Performance-based building: a state-of-the-art with respect to healthy buildings

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ABSTRACT

Within the European funded project PeBBu (Performance-Based Building), a state-of-the-art report on the performance-based building (PBB) approach with focus on healthy buildings is prepared. It deals with methods, guidelines, protocols and tools to design, evaluate and measure the health status of buildings or designs for buildings. The health of buildings in this context relates to air quality, ventilation, thermal comfort, noise and visual comfort.

After an introduction into PBB, this paper summarizes the state-of-the-art with respect to performance and healthy buildings. An important part of this summary is devoted to the definition of PBB and to the procedure that has been developed to gather the information. Based on the information gathered thus far, the main conclusion is that the PBB approach already has a firm basis in the building process, but that some specific aspects are lacking that currently impede the further integration of PBB in the total building process. Indoor environmental attributes appear specifically suited for the PBB approach.

INDEX TERMS

Performance; Indoor environment; Quality

INTRODUCTION

Performance is a concept that is gaining increasing attention over the last couple of decades. In 1982, CIB had already presented statements that define performance for the building industry:

- The performance approach is thinking and working in terms of ends rather than means.
- Performance is concerned with what a building or building product is required to do and not with prescribing how it is to be constructed.
- A design solution, traditional or novel, will always need a quantitative base for testing and evaluation of its performance.

Initiated by CIB, PeBBu (Performance-Based Building) is a thematic network under the EU-Competitive and Sustainable Growth programme. It started in 2001 and runs for 4 years. The overall objective is to stimulate and pro-actively facilitate the international dissemination and implementation of performance-based building (PBB) in the building and construction practice. It is not intended to present the ultimate solution for PBB, but to allow for a more fundamentally motivated and integrated continuation of the further development of PBB.

The PeBBu project has been divided into nine domains for which the PBB approach should be investigated. The work described here deals with the second domain, Indoor Environment. The goal of this domain is based on the belief that the achievement of healthy buildings can be pursued by designers, constructors, building owners and building occupants, through the application of qualitative and quantitative health-based criteria. From the occupant point-of-

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view, the ideal situation is an indoor environment that satisfies all occupants (i.e. they have no complaints) and does not unnecessarily increase the risk or severity of illness or injury. This environment is directly related to physical aspects of buildings such as

- air quality: health and comfort related to sensory, chemical and toxicological effects of compounds in the air,…
- ventilation: fresh air rate, re-circulation, efficiency,…
- thermal comfort: temperature, air velocity, humidity,…
- noise: noise from outside, indoors, vibrations,...
- visual comfort: view, illuminance, luminance ratios, reflection,…

Although there is a rich scientific literature and several national experiences on this subject, a uniform set of criteria across the European countries has not yet been defined. In PeBBu, one of the objectives for the Indoor Environment domain is to deliver a state-of-the-art report on existing performance criteria for healthy buildings.

PBB

The concept of PBB and its methodology have been described in CIB-Report 64 in 1982 (CIB 1982). In the report of Foliente *et al*. (1998) the state-of-the-art of PBB is updated. These two documents form the line of thinking we aim for. In the literature one can find a large amount of information on PBB and on performance criteria, but also a lot of different definitions. Foliente *et al*. (1998) have already noted that 'first and foremost, a clear definition of the performance-based concept is needed and agreed on'.

A definition of performance is context based. With respect to buildings, examples of contexts are the stakeholder, the building phase or a building object. For example, the user will have very different performance requirements from the contractor. The user wants to live comfortably in the building, whereas the contractor is interested in the performance of individual building objects, obeying the design plan. In the end, of course, everyone is interested in the total performance; in the building process this is not necessarily the case. This also means that PBB does not end with the completion of the building. Performance during the building life is considered just as important. Performance therefore is also a function of time.

With PBB 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. In the design process, however, translation rules are required to convert this subjective information into objective design rules. Translation procedures are found in, e.g. legislation, rules of thumb and more sophisticated tools such as modelling and case-/knowledge-based reasoning.

The above-described definition of performance in the building process has been visualized in Figure 1. It has been compared with the non-performance approach. The performance approach part of the figure was adapted from Huovila and Leinonen (2001) and originates from illustrations by the Dutch Government Building Agency. The total figure was developed and agreed on during the First PeBBu Domain 2 Workshop (Loomans and Bluyssen 2002).

