

## MANAGING PERFORMANCE BASED BUILDING OF SMART HOMES

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### Abstract

Smart homes are considered a vital technology in an aging society as they compensate for a shortage in care workers. However, often smart homes do not perform well. Performance management is well known in the manufacturing industry but not common in the building industry. The performance approach is the practice of thinking and working in terms of ends rather than means. It is concerned with what a building or a building product is required to do, and not with prescribing how it is to be constructed. Performance based building (PBB) includes amongst others functional briefing and performance assessments. However, an overview of tasks in PBB is lacking and the principle has not yet been applied to smart homes. Aim of this research is to contribute to performance management in the construction of health smart homes by identifying tasks and proposing a task assignment. Tasks are identified by studying the extended reporting of the Performance Based Building Network (PeBBu). In conclusion we may say that PBB of health smart homes primarily differs from traditional building in the way tasks are performed. PBB demands that the client does not design (specify how to build) but restricts himself to specifying why he wants and why he wants it. PBB also demands that the designers and contractors are selected on both price and capabilities. Besides these alterations in how tasks are performed merely two tasks are added. These are the verification of the realized design and the monitoring of performance of the building in use.

**KEYWORDS:** Smart homes, domotics, construction management, performance based building.

### INTRODUCTION

Focus of project management in construction has changed in time from project costs, to construction planning, life cycle costs, and lately to performance management. Health Smart Homes often do not perform well.

#### Performance of Health Smart Homes

A health smart home is equipped with technology to enable remote health care (Rialle et al. 2002). Examples of such technology are: 1) tactile screens, sensitive remote controls, or

audible beacons to support visually impaired subjects; 2) fall detectors, or heart rate sensors to monitor a person's health; 3) medication dispensers, or video phone to deliver therapy (Chan et al. 2008).

The European Health Telematics Association points out that without changing the way elder citizens are supported in 2020, almost 20% of all working people will have to work in health services (EHTEL 2008). This will lead to a scarcity of professional resources. At the same time, quality of life is not only about health, but also about wellness aspects (e.g. getting attention). Health smart homes can contribute to successful aging (Barlow e.a. 2007) and can therefore be considered a vital technology in an aging society.

Realizing health smart homes is technically possible (Chan et al. 2008). However, this technology is successfully applied in only a small percentage of housing stock (Franchimon, Bronswijk, and Bouwhuis 2005). Good performance is hindered by various factors, including: i) difficulty in use, ii) mismatch with user needs, and iii) lack of interoperability with other systems (Barlow, Bayer, and Curry 2005; Chan et al. 2008; Nispen 2003).

### **Performance management in construction projects**

Project management in construction has changed focus in time from project costs, to construction planning, life cycle costs, and lately to performance management. Performance Based Building (PBB) is related to well known paradigms in the manufacturing industry such as total quality management, lean management, or six sigma (Becker and Foliente 2005; Ferng and Price 2005). Quality management in construction has until the beginning of this century been focussed on product quality in relation to the construction phase (Toakley and Marosszky 2003). More recently attempts are made for quality management in building design (Whyte and Gann 2003). PBB got a large impulse from the EU funded PeBBu program. In this program PBB is described as the practice of thinking and working in terms of ends rather than means (Spekkink 2005a). PBB is concerned with what a building or a building product is required to do, and not with prescribing how it is to be constructed.

#### **Aim**

An overview of tasks in performance based building is lacking and the principle has not yet been applied to health smart homes. Therefore, the aim of this research is to contribute to performance management in the construction of smart homes by identifying tasks and proposing a task assignment.

#### **PEBBU**

The thematic network PeBBu (Performance Based Building Network) as funded under the 5th R&D Framework of the European Commission operated from October 2001 until September 2005, did much to develop performance design. More than 70 organisations worldwide, including Eindhoven University of Technology and TNO, participated in PeBBu and produced synergistic results for dissemination and adaptation of performance based building (CIB 2005).

The extended reporting of the PeBBu-program was studied to indentify tasks for performance design of smart homes (<http://www.pebbu.nl/resources/allreports>). PeBBu's results were

considered the state of the art after searching literature with Google Scholar using the following keywords in various combinations: 'performance', 'quality', 'functionality', 'lean', 'engineering', 'building', and 'design'.

