PeBBu Performance Based Building

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PERFORMANCE BASED DESIGN OF BUILDINGS

PeBBu Domain 3 Final Report

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PERFORMANCE BASED DESIGN OF BUILDINGS

PeBBu DOMAIN 3

FINAL DOMAIN REPORT

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Performance Based Building Network (PeBBu) is a thematic network funded under the European Commission's (EU) 5th framework – Competitive and Sustainable Growth and has been operational from October 2001 till September 2005. This project has been managed by CIBdf, The Netherlands. The PeBBu Network has been facilitating in enhancing the existing performance based building research and activities by networking with the main European stakeholders and other international stakeholders. The network has also been producing synergistic results for dissemination and adaptation of performance based building and construction. More than 70 organisations worldwide have been participating in the PeBBu Network.

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FOREWORD

This final report of PeBBu Domain 3 ‘Design of Buildings’ is the result of an exiting period of four year’s work, in which some 60 Domain Members from 19 different countries participated (see Annex 1). During this period the concept of Performance Based Design (PBD) was investigated and elaborated. We became convinced that PBD is a very important concept for the future, as it is essentially a client oriented way of thinking and working. Clients and end users more and more take positions in the centre of building process. They demand value for money, buildings that optimally facilitate their needs and operations. PBD is aimed at understanding and satisfying the real client needs (‘answering the question behind the question’) and leaves the design process open for creative and innovative solutions. The performance-based approach makes ‘integral design’, with parallel, interrelated contributions from all design disciplines imperative. This constitutes a challenging perspective for all design professionals. Although PBD has been put to practice in many countries to some extend, design practitioners appear to be hardly aware of it and it’s potential impact on the design profession. With this report the Domain 3 Members intend to contribute to a clearer picture.

Domain Workshops have been very important in the Domain’s methodology and process. As a rule the Domain Leader produced workshop preparation reports, which were then discussed in meetings. In the first Domain Workshop (Rotterdam, July 2002) the participants were invited to give a presentation of the State of the Art of PBD in their respective countries. The information that came out of this was completed by the responses to a questionnaire, that was sent out to all Domain Members. In addition most Members wrote a national State of the Art Report. The Domain Leader compiled all the information in a 1st “Design of Buildings State of the Art Report”. Versions of this report were discussed in the NAS Catch up Workshop (Budapest, March 2003) and the 2nd and 3rd Domain Workshops (Manchester, January 2004 and Porto, November 2004). The Domain Members gave their main inputs during and around these Workshops. In the 3rd Domain Workshop a model for the Domain’s RTD agenda was launched and excepted by the Members. After this Workshop, the final Domain Report, the RTD agenda and other deliverables were completed by the Domain Leader.

I would like to thank the Domain 3 Members for their valuable and inspiring input, Mansi Jasuja for her managerial support and patience, Wim Bakens for his initiative to start PeBBu in the first place, and the European Commission for enabling so many of us to participate in this important international network.

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EXECUTIVE SUMMARY

The conceptual framework for Domain 3 can best be described by the definition of PBD that has been developed in the project: "a Performance-based design is a building design that is based on a set of dedicated performance requirements and that can be evaluated on the basis of performance indicators."

However, Domain 3 is not only about the result of a design process, but also and primarily with that process itself. In that context a Performance-based design process is defined as follows: "a Performance-based design process is a process in which performance requirements are translated and integrated into a building design."

Designers have to deal with systematic interrelations between different performance specifications, which often relate to different fields of expertise. The performance of a building or a building part is always the result of the interaction between different solutions for different subsystems, like the architectural system, the structural system, the climate system and so on. Thus, the performance-based approach calls for integral design, with parallel, interrelated contributions from all design disciplines involved.

The main objective of Domain 3 "Design of Buildings" was to investigate and clarify the concept of Performance-based Design (PBD) for both the European R&D community and design professionals. The main drivers for PBD are user requirements (users demand better performance of buildings-in-use) and legislation that is becoming more and more performance-based (solution independent). A major part of the research in the Domain is focused on the 'translation' and management of user and stakeholder requirements into performance requirements and the prediction of the building's performance in use on the basis of a design. This results in an overview of the State of the Art of PBD, descriptions of best practices, recommendations for the implementation of the available knowledge in education, an international RTD agenda and education and training modules for design professionals.

The Domain 3 inventory of the state of the art shows that PDB is mainly an issue in research and education as yet. Design professionals (architects and engineers) are generally not very aware of PBD. In this respect a distinction should be made between two different approaches to PDB:

- designers and engineers have to meet with performance based client briefs and building regulations;
- 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.

The first approach can be recognised in most building projects in countries that apply performance based building regulations, mostly countries in the northern part of Europe. Applicants for building permits have to prove that the designs comply with the regulations, so every design professional is involved in PDB to some extend, consciously or unconsciously. Performance based building regulations and codes often include performance requirements for safety (structural safety, fire safety, earth quake resistance and so on), health, serviceability, energy efficiency and environmental impact.

The second approach is closely related to performance based procurement. Up to now, this approach has only been put to practice on a relatively small scale, mainly in the same northern countries. Mostly government building agencies take the lead; they organize pilot projects and/or experiments to set an example for innovation of the building process. The general idea is that the 'demand side' of the building process defines a functional design and a set or performance requirements, allowing the supply side to choose the most suitable technical solutions matching these requirements, availability and cost. This second approach to PBD has hardly been put into practice in non governmental projects as yet. One of the barriers is that many clients do not trust this kind of procurement, that they experience as rather abstract and intangible and therefore too unsure and risky.

In general engineers and technical designers are more used to working with performance requirements than architects. The main design areas where performance based design and procurement is applied, are service engineering (acoustics, lighting conditions, indoor climate, air quality, and so on), energy consumption and maintenance.

Too often stakeholder requirements are not met in the final product. There are various reasons for this: cutting costs in some phase of the project, inability to find suitable design solutions to fulfil the requirements, forgetting the original requirements, and so on. To avoid this, early and continuous verification and assessments of design results have to take place in the design process. Assessment methods may vary from simple measuring (e.g. the amount of net square meters offered) via standardized calculating (e.g. the strength and stability of building structures or the energy loss) to simulating certain aspects of the behaviour of the building in-use (e.g. daylight penetration in different seasons and under different weather conditions). In some EU member states national building regulations are more and more performance-based. Also European regulations, that have to be implemented in the national building regulations of all EU member states, are as a rule performance-based. Performance-based regulations often refer to national standards, where not only performance levels for building parts and properties, but also the corresponding assessment methods are defined.
Assessment methods in European and national standards are mostly aimed at the testing of actual buildings or building products. However, one of the main problems in PBD is how to predict the performance of a building on the basis of a design. For many quality aspects the 'total building performance' depends on a complex interaction of many influences. On the one hand there are no validated, standardized assessment methods available to predict the total building performance, but on the other hand this performance will determine the client's perception of the quality delivered to a great extend. The only way to do it is by simulation of the building behaviour, using integrated data models. All over the world institutes and universities are in the process of developing simulation applications to facilitate this, using modern information and communication technology (ICT).

All over Europe design professionals seems hardly aware of the concept of PBD and also for the R&D community it is a rather new and unexplored field of work. Nevertheless, PBD is already being put to practice to some extend in most countries, consciously or unconsciously. Therefore it seemed appropriate to aim the Domain 3 results at making researchers and design professionals aware of PBD.

One of the main problems in PBD appears to be how to 'predict' the performance of a building in use on the basis of a design. Therefore the Domain 3 Research Agenda is aimed at solving that problem. On the basis of a classification of performance aspects or requirements, an inventory has been made of related assessment tools. The results of this inventory are presented in a framework. This framework consists of a matrix, with a list of subjects for which performance requirements can be formulated ('performance issues') on the vertical axis and the most common design stages on the horizontal axis. 'White spots' in the matrix mark the performance aspects for which new design assessment tools need to be developed. These are mostly simulation tools, using sophisticated IT applications. The result serves two goals:

- it gives students, teachers and design professionals an overview of tools that are already available. This is an important and practical issue for knowledge dissemination to design practice;
- after further completion, it shows for which performance subjects decision support tools and/or assessment tools will have to be developed.

The education and training modules for design professionals have taken the form of:

- a report “Performance-based Design: bringing Vitruvius up to date”, explaining and defining PBD, showing where and how the concept is already being put to practice and giving best practice examples. This report will be distributed through the PeBBu website and by the Domain Members in their respective countries;

- news articles, distributed through the PeBBu website;
- a slideshow about performance-based Design, that can be used by Domain Members for the education and training of students and design professionals in their countries;
- a pilot module for an electronic education system (cd-rom), disclosing relevant results for design professionals from essentially all PeBBu Domains and Tasks.

