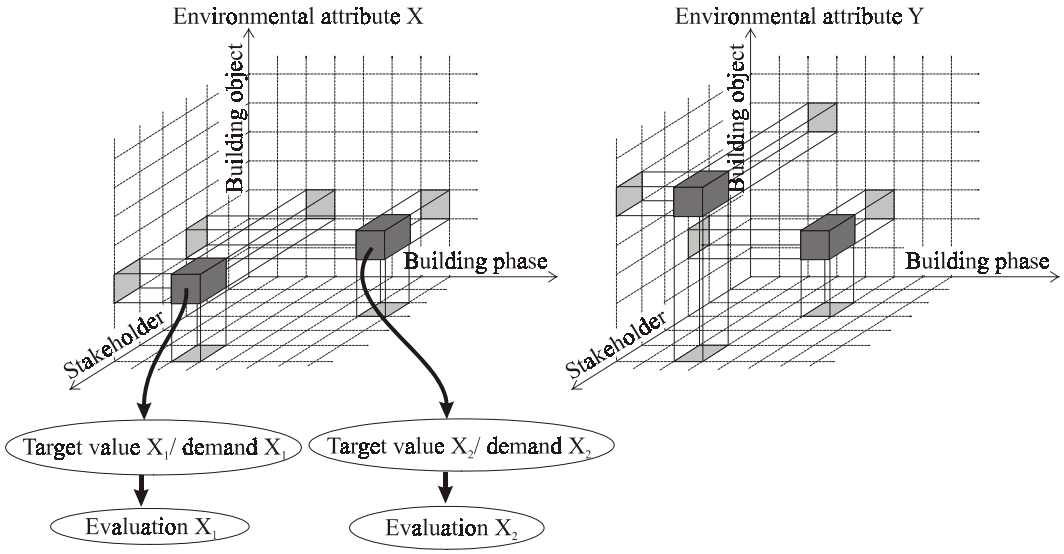

Figure 1 Performance matrix, filtered for Attribute X. For Attribute Y other/different positions in the matrix may be important (derived from the work of Hill, 1997; Foliente *et al.*, 1998).

In the framework, all information that define the required performance for the given combination of Stakeholder, Building phase and Building object can be gathered. It contains the specific performance/target values and gives a method for evaluating the performance, all in an unambiguous way. Obviously, one point in the matrix may contain many performance criteria and subsequent evaluation methods, or one performance criterion may overlap several stakeholders, building phases and/or building objects.

If the required information is put in the matrix, it can be seen that a certain environmental attribute X may be dealt with at different positions in the matrix and that the specific target values and evaluation procedures may differ. Considering another attribute, other positions in the matrix may be dealt with. This is visualized in Figure 1.

The matrix approach presents a database that allows identifying specific performance requirements for a specific building phase or stakeholder. It may also relate to a specific environmental attribute X or Y, addressed differently at several points in the building process. The translation of a certain subjective performance requirement to environmental attributes and target values and evaluation methods is, currently, the most important issue. The 3D matrix presents a logical structure to cope with the enormous amount of information. The projects HOPE and PeBBu are foreseen to develop the usability of this matrix approach further with emphasis on the indoor environmental performance.

DEFINITIONS

The following definitions have been applied in the framework introduced above:

Stakeholder: The person/entity who is responsible and/or has the means to influence or adjust/set the conditions for a certain performance criterion. For example, the investor who sets requirements for the building; the user who should be able to indicate the performance desires; the architect and HVAC consultant who have the responsibility that these criteria are met in the design; the building contractor who is responsible for constructing the actual building; and the regulator who may put forward additional criteria that should be met on a legal base.

Building phase: The phase of the building in which a certain performance criterion can be set or influenced. In principle, performance criteria can be set or influenced throughout the whole building life cycle. The main difference in performance criteria between the different phases is found in the way the performance criteria are dealt with, more subjectively or more objectively. Between phases, therefore, usually translation rules will be required to interpret the performance criteria from one building phase to another.

Building object: The part/component of the building through which a certain performance criterion is set or influenced. Building objects can be broken down in different component levels, starting from a material up to a building system level. Performance criteria can, therefore, be defined for the material level, but also at system level. Inherently, the specified criteria and level of criteria specification will be linked to the building phase. Examples of building objects are the structure, the envelope, the material used, installations, etc.