The first step in identifying tasks was to assess the 26 PeBBu-reports for relevance based on titles. Secondly, the table of contents were scanned for words indicating relevant information. Finally, relevant sections were read and tasks were identified.

### **Tasks in PeBBu**

Tasks for performance based building are mentioned throughout the 26 PeBBu reports. Some are mentioned frequently, others only once. PeBBu provides no clear sequence, although it is made clear that in PBB an overlap of the briefing and design process exists {see PeBBu Report #7, listed in Annex 1}. In the text below tasks are structured according to the five phases in the traditional building process (Vrijhoef and Koskela 2000): i) initiative (briefing), ii) design, iii) procurement, iv) realisation, and v) use.

PBB's initial phase starts with users', entrepreneurs' (principal), and building owners' needs. These need to be captured in qualitative functional criteria {#2, 6, 8, 17, 19}. A distinction is to be made between essential and optional needs{#2}. The essential requirements are dictated by the Construction Product Directive and cover i) mechanical resistance and stability, ii) safety in case of fire, iii) hygiene, health, and the environment, iv) safety in use, v) protection against noise, and vi) energy economy and heat retention{#22}. Optional needs can be generated by combinations of user-activity modules (e.g. person-sleeping, pupil-listening, etc.){#2}. For each functional requirement physical factors that serve as quantitative performance indicators or KPI's are to be identified{#2, 6, 17, 19}. The requirements are documented in the performance based design brief{#2, 18}.

The design phase starts with the selection of the design team consisting of architects and consultants{#2}. The requirements are communicated to the design team {#9} and communication between all actors involved can be coordinated by the project manager{#19}. Performance Based Design {#2, 7, 18} knows two different approaches {#7}: i) designers and engineers have to meet with performance based client briefs and building regulations, ii) designers define their work in a functional design plus a set of performance criteria, rather than work out the design traditionally in technical drawings and specifications. Which of the two is applied depends on the moment in which the procurement takes place. Either way, the service life of the design is estimated by the design team, based on the reference service life as assessed by the manufacturer and project specific information{#5}. A more profound (compared to traditional design) analysis of the design results {#2} is made by the design team by assessing or simulating design alternatives and predicting the performance of a building on the basis of a design{#2, 6, 7}. Checking the performance specifications with the performance requirements is considered a responsibility for the principal{#2, 4}. This should be done continuously during the design {#9} for example through visualisation{#17}. There are four design phases: i) master plan, ii) preliminary design, iii) final design, iv) technical design {#7, 18}.

Performance Based Procurement is possible in various ways. Common options are; Design & Build, Build Operate Own Transfer, and Design Build Finance Operate{#2, 4, 16, 17, 25}. Naturally, when both design and build are tendered, the procurement phase takes places

before the design phase. The procurement can be executed by the building manager {#18} and will be based on whole life costs {#25} or cost-benefit-analysis{#2}.

During realisation budding and control can take place{#18}.

Once the building is in use Facility Management {#2, 25} can take responsibility. Through post occupancy evaluation {#2, 18} the realized functionality and performance is monitored. When requirements are not met the contractor will have to bear responsibilities for the outcomes{#2, 18}.

### Specifying performance requirements according to PeBBu

Two models are mentioned in PeBBu that provide some structure for the PBB process i) the hamburger model and ii) the nordic model{#4, 7}. Both provide a structure for thinking about the specification of performance requirements..

The hamburger model, see figure 1, is based on two observations: i) the user and supplier speak different languages, ii) it is an illusion to think that the design process can start with a complete and unchangeable client's brief {#4}. It is suggested to let the user specify the 'why and what' is required (functional concept), and let the supplier specify the 'how' (solution concept). Also characteristic for the hamburger model is the decomposition of the building in four levels: i) whole building, ii) building elements, iii) building components, and iv) building products and materials.