CONTENTS

Introduction & Reading Instruction

CHAPTER 1

1 Introduction & Reading Instruction

This is the Final Report of Domain 3 'Design of Buildings' of the PeBBu programme. This Report is the result of four years' work by over 40 Task Members from 18 different countries. The report introduces the concept of Performance-Based Design, a new way of thinking and working in design that responds to the need to satisfy client and user requirements and the need to comply with building codes and regulations, that are more and more performances based. The report is a further elaboration of the 3rd Domain Report "Bringing Vitruvius up to date", that was issues in November 2004.

First, in chapter 2 the Performance-based approach and the concept of Performance-based Building (PBB) are explained. The Scope and Objectives for the Domain 3 work are discussed in chapter 3. Chapter 4 is more or less the heart of the report while Performance-based Design (PBD) is explained and elaborated here in detail. The following chapter describes the world wide State of the Art of PBD. Barriers and Incentives for the further development and implementation of PBD are listed in chapter 6 and – following that – some recommendations for knowledge dissemination and implementation are given in chapter 7.
The Domain 3 Members came up with a lot of visions, plans and suggestions for future research in the field of PBD. These visions, plans and suggestions are categorized, explained and listed in chapter 8. Finally, chapter 9 contains some conclusive remarks.

There are two Appendixes to this report. The first Annex gives an overview of all the Domian 3 Members and other contacts that participated in the work since 2002, including their e-mail addresses.
Annex 2 describes a framework for making an inventory of available Design Assessment Methods. This is a part of what is considered one of the PBD top research priorities: developing and maintaining an up to date overview of which performance items can be assessed in which design stages and of the assessment tools that are available for that. The idea is to publish this overview on the internet, so that interested design professionals, developers and researches can both give input and consult the list of assessment methods.

Background Information
Performance Based Building

CHAPTER 2

2 Background information Performance-Based Building

2.1 The Performance concept

After many discussions, the consensus within PeBBu is that the simplest, most useful and clearest definition is contained in CIB Report # 64 'Working with the Performance Approach in Building':

"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." (Gibson 1982)

Performance Based Building focuses on the target performance required for the business processes and the needs of the users. It is about the defining of the requirements and fitness for purpose of a building, constructed asset or facility, or a building product, or a service, right from the outset (Szigeti and Davis, 2005). This is as opposed to the more traditional, prescriptive approach, which is concerned with describing type and quality of materials, method of construction, workmanship, etc.

2.2 Key Characteristics of the Performance Concept

Two key characteristics of the Performance concept are:

1. the use of two languages, one for the demand for the performance and the other for the supply of the performance;
2. the need for validation and verification of results against performance targets.

(Szigeti and Davis, 2005).

Both characteristics can be explained by use of the 'Hamburger Model', first used in the Netherlands by Ghieling (1986). This model distinguishes a 'Functional Concept' on the demand side and 'Solution Concepts' on the supply side of e.g. a built facility.

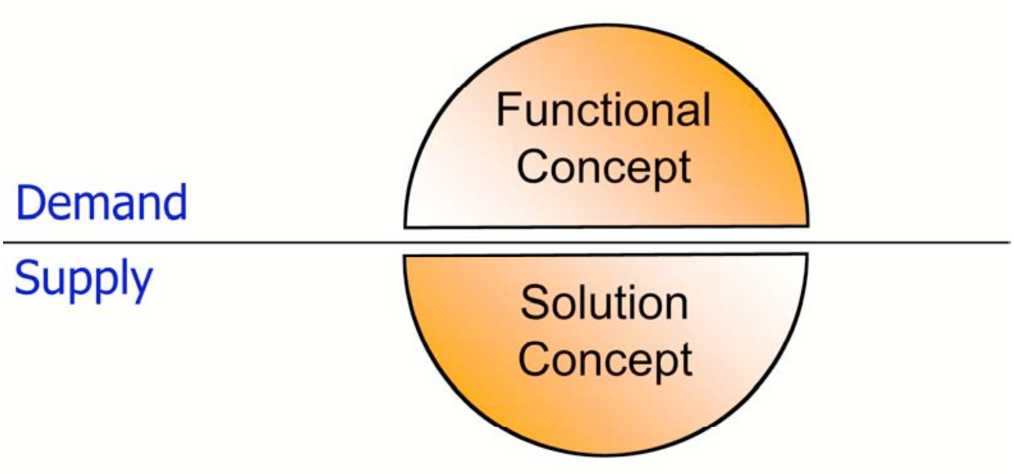

Figure 1: the 'Hamburger Model'

The Solution Concept has to comply with the Functional Concept, but a problem here is that the two concepts basically are expressed in two different languages, that make it difficult to match them.

The Functional Concept is primarily related to the intended use of the facility. It represents the users' functional needs and requirements, which derive from the users' own operations. In other words: the Functional Concept states in 'user language' WHAT is required and WHY it is required; it states what a facility should do for the users.

The Solution Concept states in terms of technical specifications HOW the requirements are supposed to be met.. This is done in 'technical language' that is understood by supply chain participants: the Solution Concept basically states how a facility could or should be constructed (Figure 2).

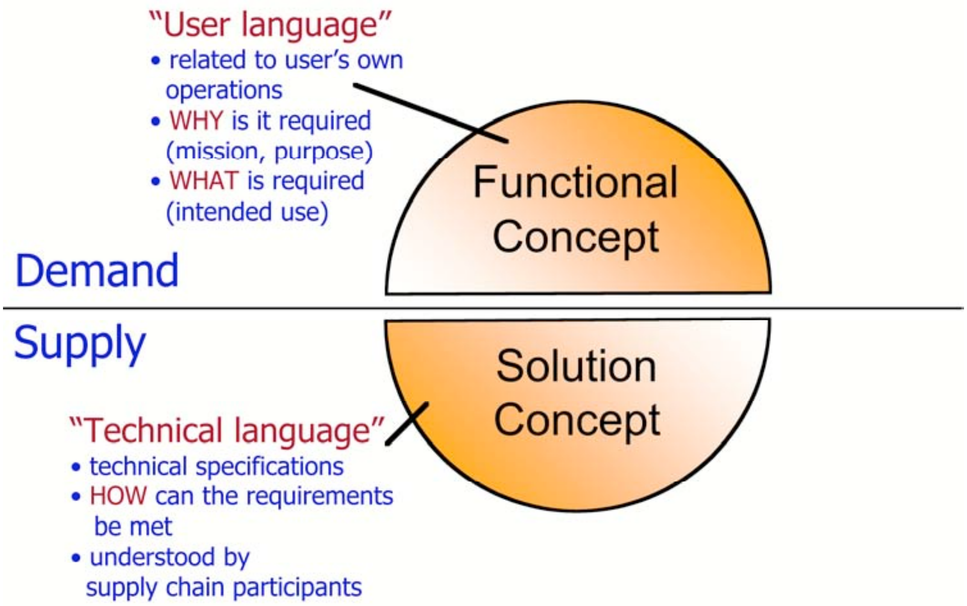

Figure 2: User language versus Technical language

The Functional Concept and the Solution Concept represent two different viewpoints of the same facility. At the end of the day, clients and users need to be able to verify that what they get, at move in and over the life cycle of the facility, is what they asked for and paid for. Evaluations and reviews, as part of design, construction and commissioning, need to refer back to explicit statements of requirements, otherwise they are based on perceptions, intuitions and guess work (Szigeti and Davis, 2005). There is a need for making functional (user) needs and requirements more explicit and for linking those to the objectives for the project. Furthermore, there is a need for checking whether or not proposed solutions comply with the requirements. But, because of the different languages that are inherent to the different viewpoints mentioned above, this is quite a difficult thing to do

The Performance approach offers a solution here, using 'performance language' as an intermediate between functional needs and requirements and technical solutions. On the demand side functional needs are translated into performance requirements. These are facility or product related requirements, expressing what properties the built facility should have to facilitate the intended use. On the supply side the technical specifications are translated into performance specifications, expressing the measured or predicted properties of the offered solution. For this translation, validation and/or assessment methods and tools are needed. These may vary from simple measuring to (standardized) calculation methods en sophisticated IT-based simulation tools.

Once both the Functional and the Solution Concepts are translated into 'performance language', a sound comparison and matching between demand and supply are possible (Figure 3).