Environmental attribute: A physical, chemical and biological parameter that is related to a certain performance criterion, such as temperature, VOC (volatile organic compound) concentration.

Target value and/or demand: A quantitative target value or a qualitative demand that is related to the environmental attribute that influences a certain performance criterion. A target value will often not be one value. Normally, this will be represented by a value with a bandwidth, as, on the one hand, performance requirements cannot always be determined with great precision and, on the other hand, the data for a target value often will be based on, e.g., statistical information, so that also reliability, safety and risk is included.

Evaluation procedure: the method or procedure that is applied to check the target value/demand.

HOW TO USE THIS FRAMEWORK

To get a better idea of the framework and its possibilities, an indicative example is given in Table 1 for the performance criterion ‘it should not smell in the building’. What is needed for that and how one should quantify that is generally not known for all contexts. If a fully filled PBB matrix was available, filtering for this criterion would be possible and information on, for example, target values and evaluation procedures for the air quality, ventilation rate and material use could be identified. This information would become available at different positions in the matrix, depending on the stakeholder, the building phase and building object. In the example some references to the air quality attribute VOC with respect to the performance criterion are presented. It shows that in brief an air handling unit (AHU) could be incorporated in the design in order to adhere to the criterion, but alternatives can also be found in, e.g. natural ventilation. It is seen that the requirements for this building object, related to the performance criterion, need to be checked in the different phases of the building life.

Environmental attribute	Building object	Building phase	Stakeholder	Target value/demand	Evaluation procedure
Air quality: VOC	AHU	Brief	Architect	Include an HVAC-system	Brief
	AHU filter	Final design	HVAC consultant	Select a filter that …	Checklist
				TVOC < 300 μg/m^3	TVOC meas.
	AHU filter	User/maintenance	Facility manager	Change filter at least once per year, etc.	Checklist
	Air distribution network	Final design	HVAC consultant	Select ductwork that…	
	Etc.				
Ventilation: individual control	Control system for mechanical ventilation	Brief	HVAC consultant	Include possibility for individual control	Brief
Etc.	Etc.				

Table 1 Example PBB matrix result for the criterion: 'it should not smell in the building'

DISCUSSION

For the domain 'Indoor Environment' in PeBBu, a first workshop was held in England in September 2002 at the premises of BRE, in conjunction with one of the HOPE project meetings, at which, among others, the framework described above was agreed upon. The next and last workshop will most likely take place at TNO, when the recommendations for research and standardization required and ways to disseminate and exchange information to respective professionals and stakeholders will be the main focus.

In the project HOPE, a first set of performance criteria for healthy and energy-efficient buildings has been defined as well as a first definition of a healthy and energy-efficient building. Based on available knowledge and the HOPE research scope, the definition of a 'Healthy and Energy-Efficient Building' adopted here is as follows:

- Does not cause or aggravate illnesses in the building occupants.
- Assures a high level of comfort for the building's occupants with respect to the designated activities for which the building has been intended and designed.
- Minimizes the use of non-renewable energy taking into account available technology including life cycle energy costs.

As a first approach, the framework seems rather wide to cope with in the project HOPE. Therefore, it was decided to deal with the following situation: Building phase-use and Stakeholder-user, deleting two dimensions of the framework, and leaving the axis Building object. For this axis performance criteria will be translated to environmental attributes, target values/demands and evaluation procedures.

From the example in Table 1 it is obvious that an enormous amount of information must be incorporated into the framework. The example presents just one small item with respect to this specific performance criterion and naturally there will be a lot more criteria that need to be set.

Therefore, it will be important that all the available and newly developed information is organized well. The application of a database structure seems to be a useful manner for this. It for sure will take a lot of effort to develop such a PBB database and to fill it with all the information that is required for a complete introduction of the PBB approach in the building process and the building. However, the HOPE and the PeBBu projects appear as exquisite

opportunities to give a good start to that development. Furthermore, the framework is open to include all the work that is already available and useful for the PBB approach. So the framework will not aim to present a new start for developing the PBB approach. Instead, it aims to make better use of the knowledge that is already available and present a method to better structure and direct future research on this important topic.

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