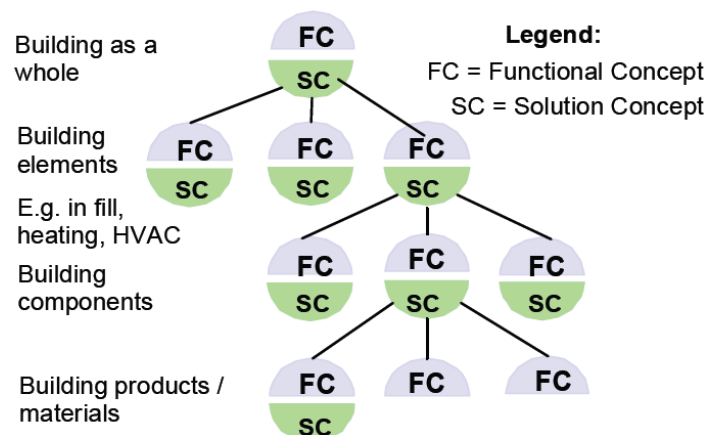


Figure 1: Four levels of the built facility {# 4}

The nordic model distinguishes five types of specifications (Hattis and Becker 2001; Oleszkiewicz 1994): i) objectives - what is expected in terms of societal goals (e.g., safeguarding people during escape and rescue), ii) functional statements - in general terms, what function the building or element must provide to meet the objective (e.g., the building must be constructed to give people adequate time to reach a place of safety without exposure to untenable conditions), iii) performance requirements - detailed statements necessary to achieve the requirements of the functional statements, and iv) verification methods, and v) examples of acceptable solutions.

### Health smart homes in PeBBu

Three reports mention smart homes (intelligent homes). It is stated that “Domotics and Immotics are made for everyone, particularly for those who want to find a positive evolution in their living and working conditions, in terms of degree of comfort, safety and accessibility, communication and easiness of use“{#17}. Also the expectation is expressed that “The idea

*of intelligent buildings looks compatible with PBB as the building intelligence responds to user needs” and that PBB of “...intelligent buildings could give answers to several questions: ... - how intelligent building should be designed in case the investor does not know who will be the future user;... - the scope of necessary services required by current user or tenant and the ones he wants to pay for (it concerns the clarification of necessary services and systems){#18}. Finally it is mentioned that the brief should include requirements for the information technology to be applied {#25}.*

## **PERFORMANCE BASED BUILDING OF SMART HOMES**

Performance Based Building (PBB) is only partly covered by PeBBu. Also PeBBu does not cover the whole building. Although PeBBu in name is concerned with all activities in the building process, its focus is without doubt on briefing and designing. Some statements concerning procurement are included, though limited to summing up contract types. Realisation and use (including maintenance) are hardly mentioned at all. Also the width of the focus concerning the whole building is limited to fire safety, structural safety, energy, acoustics, moisture protection, durability, and indoor air quality. Other functionalities of the building such as health smart home technology are not considered. Supplements for procurement, realisation, and maintenance as well as tasks specific to the building of smart homes are suggested below. Finally, all tasks are structured in a protocol for performance based building of health smart homes.

### **Tasks in performance based procurement, realisation, and maintenance**

In addition to the briefing and design tasks as mentioned in PeBBu the following activities are proposed for performance based procurement, realisation, and maintenance.

Successful performance based procurement is described by Favié (2009): The principal drafts a capable team to manage the procurement process and gives them the proper mandate. The functional specifications are communicated clearly to the consortia (potential contracting partners). The consortia inform themselves well in order to get a good and quick understanding of the projects’ objectives. The number of consortia taking part in the tendering are reduced as fast as possible in order to prevent unnecessary costs for those that are let off. Openness and trust are essential in negotiating and communication should be timely. Finally, the procurement process should be standardized as far as possible. Such a standardized protocol is introduced in the Netherlands by Van de Rijt and Santema (2009) based on Kashiwagi’s (1999) approach to performance management in procurement.