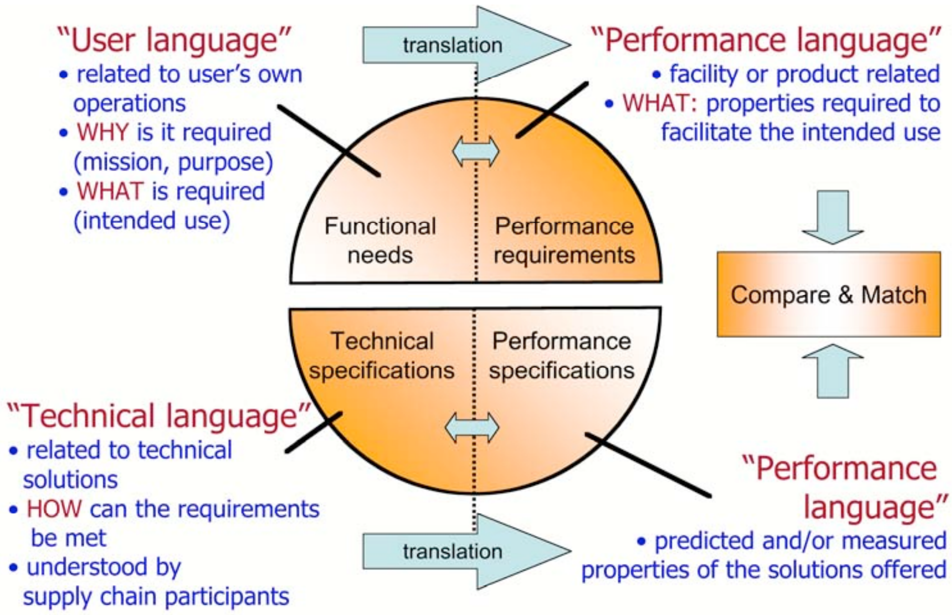

Figure 3: 'Performance language' as an in-between

2.3 The Performance concept is applicable on different levels

The performance concept as described in paragraph 2.2, is applicable on different levels of decomposition and aggregation of a built facility. This is shown in Figure 4. The need for a facility (Functional Concept on the facility level) expressed by the demand side, may provoke a Solution Concept on the whole building level by parties on the supply side. Once accepted, the Solution Concept for the building may be decomposed into building elements, for each of which functional needs and performance requirements can be formulated. The supply side may react to these 'Functional Concepts on building elements level' with Solution Concepts on the same level. Again these Solution concept may be further decomposed to next level, and so on.

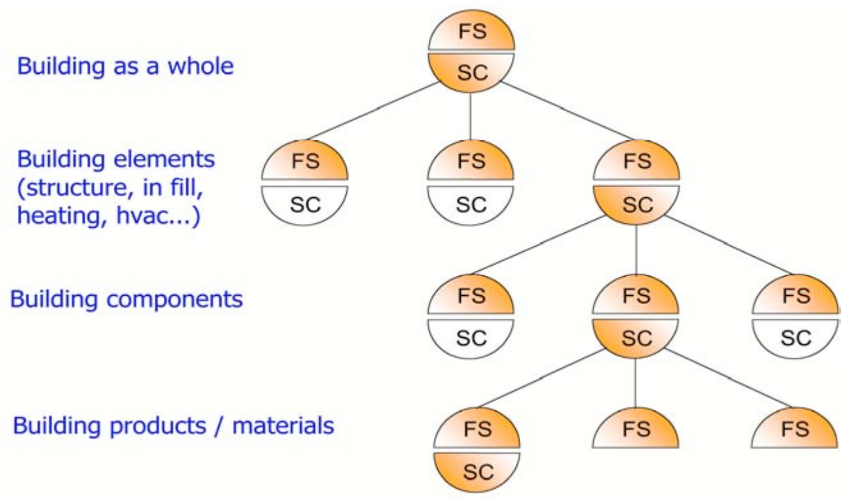

Figure 4: PBB applies to different levels of decomposition and/or aggregation of a built facility

2.4 It is not all one or the other

Using a Performance Based Approach does not exclude the use of prescriptive specifications. There is not yet very much experience with this approach in building. Therefore it is not likely that a facility will be planned, procured, delivered, maintained, renovated and used using solely Performance Based documents at each step of the way. Prescriptive specifications will probably still be applied when the use of such specifications is more effective, efficient, faster or less costly. They continue to be useful in many situations. Prescriptive codes, regulations and specifications are rooted in the experience of what has worked in the past – they are more or less the expression of the performance embedded in the chosen solution and of the knowledge and experience of those who use them. The down side of any prescriptive documents is that, unless they are regularly updated and take into account feedback from the field, they run the risk of codifying misunderstandings and mistakes, stifling change and innovation, freezing solutions and keeping the customer from benefiting form the knowledge of the provider.

Nevertheless, it is not either performance or prescription. Blending the two is often having best of both worlds (Szigeti and Davis, 2005).

2.5 Drivers for Performance Based Building

Why is Performance Based Building (PBB) important? The main drivers for PBB are performance requirements by clients and performance requirements in legislation.

Clients and users more and more demand value for money and expect the building industry to be customer focussed. There is an economic need for the industry to become more client oriented. In order to be able to meet the requirements of the clients, it is essential that:

a. the clients really know and understand what they require, why they require it and that they state their requirements clearly, explicitly and comprehensively;
b. building process participants understand what is required, can create optimal solutions that comply with these requirements and can prove compliance on beforehand.

Performance Based Building potentially provides for both the philosophy and the tools to accomplish this.

In the building and construction industry prescriptive codes, regulations, standards and specifications haven been perceived as getting in the way of innovation and creating technical restrictions to trade. These concerns have been the major drivers towards the use of a Performance Based Approach to codes, regulations and standards (Bergeron 2004, Ang at al, 2005, Meacham at al, 2005). In 1997 the World Trade Organization stated in Clause 2.8 of the Agreement on Technical Barriers on Trade that "… whenever appropriate, Members shall specify technical regulations based on product requirements in terms of performance rather than design or prescriptive characteristics." As a result e.g. in the US government, performance-based contracting is mandatory. In the European Union, European Directives that have to be implemented in the national legislation of the EU member states, are basically Performance Based. Very often these Directives refer to European standards, that are also basically Performance Based. In increasing number of EU member states, like the Netherlands and the Nordic countries, develop Performance Based Building Codes.

Scope and objectives

CHAPTER 3

3 Scope and Objectives

3.1 General scope & objectives for the PeBBu Programme

The overall objectives for the PeBBu network are:

- to stimulate and pro-actively facilitate the international dissemination and implementation of PBB – Performance-based Building – in building and construction practice, and in this context: to maximize the contribution to this by international R&D.

In this context the specific objectives for each of the nine PeBBu domains are:

- to programme and coordinate international R&D that falls within the domain's scope in order to ensure internationally accepted prioritizing, maximal stimulus of international collaboration and maximal compatibility of results of such R&D;
- to establish relationships with other international experts' or stakeholders' networks that have overlapping scope and objectives.

3.2 Scope & objectives specific for the Domain 'Design of Buildings'

The scope that has been chosen for the Domain is strongly related to the notion that the 'end user' of built facilities becomes more and more important in the building process. We feel that a strong incentive for performance-based design derives from this 'emancipation of the end user'. 'The' end user demands quality and value for money from his own perspective. During the last few years it has become more and more clear that it is an economic necessity for the building industry as a whole to act more consumer oriented and to pay more attention to meeting with the requirements of end users and other stakeholders. As a result and in the field of performance-based building, we see a certain shift from a primary focus on performance specifications for building parts to a mix of this 'hard' perspective and a more 'soft', holistic perspective of performance-based building. In the latter perspective the focus is e.g. on the management of functional user requirements and user involvement during the design process and beyond. Which is basically a shift from solving an internal problem of the building industry to solving the end users' problem.

Therefore, a major part of the work in the domain 'Design of Buildings' has been focused on the management of user requirements throughout the design process, resulting in:

- an overview of the state of the art of performance-based design;
- a description of best practices;
- recommendations for the implementation of the gained knowledge and insights in design education programs;
- a framework for further development (Domain 3 Research Agenda)

As a result of growing insight and e.g. ongoing discussions in the PeBBu Technical Committee, this objective has been elaborated into issues to be addresses in the Domain's work. PBD is of strategic importance for achieving the PeBBu objectives, especially because a building design stage determines to a large extend, intended or unintended, what the performance of the building in use will be. In this respect two aspects are of crucial importance in the design stage:

- making sure that the right users' performance requirements are considered;
- the prediction of the building performance on the basis of (preliminary) design results, in other words the assessment of the design. It is very important to have reliable assessment methods, because a design can relatively simply be adjusted when performance requirements are insufficiently met, a completed building cannot.

This leads to the following leading issues that are addressed in the Domain's work:

- the translation of client and user needs into assessable performance specifications (or: the matching of user needs and user requirements and performance specifications of built assets);
- classifications and formats for performance requirements and specifications;
- the management of client and user involvement in the design process;
- assessment methods for design results;
- structuring the design process.

These issues are elaborated into further detail in paragraph 3.3. The aim of the Domain 3 work is to clearly define the issues, give a comprehensive state-of-the-art overview and, from that, give recommendations for future research in these fields.