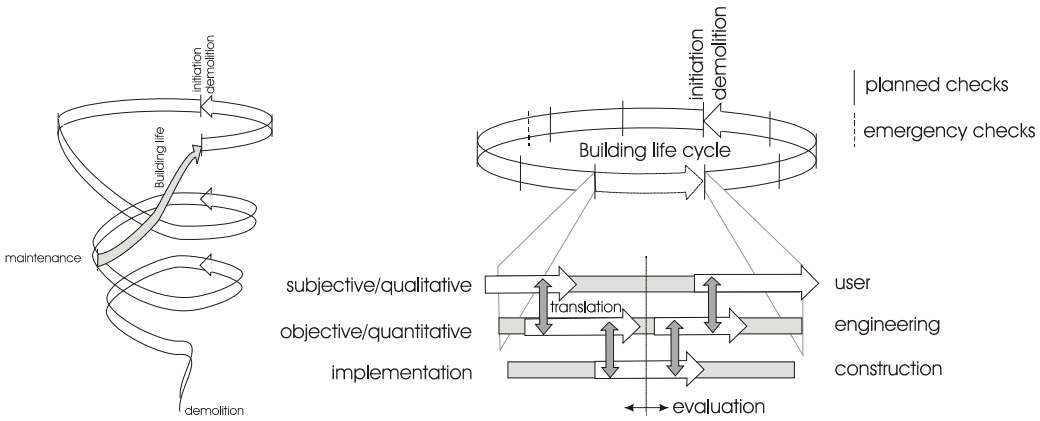

Figure 1 Non-performance- versus the performance-based approach.

The idea for the non-PBB approach is that maintenance is performed at a point of time of the building life when problems already have arisen and extra costs are required to correct the situation. With the PBB approach the performance of the building should stay at its desired performance level throughout the building lifetime, and this is checked regularly. The zoomed-out process for a specific change in the user requirements is similar for other required (performance) changes during the building life and is also the same for the initiation, design and construction of the building.

A FRAMEWORK

Given the number of performance definitions and the different contexts that can be found, it is difficult to keep track of all the building performance information that is available. This also accounts for all the translation rules that can be derived. Therefore a system should be developed that allows a logical structuring of all the information related to PBB, but also may improve the applicability of the PBB approach. Obviously we are looking for a framework in which we can fit the PBB approach and the available information in a logical and unambiguous way.

Several parameters should be incorporated in the framework. The most important parameter is the performance requirements that are set by the stakeholders.[1] Furthermore, the point of time in the building process will determine the type of requirements that are set. This will be closely related to the building phases[2] that can be identified. Finally, the actual building performance is of interest. This parameter has a close relation with the building objects.[3]

Inter-relations between the building phase and the type of stakeholder are obvious, as is the case for building objects and building phase. 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.

This approach has been derived from the work of Hill (1997) and can also be found, though in a different context, in Foliente *et al*. (1998).

The framework is visualized in Figure 2. The matrix approach presents a database that allows filtering to come up with the specific performance requirements that relate to a specific

[1]A **stakeholder** is defined as the person/entity who is responsible and/or has the means to influence or adjust/set the conditions for a certain performance criterion. Examples are the investor, the architect, the HVAC consultant or the building contractor. But the regulator and the user are also important stakeholders.

[2]The **building phase** is defined as the phase of the building in which a certain performance criterion can be set or influenced. Examples are the initiation phase, the design phase, the construction phase and the user phase.

[3]A **building object** is defined as the part/component of the building through which a certain performance criteria is set or influenced. Building objects can be broken down into different component levels, starting from the material up to the building and building systems level. Performance criteria therefore can be set to the material, but also to the complete system set-up. Examples are the structure, the envelope, material use and installations.

building phase or stakeholder. It may also relate to a specific environmental attribute X or Y that is addressed differently (i.e. different target values and evaluation methods) at different points in the building process.

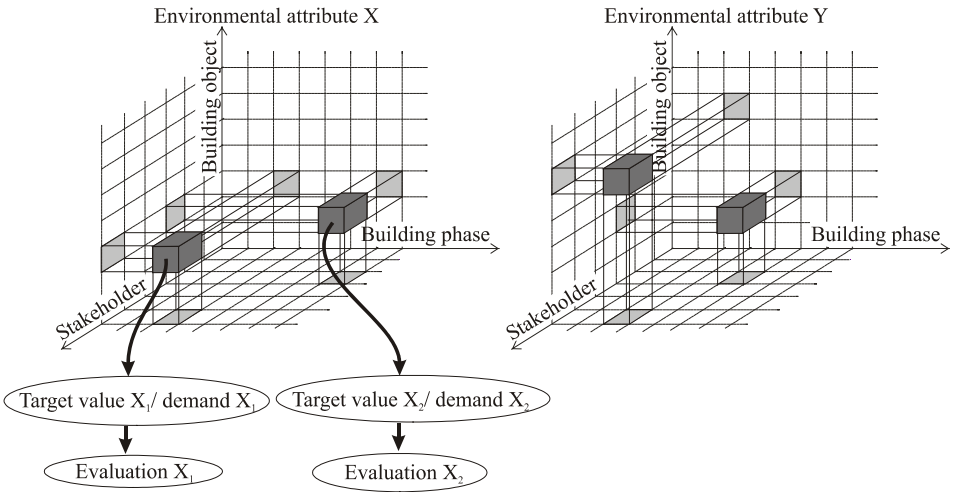

Figure 2 The performance-based matrix.

STATE-OF-THE-ART

The above-presented definition of PBB and the developed framework were required to come up with a state-of-the-art report on PBB, and on PBB and the indoor environment in particular. This state-of-the-art report in the PeBBu project is derived through a literature study and a study of ongoing research. This is an ongoing process, given the enormous amount of work that has already been devoted to PBB.