Performance management in project realisation is closely related to quality management in the construction company itself. Well known systems to support quality management are ISO9001, Balanced Score Card, and EFQM (European Foundation of Quality Management Excellence Model) (Beatham et al. 2004; Robinson et al. 2005). The EFQM model includes five tasks (enablers): i) leadership, and management of ii) policy and strategy, iii) people, iv) partnerships and resources, and v) processes. These enablers result in: i) customer results, ii) people results, iii) society results, and iv) key performance results (INK 2009). Notice that ‘society results’ and ‘customer results’ correspond with ‘objective’ and ‘functional statements’, two levels in the nordic model for performance specification of buildings. A protocol for EFQM self assessment is published by INK (2009), the dutch institute for quality management.

When a performance approach is chosen, maintenance is often combined with design and build into one (DBFMO) contract. In case it was not integrated with design and build into one contract it is possible to separately tender for performance based maintenance (Straub 2009). Before tendering, performance based specifications are written by the principle. During the procurement process, multiple maintenance scenario's are designed by the contractor and for the one preferred by the principle activity plans are written. After reaching an agreement, the building is maintained for several years during which performance is monitored. When requirements are not met, the contractor will bear the consequences. A guide to performance maintenance was written by Sprong, Raasveld & Keus (2009).

### Tasks in building of health smart homes

Contemporary designing and building of health smart homes consists of the selection of a bus system, configuring it for the individual project, and implementing it in the building. Whereas selecting a bus systems can be considered similar to selecting any other building element, the configuring of the bus system introduces a significantly new task to the construction project. Two models known in project management of software development are briefly compared to PBB.

The waterfall model (Royce 1970) and the V-model (IABG 1993) are models describing tasks taking place during software development. Since the waterfall model was the basis for the V-model most tasks are similar, see figures 2a and 2b. Compared to PBB one task is introduced: verification. Although not uncommon to some construction projects, verification is currently not identified as of key importance to the performance of (smart) buildings.

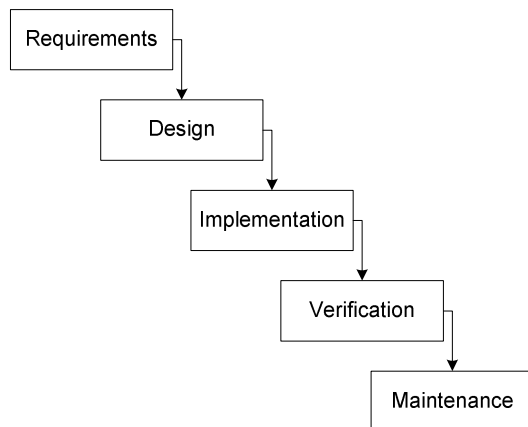


Figure 2a: simplified waterfall model

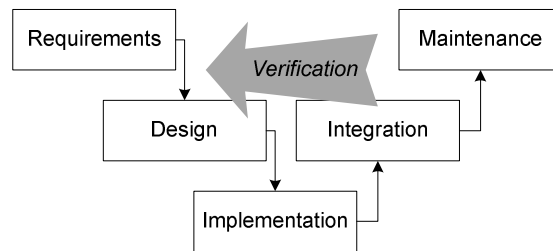


Figure 2a: simplified V-model

### Task assignment for PBB of health smart homes

All tasks mentioned previously are clustered and organised according to the traditional building phases in one task assignment. See figure 2. Six clusters of tasks are identified; i) initiation, ii) performance specification, iii) performance procurement, iv) performance design, v) realisation, and vi) maintaining performance. Some of these clusters stretch out over multiple phases. For example, *performance procurement* starts in the initiative phase

with the *call for tender* and stretches out to the usage phase with *monitoring realised performance*. Tasks in *performance specification* (what and why) and *performance design* (how) are closely related as suggested with the hamburger model. Dotted lines in figure 3 connect related pairs of task, for example; specification of the *functional requirements concerning the whole building* and design of the *master plan*. Tasks in the *performance specification* cluster are defined according to the nordic models' five types of specification and the hamburger models' decomposition of the building in four levels.