Originally, a second objective for Domain 3 was:

- the development of modules for programmes that aim for the education and training of design professionals, including the implementation of knowledge and tools.

Considering the state of the art of PBD (PBD is hardly put into practice as yet and practitioners seem to be hardly aware of the subject), it seems appropriate that the 'implementation of knowledge and tools' should be aimed primarily on enlarging the awareness of Performance Based design.

3.3 Elaboration of Domain 3 research issues

In the context of the PeBBu project, the Domain 3 'Design of Buildings' especially focuses on the problem of 'meeting with performance specifications' in the design stage of the building process. Those performance specifications can come from two sources: clients and legislation. The Domain 3 members feel that in this respect five issues are very important and need to be looked at more closely:

a) **The translation of client and user needs into assessable performance specifications (or: the matching of user requirements and performance specifications of built assets)**
Clients and future users don't usually communicate in performance requirements but in 'user language' that derives form their own field of work and/or their own perception of the environment. The translation of user requirements into performance requirements is a specialized job that requires specific skills.

b) **Classifications and formats for performance requirements and specifications**
Different governmental organizations, research institutes, building and real estate agencies and others use different formats and classifications for performance specifications in e.g. legislation, clients' briefs (statements of requirements), reports and publications. Already on a national level very often several classifications, formats and interpretation systems are used. This is confusing for clients and users, as

well as for the other partners in the building process (e.g. designers, contractors and suppliers). International alignment and standardization will be helpful in targeting clients issues from 'general to specific'. PeBBu may contribute to that..

c) The management of client and user involvement throughout the design process

It seems to be a world wide trend that clients and future users demand more involvement and influence in the building process as a whole and in the design process in particular. E.g. modern ICT provides them with the tools, like internet and virtual reality, that enable them to participate actively in the process. Moreover, it becomes more and more clear that it is an illusion to think that the design process can start with a complete and unchangeable client's brief. Also for the clients and users the design process is a voyage of discovery and they expect the designers to facilitate that voyage. The question is how to do that and at the same time improve the efficiency and manageability of the design process.

d) Assessment methods for design results

One of the main problems in performance-based design is how to predict the building's performance on the basis of a design. All over the world institutes and universities are in the process of developing methods and simulation applications to facilitate this. It is very appropriate and useful to make a state of the art inventory in the context of PeBBu and to develop a research agenda for the future in this field.

e) Structuring the design process

It is already stated in chapter 2 that PBD calls for integral design, with parallel and interrelated participation of all necessary design disciplines. This will have consequences for the way a design process is structured and organized. In this context (and in relation to issue d) it is also important to gain insight in which building performances can be assessed in which design stages and on the basis of which performance indicators.

Another aspect related to the performance-based approach could be the adjustment of the building design to the building techniques. It is impossible for architects and other building design disciplines to have sufficient knowledge of the wide range of building techniques that contractors may apply. As a consequence, in many cases building designs are not very well adjusted to the building techniques and methods that contractors who will eventually construct the buildings, are specialized in. Consequences may be inefficient building processes, increase of costs and decrease of quality delivered. The further development and application of PeBBu may provide the techniques to make a design consisting of a functional and architectural design and a set of performance requirements for the technical solutions. The contractors will then be able to choose and apply their own building techniques and methods, provided that they prove that these techniques and methods meet with the performance specifications.
This aspect however is not considered to be the most urgent focus point for Domain 3. First of all it is important for designers to learn to deal with a performance-based client's brief and to understand the concept of and the necessary attitudes and ways of working for PBD. Passing performance specifications through to contractors and suppliers will just be a following step. Already today we see hybrid tender documents in procurement processes, consisting partly of prescriptive specifications and partly of performance requirements on the level of building parts or subsystems. This is especially the case in relation to building service installations. It is to be expected that these tender documents will always remain hybrid to a certain extend (as clients' briefs will).

Explaining Performance Based Design

CHAPTER 4

4 Explaining Performance Based Design

4.1 Towards a definition

The CIB report 64 "Working with the Performance Approach in Building" (1982) contains the following overall definition of 'the Performance-based approach':

- *The Performance-based (PB) approach is the practice of thinking and working in terms of ends rather than means.*

Performance-based building, with which the PeBBu project is concerned, is the application of the Performance-based approach to building. This leads to the following definition:

- *The Performance-based building (PBB) approach is the practice of thinking and working in terms of ends rather than means, as applied to building and constructing.*

Performance-based building is concerned with orientating activities around the performance in-use of built environment products and services and extending this approach as far back along the supply chain as is appropriate. PBB is about what a building should do for the client, the users and other stakeholders. The building must facilitate the intended use. The design stage is very important in this context, because in this stage most decisions are made that will determine the performance of the building in-use. In order to be able to design a 'well performing building', that is a building that is well fit for the intended use, it is crucial for designers to understand what the user organisation wants to do in the building, what it's operations and processes are, or in other words: what the 'user requirements' are. But that is not enough. Designers also have to understand what properties the building should have to meet with the user requirements. When these required properties are expressed in solution independent, measurable terms, we talk about 'performance requirements'. This leads to the next definition:

- *Performance requirements in building express in measurable, solution independent terms the properties of a building, space or building part, that are required to facilitate the intended use.*

One user requirement may lead to several performance requirements. This is illustrated in table 1, where the organisations need to be able to have meetings with 25 people, is translated into performance requirements for the facility.

User requirement	**Performance requirements**
Have meetings with max. 25 people in different settings (theater and round table)	– Required space: 3 m2 per person – Space shape: ratio length : width ≤ 1,5 : 1 – Ventilation: min. 30 m^3 fresh air per person and per hour – Air temperature: 19° C < t < 21° C – Back ground noise (due to external sources): max. 35 dB(A) – Reverberation time: 0,8 – 1,0 sec – Lighting level on desktop level: min. 500 lux

Table 1: One user requirement may lead to several performance requirements

Table I also illustrates an important difference between user requirements and performance requirements. User requirements are in language that a user understands very well, because it tells something about how the user organisation want to operate. In fact the user organization is the only participant in a building project that can formulate these kinds of user requirements. Performance requirements on the other hand, are in a language that does not mean anything to the average user. It is specialist language; the translation of user requirements into performance requirements is specialist work, that has to be done by e.g. architects and/or consulting engineers.

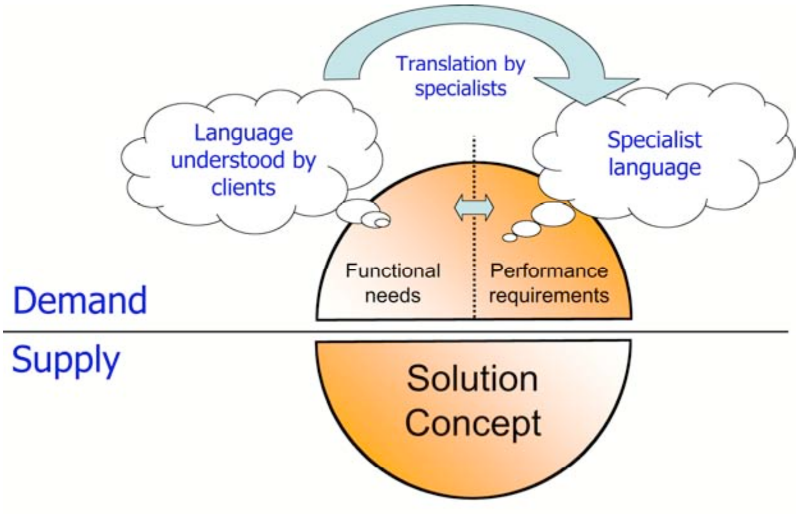

Figure 5: Formulating performance requirements is specialist work

Table I shows that performance requirements describe the required quality levels for different aspects of the building in-use, without suggesting any solutions. This leaves the design and engineering process open for creative, innovative solutions. To make sure that these solutions do meet with the performance requirements, they have to be assessed. This is done on the basis of 'performance indicators' (PI's) or performance specifications. These specifications can be deduced from the proposed design solutions (by measurement, calculation or simulation).