The intention also was to organize and categorize this information, in order to identify gaps in the PBB information. That is why the state-of-the-art has been summarized according to the different axes of the framework in Figure 2. A database structure has been developed for this. For a categorization of the indoor environment, attributes such as air quality, ventilation, indoor climate, acoustics and lighting have been used. Assuming that the framework/database can be filled with information derived from literature and ongoing research, it eventually should be possible to identify the gaps in the matrix. These gaps should be evaluated and commented on, and it should be determined, in combination with the available information, whether they require additional research. This presents the goal of the PeBBu project. Of course, available references may fit well in the eventual future PBB framework, e.g. as a reference to a target value or an evaluation procedure, or as a translation technique.

Summarizing the information that has been gathered from the literature research thus far, and assuming the above-described context-based performance approach, one can conclude that a lot of information on PBB is already available. However, most of this information deals with isolated topics and lacks the connection to the larger point-of-view. For example, with respect to materials and some individual building objects, the performance thinking is well established. Furthermore, focus has mainly been put on the separate (building) phases and not on the translation between higher-level performance requirements and lower-level implications (see Figure 1b). A general translation from subjective criteria to objective design parameters, and the reverse when dealing with the evaluation, to a large part is still lacking. Individual initiatives on several aspects however can be found. The coupling of these initiatives and the generalization appear to be important research areas for PBB. The Indoor Environment domain is one of the domains within PeBBu for which the translation from subjective to objective information is a key item.

Some interesting examples of PBB and the indoor environment already can be found. For example, the Government Building Agency in the Netherlands presents a progressive approach with respect to the application of PBB. It builds on developments in the Dutch Building Decree (Scholten *et al*. 2001). The integral quality of buildings that are designed by the Agency is captured through the use of performance specifications. Indoor environmental attributes form an important part of these requirements. The performance specifications for building environmental attributes are presented in a subjective manner that fits in with the brief phase. Translation into the next phases, as visualized in Figure 2, is partly made by referring to, e.g. rules of thumb and guidelines. On the other hand, for some attributes values are prescribed that restrict the freedom of design. So the trade-off between performance and prescriptive-based values is still under discussion. Regulations currently restrict the unprecedented use of the performance approach in the design phase. On the other hand, the equivalence principle that is introduced in the Dutch Building Decree allows for new developments. From the literature study, it appears that the Government Building Agency presents the state-of-the-art with respect to PBB as currently implemented in the actual building process. Note that this only applies to the first phases of the building process.

A different approach with regard to PBB has been developed by the Finnish Society of Indoor Air Quality and Climate (FiSIAQ). They have combined specific performance criteria in order to come up with a classification of the indoor climate (FiSIAQ 2001). The classification deals amongst others with target and design values for thermal conditions and the indoor air quality, with criteria for construction cleanliness and moisture control and criteria for material emissions and clean HVAC components. For these topics a categorization is proposed from which target values and material use are derived, including general verification procedures. The classification affects the design as well as the construction phase. For the latter, categories are determined that rank the construction cleanliness. For building materials classification labels have been developed that objectively qualify a building product. In general, the highest classification for construction and building materials is required to obtain the highest classification for the indoor climate. This classification is in action in Finland since 1995 and has been developed further since then. The FiSIAQ classification is voluntary, but currently applying this classification of the indoor climate is in the code of practice, especially when it is used for marketing purposes. Developments in the building industry, e.g. labelling of materials and cleanliness of HVAC systems, are adapted to this procedure.

The above two examples relate performance thinking mainly to the design and construction phases. The user phase nevertheless is just as important. This is where the Real Estate Norm (REN 1992) may be applied. This evaluation procedure captures the quality, i.e. the performance, of a building by valuing a listing with definitions. To a large part objective determination methods can be used for this. The actual performance and desired performance can be compared in order to derive actions to be taken or not.

In Loomans and Bluyssen (2002), approximately 30 other approaches that are performance based have been categorized to the building phase(s) in which they can be applied. Such a categorization has also been made for the other axes of the framework, i.e. stakeholders and the building objects. From this categorization, one can conclude that the (limited) translation between building phases as found in the approach by the Dutch Government Building Agency and FiSIAQ are relatively scarce. An important question of course is how this translation should be determined. In this respect, interesting initiatives on PBB that specifically deal with indoor environmental attributes present possible solutions. These initiatives try, e.g. to translate complex material properties in low-level user-friendly performance characteristics (van Dijk 2001) or present design decision support in the early design phase to make the design adhere to desired performance requirements (de Groot 1999).

With respect to health and comfort, we can find several initiatives on defining performance criteria and translating them into design solutions (Bluyssen 2002; Kurnitski *et al*. 2002). This however remains a difficult task, and the current status indicates that it still will require a lot of work for the near future.

DISCUSSION

The current state-of-the-art as summarized in this paper shows that PBB, in the Indoor Environment domain, already is being applied to some degree in the different phases of the building process. However, application is mostly restricted to a single building phase or building object and little information is available on the translation of qualitative performance requirements to quantitative implications for the building, and this hampers the further introduction of PBB in the building process.

For performance requirements on health and comfort, several interesting initiatives are ongoing. However, a lot of work still is required before PBB can completely replace the current prescriptive building methods, if possible at all.

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