<i>Phase</i>	<i>Tasks</i>	
	<b>User, Owner, &amp; Principal</b>	<b>Construction industry</b>
<b>Initiative</b>	<b>Initiation</b>	
	1) <i>Users', owners', and principals' objectives</i>	
	<b>Performance Specification</b>	
	2) <i>Functional requirements concerning the whole building</i>	
		<b>Performance Procurement</b>
		3) <i>Call for tender</i>
<b>Design</b>		
	5) <i>Functional and performance requirements concerning the building elements</i>	
	7) <i>Performance requirements concerning and verification methods for building components</i>	
		<b>Performance Design</b>
		4) <i>Master plan</i>
		6) <i>Preliminary design</i>
		8) <i>Final design</i>
	9) <i>Verification methods (and acceptable solutions) for building materials and products</i>	
		10) <i>Technical design</i>
		11) <i>Award contract</i>
<b>Realisation</b>		
		<b>Realisation</b>
		12) <i>Construction</i>
		13) <i>Verification</i>
<b>Use</b>		
		<b>Maintaining performance</b>
	14) <i>Monitoring realised performance</i>	
		15) <i>Performance Based Maintenance</i>

Figure 3: Task assignment in performance based building of health smart homes

## **CONCLUSIONS**

In conclusion we may say that performance based building (PBB) of health smart homes primarily differs from traditional building in the way tasks are performed, and not so much in what tasks are performed. PBB demands that the client does not design (specify how to build) but restricts himself to specifying why he wants and why he wants it. PBB also demands that the designers and contractors are selected on both price and capabilities. Besides these alterations in how tasks are performed merely two tasks are added. These are the verification of the realised design and the monitoring of performance of the building in use.

Further research is dedicated to testing the proposed task assignment and identifying relevant tools to support complex tasks. The proposed task assignment is currently tested in two housing projects and the building of two schools in the Netherlands. Preliminary results of these pilots are expected by the end of 2010. Also, tools are sought and tested for specifying, designing, and assessing quality of buildings. Special interest goes to those tools helping to counter the barriers (A. Sixsmith and J. Sixsmith 2000) for identifying and interpreting needs of health-smart-home users.



## ANNEX 1

*PeBBu Reports:* <http://www.pebbu.nl/resources/allreports/>

- 1) PeBBu Final Report (CIB 2005)
- 2) PBB International State of the Art (Becker and Foliente 2005)
- 3) Performance Based Building R&D Roadmap (Foliente 2005)
- 4) Performance Based Building: Conceptual Framework (Szigeti and Davis 2005)
- 5) Life Performance of Construction Materials & Components (Sjöström and Trinius 2005a)
- 6) Indoor Environment (Loomans and Bluysen 2005)
- 7) Performance Based Design of Buildings (Spekkink 2005a)
- 8) Built Environment (Gray 2005)
- 9) Organisation & Management (Huovila 2005a)
- 10) Legal & Procurement Practices (Fenn, Haugbølle, and Morse 2005)
- 11) Performance Based Building Regulations (Pilzer 2005)
- 12) Performance Based Building Innovation (Barrett, Sexton, and Lee 2005)
- 13) Information & Documentation (Davidson 2005)
- 14) PeBBu User Platform: Building Owners, Users & Managers (Yates and Prior 2005)
- 15) PeBBu User Platform: Building & Construction Industry (Vandaele and Goffinet 2005)
- 16) PeBBu: Regional Platform: North European (Sjöström and Trinius 2005b)
- 17) PeBBu Regional Platform: West/Central European (Vandaele 2005)
- 18) PeBBu Regional Platform: East European (Matolcsy and Tiderenczl 2005)
- 19) PeBBu Regional Platform: Mediterranean Europe (Cardillo and Varone 2005)
- 20) International Research Mapping (Jasuja 2005)
- 21) NAS state of the art report on performance based building (Matolcsy, Tiderenczl, and Matiasovsky 2005)
- 22) PBB and the construction product directive (Winnepeninckx, Vandaele, and Vitse 2005)
- 23) Decision Support Toolkit (Huovila 2005b)
- 24) Crisp Indicator Analysis (Huovila 2005c)
- 25) PeBBu Compendium: Statement of Requirements (Szigeti, Bourke, and Prior 2005)
- 26) Performance Based Design: Bringing Vitruvius up to Date (Spekkink 2005b)

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