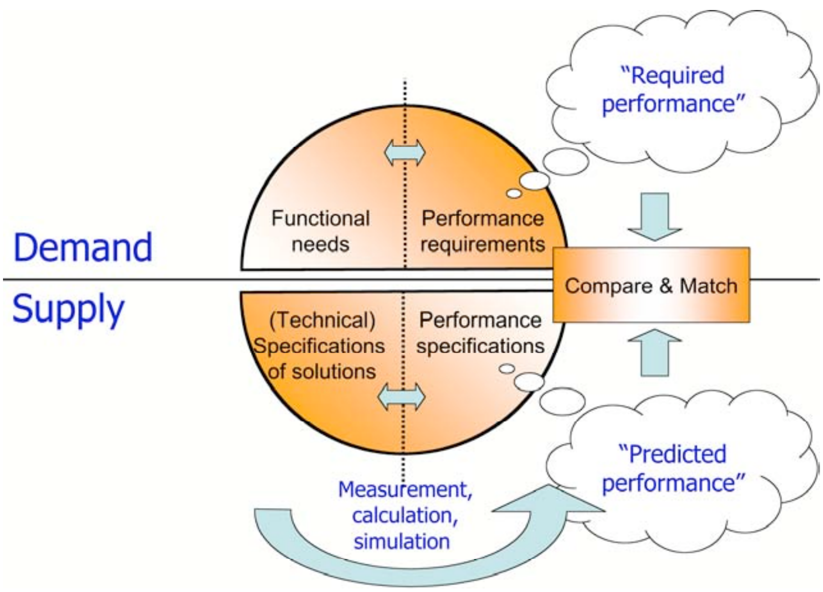

Figure 6: Translation of solutions into performance specifications by measuring, calculation and/or simulation

A distinction is made between 'performance requirements' and 'performance specifications':

- performance requirements represent the demand side: they describe the quality (performance in-use) that is required by stakeholders (owners, future users and others) and legislation;
- performance specifications represent the supply side: they specify the (expected) performance of specific design solutions and/or built assets.

Following these principles a Performance-based design (PBD) can be defined as follows:

- *A Performance-based design is a building design that is based on a set of dedicated performance requirements related to the intended use of the building, and that can be evaluated on the basis of performance specifications.*

However, Domain 3 'Design of Buildings' is not only about the result of a design process, but also and primarily about that process itself. A Performance-based design process can be defined as follows:

- *A Performance-based design process is a process in which performance requirements are translated and integrated into a building design.*

4.2 PBD calls for integral design

The essential role of Domain 3 is about the integration of knowledge and systems from other PeBBu Domains in the context of real building designs. The building design is where it all comes together. Designers have to deal with systematic interrelations between different performance specifications, which often relate to different fields of expertise (as illustrated in table 1). Thus, the performance-based approach calls for integral design, with parallel, interrelated contributions from all design disciplines involved.

The performance of a building or a building part is always the result of the interaction between different solutions for different subsystems, like the architectural system, the structural system, the climate system and so on. This is depicted in figure 7.

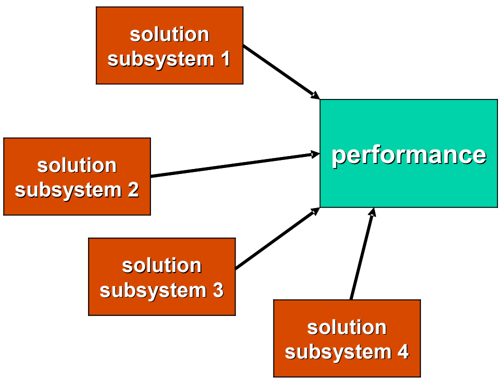

Figure 7: 'Performance' as the result of different solutions for different subsystems

In practice, the end user is not really interested in the performances of different subsystems; he experiences the performance of a built facility as a whole. The design disciplines will have to co-operate closely to create an integrated facility design. In some aspects also the expertise of the contractor and specialized subcontractors will be needed to get optimal performance (figure 8).

As the Performance-based approach is the practice of thinking and working in terms of ends rather than means, it provides for openness to the infill of the design process. It provides suppliers (both designers and contractors) with the opportunity to come up with creative solutions. Therefore, in principle all requirements should be performance-based and measurable. Requirements and solutions (prescriptive specifications) should be mixed up as little as possible, as solutions will essentially always be compromises.

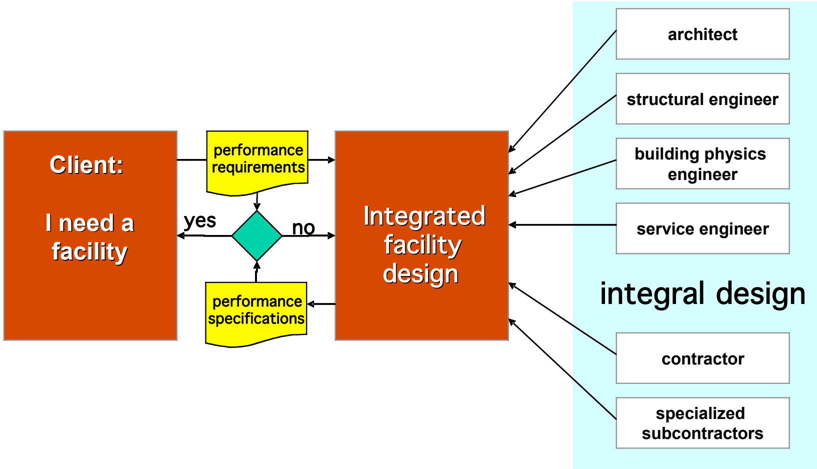

Figure 8: PBD calls for integral design

4.3 In practice: not 100% Performance-based

However, some essential aspects of design, such as architectural and cultural value, cannot be expressed in 'hard' measurable performance requirements. Nevertheless these aspects may be quite an important component in a stakeholder's general appreciation of a built asset. This means that also in a performance-based design process, these aspects should be fully taken into account. Also a client should be free to choose a specific solution or product, if he really wants that. In other words: in practice it will be unwise to be too fundamental in following a performance-based design approach; a design process will always be hybrid to some extend. This is also (more or less) illustrated in a diagram by professor Graham Winch of UMIST (figures 9 to 11). Figure 9 represents the building process from inception to completion. In the beginning no information about the end result is available; there is much uncertainty about the end result. At completion all information is available and there is complete certainty about the end result. The dotted line represents the growth of the amount of information in an 'average' building process. In the area above the line there is uncertainty, in the area underneath there is certainty about the end result.

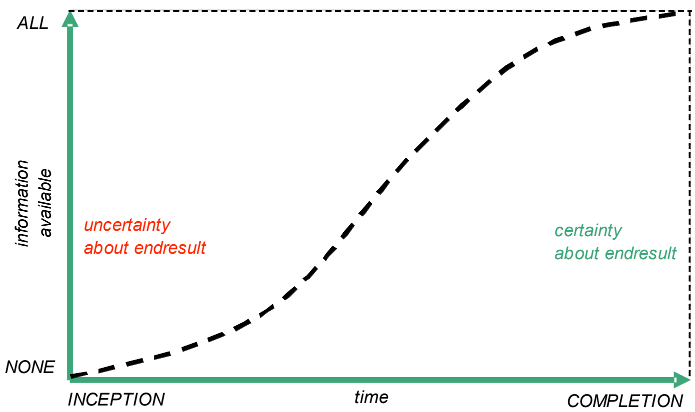

Figure 9: information development in the building process

On the one hand clients may gain earlier certainty by giving a brief in terms of prescriptive requirements (figure 10). On the other hand, by doing so, there is a fair chance that they 'jump to conclusions' too early and cut off unexpected and innovative solutions. They don't make optimum use of the creativity and expertise of the supply side.

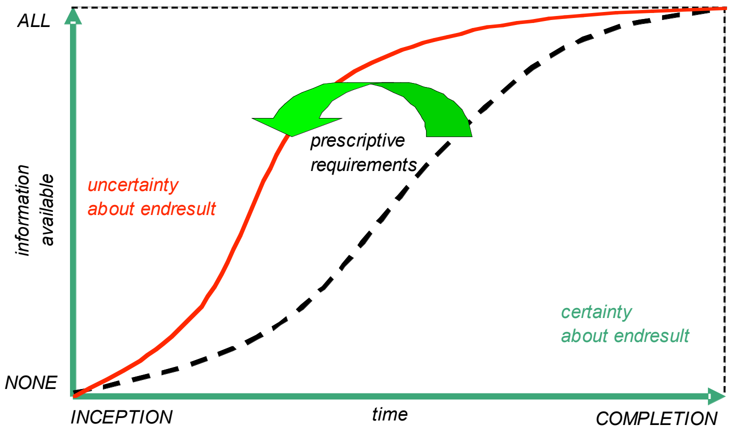

Figure 10: the effect of prescriptive requirements

By giving a performance based brief, clients may on the one hand postpone certainty about the end result it's true, but on the other hand keep the design process open for change and growing insight (figure 11). Performance specifications offer the opportunity to postpone the decision for detailed prescriptive specifications. They give clients the opportunity to 'grow' into the project, allowing them to think better about what their real needs ('the question behind the question') and allowing designers and suppliers to come up with the best solutions.

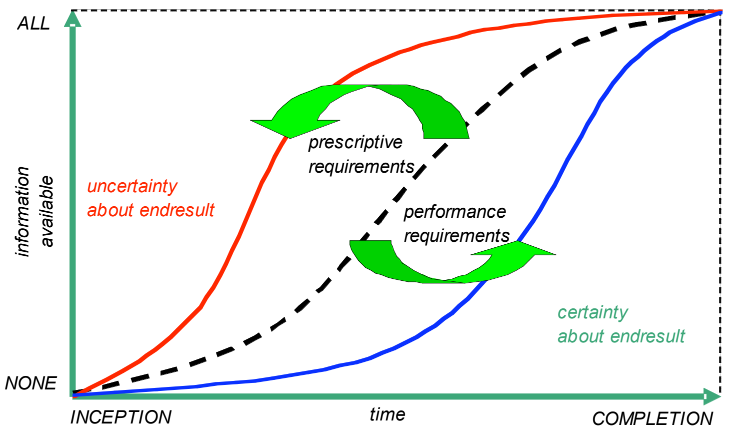

Figure 11 effect of performance requirements

At some time in a project performance requirements need to be translated into prescriptive solutions; on a project level you need both. For some aspects the translation may be done by the client or the architect, for other aspects it may be done by the one that is instructing the carpenter. This may differ per project or even per subsystem in a project. Moreover, PBD does not end with the completion of the building, as only in the in-use stage of a building it becomes apparent in how far the real client and user needs are fulfilled.

State of the Art of Performance Based Design

CHAPTER 5

5 State of the Art of Performance Based Design

5.1 Performance based Design in general

The inventory of the state of the art in Domain 3 shows that PDB is mainly an issue in research and education. Design professionals (architects and engineers) are generally not very aware of PBD. In this respect a distinction should be made between two different approaches to PDB:

1. designers and engineers have to meet with performance based client briefs and building regulations;
2. 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.

The first approach can be recognised in most building projects in countries that apply performance based building regulations. Applicants for building permits have to prove that the designs comply with the regulations, so every design professional is involved in PDB to some extend, consciously or unconsciously. Performance based building regulations and codes often include performance requirements for safety (structural safety, fire safety, earth quake resistance and so on), health, serviceability, energy efficiency and environmental impact.

The second approach is closely related to performance based procurement. Up to now, this approach has only been put into practice on a relatively small scale, mainly in the same northern countries. Mostly, government building agencies take the lead; they organize pilot projects and/or experiments to set an example for innovation of the building process. The general idea is that the 'demand side' of the building process defines a functional design and a set or performance requirements, allowing the supply side to choose the most suitable technical solutions matching these requirements, availability and cost. This second approach to PBD has hardly been put into practice in non governmental projects as yet. One of the barriers is that clients, apart from a few very professional clients, do not trust this kind of procurement, that they experience as rather abstract and intangible and therefore too unsure and risky. They often prefer to be able to control the whole design and building process.
Another drawback is the reluctance or even the opposition of design professionals. Many of them consider PDB as a further degradation of their positions and interests in the building process. In general engineers and technical designers are more used to working with performance requirements than architects. The main design areas where performance based design and procurement is applied, are service engineering (acoustics, lighting conditions, indoor climate, air quality, and so on), energy consumption and maintenance.

5.2 Translation of client and user needs into assessable performance specifications

Interesting methods for the matching of user needs and performance requirements and/or specifications are found in e.g. the Netherlands, Canada and Finland. The Dutch Government Building Agency (GBA) e.g. is developing a computer aided interview technique for (future) users of office buildings. The questions that users have to answer, are formulated in 'user language'. To give an example: users are not asked what the air refreshment rate per hour should be in a certain area, but they are asked to give any reasons why the ventilation of a room should deviate from the standard value of 'good ventilation'. Dependent on the combination of answers that are given to predefined questions ('question tree'), the computer generates a set of specialist performance requirements. It is more or less an 'expert system', based on fifteen years of experience with the performance-based briefing and procurement and assessment of design solutions. Figure 12 shows the 'top of the question tree', where potential users are asked to indicate the relative importance of different performance or quality issues. In a brief a lot of performance requirements will be described. Some requirements are very general, while others are very detailed. Through this sheet future users are asked to indicate how important they consider different performance issues to be for their organization and processes. When "standard" is filled in, a standard performance level is sufficient and the system will automatically generate a corresponding set of performance requirements. When "medium" or "high" is filled in, extra attention must be paid to the subjects concerned. This is done in follow-up sheets. In this way, the performance-based brief is built up and detailed gradually, without bothering the user with difficult specialist 'performance language' too much.

User needs	Importance		
Functionality	**Standard**	**Medium**	**High**
Space requirements building	○	○	◉
Flexibility / adaptability building and building lay out	○	○	◉
Relations / logistics	○	○	◉
Communication and telematics	○	○	◉
Comfort	**Standard**	**Medium**	**High**
Thermal comfort	○	◉	○
Air quality	○	◉	○
Acoustical comfort	○	◉	○
Visual comfort	○	◉	○
Hygiene	○	◉	○
Security / Safety	**Standard**	**Medium**	**High**
Safety with calamaties	◉	○	○
Occupants' safety	◉	○	○
Social safety	◉	○	○
Operational reliability	◉	○	○
Anti burglary safety	◉	○	○
Safety as regards to harmful influences	◉	○	○
Architecture	**Standard**	**Medium**	**High**
Town planning	○	○	◉
Architecture	○	○	◉
Interior	○	○	◉
Environment	**Standard**	**Medium**	**High**
Sustainability	○	○	◉
Energy consumption	○	○	◉
Materials	○	○	◉
Waste	○	○	◉
Soil pollution	○	○	◉
Water consumption	○	○	◉
Air pollution	○	○	◉
Internal constraints	**Standard**	**Medium**	**High**
Investment costs	○	○	◉
Operational costs	○	○	◉
Planning / delivery time	○	○	◉

Figure 12: sample sheet from a briefing system by
the Dutch Government Building Agency (in development)

In Canada, the International Centre for Facilities (ICF) developed the 'ST&M-approach' ('Serviceability Tools & Methods'). The method comprises a set of standard tools for measuring in broad terms what is needed and what is provided; it compares what functionality the occupant groups require and how well assets support those needs. Scales are used, giving a range of standard levels, so that stakeholders can choose how much of each topic is needed. For every topic there are two scales. The first is a functionality requirement scale giving levels of functionality from 0 to 9 (demand). The second is a serviceability scale for assets, also ranging from 0 to 9 (supply). Each couple of scales is calibrated. There are scales for some 200 topics. This is probably the most elaborated and easy to use example of how performance specifications (of design solutions offered) can be matched with user requirements (and the other way around). The ST&M approach was standardized by ASTM and in 1996 became a set of American National Standards and is presently an ISO Committee Draft as well (reference number: ISO/TC59/SC3N474).

The principle of the ST&M-method is shown in figure 13.

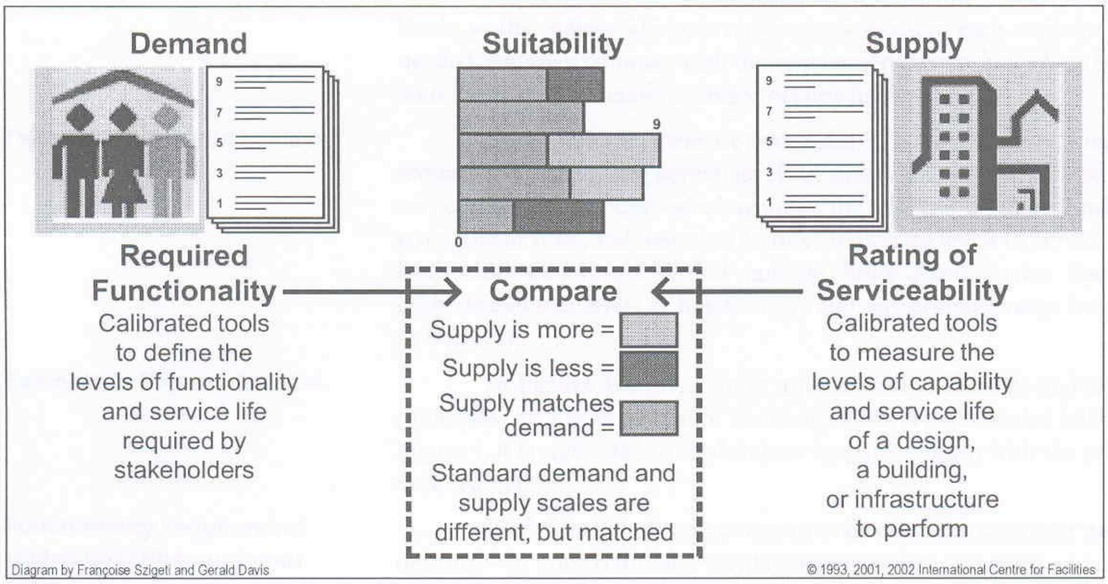

Figure 13: The core elements of the ST&M approach

In many countries client briefs are usually solution oriented. They often contain technical and space solutions, that belong to the domain of the building industry. These are hard for clients and end users to understand, because they are not involved in that domain. Research by VTT in Finland shows that performance based briefs turn out to be easier for the end users to understand, because they appeal more to the end users' own domains and processes. Moreover, performance based requirements in briefs give designers possibilities to fully exploit their knowledge accomplishing creative and flexible solutions.

Probably one of the best examples of the performance-based approach is represented by the 'European Concept for Accessibility' (European Center for Accessibility, 1996, website: www.eca.lu). The concept serves as a reference work for the harmonisation of the concept of accessibility in Europe and provides a basic foundation for a European standard of accessibility. With this in mind, the document can also be used as a reference for the development or revision of nationally oriented manuals and design directives. Therefore, the document is primarily intended for policy-makers and legislators and internationally and nationally oriented consumer organisations that wish to represent their interests in a European perspective. The author is professor Maarten Wijk, architect/researcher from the Netherlands, with the support of some 40 experts in the field of accessibility from various European countries.
Usually, accessibility provisions in buildings are associated with disabled persons and are very often treated as add-ons to the 'normal' building (design). This often stigmatizes people with disabilities. Moreover,

provisions are often aimed at certain categories of disabled (e.g. wheelchair users), not taking other categories into account. The 'European Concept for Accessibility' provides the principles and criteria for 'universal design'; it contains performance requirements to make the built environment accessible for all people in a natural and independent way, regardless of size, age, circumstances, abilities or disabilities. As such, the concept is fully performance-based[1].

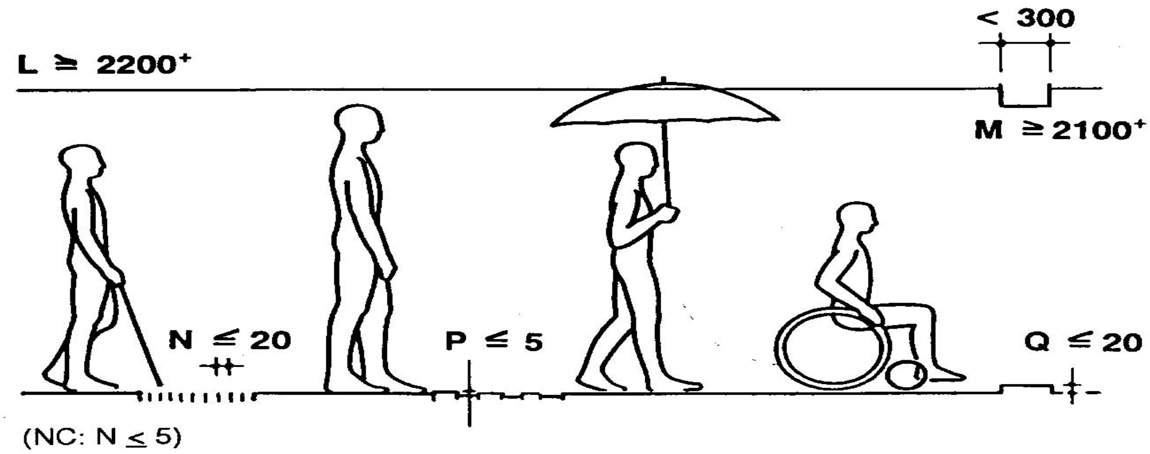

Figure 14: illustration of some performance requirements from the 'European Concept for Accessibility'

5.3 Classifications and formats for performance specifications

A survey of material from only a few countries already shows a wide variety of 'classifications' that are used for arranging performance specifications in briefing methods. Even on a national level (and sometimes even within one client organisation) we encounter several different classification methods.
Figure 15 shows the Finnish building property classification as used in the EcoProp system.

K CONFORMITY	A PERFORMANCE	B COST AND ENVIRONMENTAL PROPERTIES	C BUILDING PROCESS
K1 LOCATION K1 Site characteristics K2 Transportation K3 Services K4 Impact on immediate surroundings **K2 SPACES** **K3 SERVICES**	**A1 INDOOR CONDITIONS** A1.1 Indoor climate A1.2 Acoustics A1.3 Illumination **A2 SERVICE LIFE** A2.1 Service life A2.2 Deterioration risks **A3 ADAPTABILITY** A3.1 Adaptability in design and use A3.2 Space systems and pathways	**B1 LIFE CYCLE COSTS** B1.1 Investment costs B1.2 Service costs B1.3 Maintenance costs B1.4 Disposal and value	**C1 Design** **C2 Site operations** **D OPERATION** **D1 Usability** **D2 Maintainablity**

[1] The 'European Concept for Accessibility' is presently being revised by another author. Unfortunately is lookes like if the performance-based approach is not maintained as consistently as in the 1996 edition.

K CONFORMITY	A PERFORMANCE	B COST AND ENVIRONMENTAL PROPERTIES	C BUILDING PROCESS
	A4 SAFETY A4.1 Structural safety A4.2 Fire safety A4.3 Safety in use A4.4 Intrusion safety A4.5 Natural catastrophes **A5 COMFORT** **A6 ACCESSIBILITY** **A7 USABILITY**	**B2 ENVIRONMEN-TAL PRESSURE** B2.1 Land use B2.2 Embodied environ-mental pressure B2.3 Recycling B2.4 Environmental pressure from use of building B2.5 Environmental pressure because of users	

Figure 15: VTT EcoProp Building property classification

This resembles, but is not quite the same as the classification that is used in the Dutch publication 'The materials for the clients' brief', issued by the Dutch Building Research Institute (SBR), which is shown in figure 16.

Location	Performance	Building Identity	Internal Constraints	External Constraints
• Accessibility • Facilities and services • Social and cultural identity • Constraints	**USE** • Net floor space • Interrelations (between spaces) • Accessibility • Usability • Adaptability **INDOOR CONDITIONS** • Indoor climate • Air quality • Acoustical comfort • Vibrations • Visual comfort • Hygiene **SAFETY** • Safety in use • Safety in operation • Social safety • Resistance to natural catastrophes	**EXTERIOR** • Cultural value • Representative ness • Perception value **INTERIOR** • Cultural value • Representative ness • Perception value	**COSTS** • Investment costs • Operation costs • Maintenance costs **ENVIRONMENT** • Energy consumption • Water consumption • Materials consump-tion (natural resources) • Nature **SITE OPERATIONS** • Planning, date of delivery • Labour conditions	**LEGISLATION** • General legislation • Sectoral legislation • Local legislation **STAKEHOLDERS** • Stakeholder (management) **FINANCIAL** • Subsidies • Taxes • Insurance **TIME ASPECTS** • Terms for acquiring official permits • EC guidelines • Appeal procedures

Figure 16: classification used in SBR publication "The materials for the clients' brief"

There are more examples like this.

A completely different classification is used in the Canadian ST&M approach, as shown in Figure 17, stemming from the ASTM Standard on Whole Building Functionality and Serviceability (second edition, Davis & Szigeti, 2000).

A. GROUP AND INDIVIDUAL EFFECTIVENESS

A.1 Support for Office Work (E 1660)
A.1.1 Photocopying and office printers
A.1.2 Training rooms, general
A.1.3 Training rooms for computer skills
A.1.4 Interview rooms
A.1.5 Storage and floor loading
A.1.6 Shipping and receiving

A.2 Meetings and Group Effectiveness (E1661)
A.2.1 Meeting and conference rooms
A.2.2 Informal meetings and interaction
A.2.3 Group layout and territory
A.2.4 Group workrooms

A.3 Sound and Visual Environment (E1662)
A.3.1 Privacy and speech intelligibility
A.3.2 Distraction and disturbance
A.3.3 Vibration
A.3.4 Lighting and glare
A.3.5 Adjustment of lighting by occupants
A.3.6 Distant and outside views

A.4 Thermal Environment and Indoor Air
A.4.1 Temperature and humidity
A.4.2 Indoor air quality
A.4.3 Ventilation air (supply)
A.4.4 Local adjustment by occupants
A.4.5 Ventilation with openable windows

A.5 Typical Office Information Technology (E1663)
A.5.1 Office computers and related equipment
A.5.2 Power at workplace
A.5.3 Building power
A.5.4 Telecommunications core
A.5.5 Cable plant
A.5.6 Cooling

A.6 Change and Churn by Occupants (E1692)
A.6.1 Disruption due to physical change
A.6.2 Illumination, HVAC and sprinklers
A.6.3 Minor changes to layout
A.6.4 Partition wall relocations
A.6.5 Lead time for facilities group

A.7 Layout and Building Features (E1664)
A.7.1 Influence of HVAC on layout
A.7.2 Influence of sound and visual features on layout
A.7.3 Influence of building loss features on space needs

A.8 Protection of Occupant Assets (E 1693)
A.8.1 Control of access from building public zone to occupant reception zone
A.8.2 Interior zones of security
A.8.3 Vaults and secure rooms
A.8.4 Security of cleaning service systems
A.8.5 Security of maintenance service systems
A.8.6 Security of renovations outside active hours
A.8.7 Systems for secure garbage
A.8.8 Security of key and card control systems

A.9 Facility Protection (E 1665)
A.9.1 Protection around building
A.9.2 Protection from unauthorized access to site and parking
A.9.3 Protective surveillance of site
A.9.4 Perimeter of building
A.9.5 Public zone of building
A.9.6 Facility protection services

A.10 Work Outside Normal Hours or Conditions (E 1666)
A.10.1 Operation outside normal hours
A.10.2 Support after-hours
A.10.3 Temporary loss of external services
A.10.4 Continuity of work (during breakdowns)

A.11 Image to Public and Occupants (E 1667)
A.11.1 Exterior appearance
A.11.2 Public lobby of building
A.11.3 Public spaces within building
A.11.4 Appearance and spaciousness of office spaces
A.11.5 Finishes and materials in office spaces
A.11.6 Identity outside building
A.11.7 Neighborhood and site
A.11.8 Historic significance

A.12 Amenities to Attract and Retain Staff (E 1668)
A.12.1 Food
A.12.2 Shops
A.12.3 Day care
A.12.4 Exercise room
A.12.5 Bicycle racks for staff
A.12.6 Seating away from work areas

A.13 Special Facilities and Technologies (E 1694)
A.13.1 Group or shared conference centre
A.13.2 Video teleconference facilities
A.13.3 Simultaneous translation
A.13.4 Satellite and microwave links
A.13.5 Mainframe computer centre
A.13.6 Telecommunications centre

A.14 Location, Access and Wayfinding (E 1669)
A.14.1 Public transportation (urban sites)
A.14.2 Staff visits to other offices
A.14.3 Vehicular entry and parking
A.14.4 Wayfinding to building and lobby
A.14.5 Capacity of internal movement systems
A.14.6 Public circulation and wayfinding in building

B. THE PROPERTY AND ITS MANAGEMENT

B.1 Structure, Envelope and Grounds (E 1700)
B.1.1 Typical office floors
B.1.2 External walls and projections
B.1.3 External windows and doors
B.1.4 Roof
B.1.5 Basement
B.1.6 Grounds

B.2 Manageability (E 1701)
B.2.1 Reliability of external supply
B.2.2 Anticipated remaining service life
B.2.3 Ease of operation
B.2.4 Ease of maintenance
B.2.5 Ease of cleaning
B.2.6 Janitors' facilities
B.2.7 Energy consumption
B.2.8 Energy management and controls

B.3 Management of Operations and Maintenance (E 1670)
B.3.1 Strategy and program for operations and maintenance
B.3.2 Competences of in-house staff
B.3.3 Occupant satisfaction
B.3.4 Information on unit costs and consumption

B.4 Cleanliness (E 1671)
B.4.1 Exterior and public areas
B.4.2 Office areas (interior)
B.4.3 Toilets and washrooms
B.4.4 Special cleaning
B.4.5 Waste disposal for building

Figure 17: Topics of the Serviceablity Scales (ST&M approach, ICF, Canada)

5.4 The management of client and user involvement throughout the design process

As this is quite a new topic, there is little information available about the state of the art in this field. The best examples probably come from project developers who open project websites, which allow future users to follow the development process online. Some developers offer future users the opportunity to give input and choose from options during the development process by means of these project websites. These project developers experience that, when they offer these opportunities (and end users more and more will demand them), they have to make the processes very transparent. Not only for the clients, but certainly also for themselves and their project partners. It has to be very clear for all parties involved until which moments which decisions (e.g. of end users) may be postponed, in order to prevent frustration of the process and extra costs. Several market parties in Western European countries struggle with this. In general we may conclude that the building industry is not a very user oriented industry as yet.

In several countries we see large scale programmes aimed at structural changes in the building industry. Examples are 'Rethinking Construction' in the UK, 'Process and Systems Innovation in the Building Sector' (PSIB) in the Netherlands, the 'SARA' programme in Finland and 'Project Hus' in Denmark. One of the common goals of these programmes is to change construction into a more consumer oriented industry, where incentives for change and innovation should come from clients. Further development of the performance concept can strongly contribute to that goal, as this concept is user oriented by nature. The management of user involvement throughout the process is one of the aspects that needs to be developed further.

Already in 1992 the Dutch Building Research Institute (SBR) issued a report about a new system of briefing that allows clients to develop the brief in interaction with the design. This should be done in a controlled process, in which briefing and designing are, though parallel, separate processes. According to this system, after each formally concluded design stage the brief should be updated and further completed with the information that is necessary for decision making in the next design stage. This process is depicted in figure 18 ('ass.' means assessment).

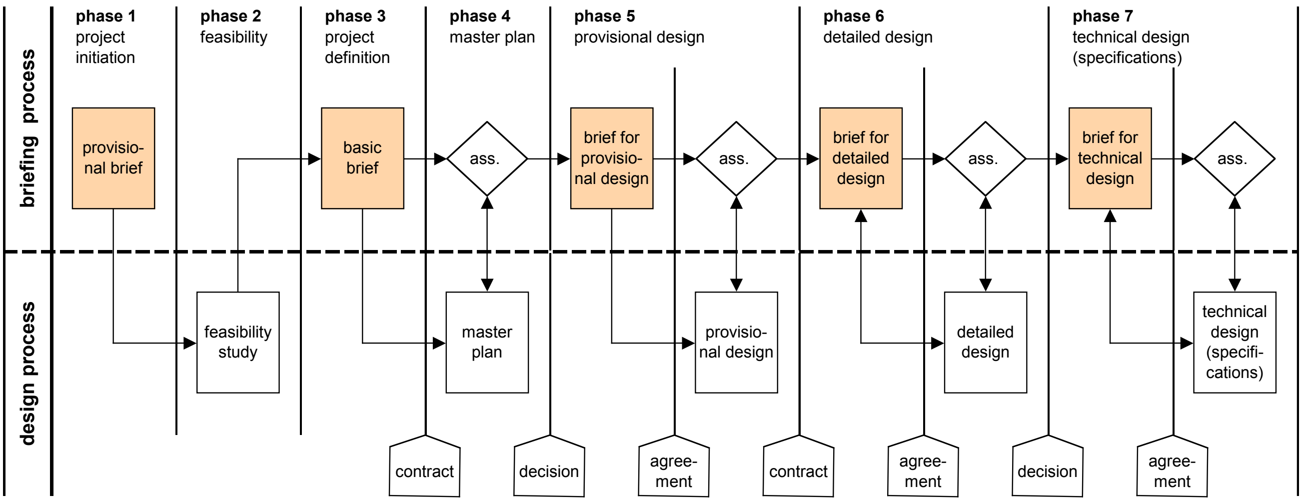

Figure 18: overlapping of the briefing process and the design process (source: SBR publication nr. 258, Rotterdam, 1992)

This principle is taken over by the Royal Institute of Dutch Architects (BNA) and the Dutch Association of consulting Engineers (ONRI), who will issue a common ‘Standard Task Description’ (STD) for designing buildings in 2004. This STD is basically a breakdown of the design process into interrelated tasks per phase for all disciplines involved (commissioning, architecture, building physics, interior design, structural engineering, service engineering, landscape design, projectmanagement). In this system, that will be the basis in the Netherlands for contracts between clients on the one side and architects and consulting engineers on the other, each new design phase starts with an evaluation, update and further elaboration of the brief.

In the **UK** Barrett and Stanley also make a plea for empowering the client and developing the brief in interaction with the design in their book “Better Construction Briefing” (2001). Based on research findings, the authors present a briefing method that – among other issues – include these two starting points. It is the result of a three years’ research project that started in 1997. The method was tested in several pilot projects. Best practices and recommendations deriving from these pilot project, are described in the book. The authors conclude that the briefing method may improve the clients’ position and the process and product quality considerably, but that it will be a hard job making it common practice.

5.5 Assessment methods for design results

Too often also important basic (performance-based) requirements are not met in the final product. There are various reasons for this, e.g. cutting costs in some phase of the project, inability to find suitable design solutions to fulfil the requirements, ‘forgetting’ the original requirements due to several translations and modifications in the course of the design process (‘growing insight’ that obscures the original objectives and demands), and so on. To avoid this, an early and continuous verification has to take place in the design process (Ang et. al, 1999, Becker 1999). The user has to be sure that the desired performance targets will be fulfilled. And if this is not possible, the user has to know this on beforehand. This is already shown in figure 18, but also in figure 19 (Wyatt and Ang, CIB 2000).

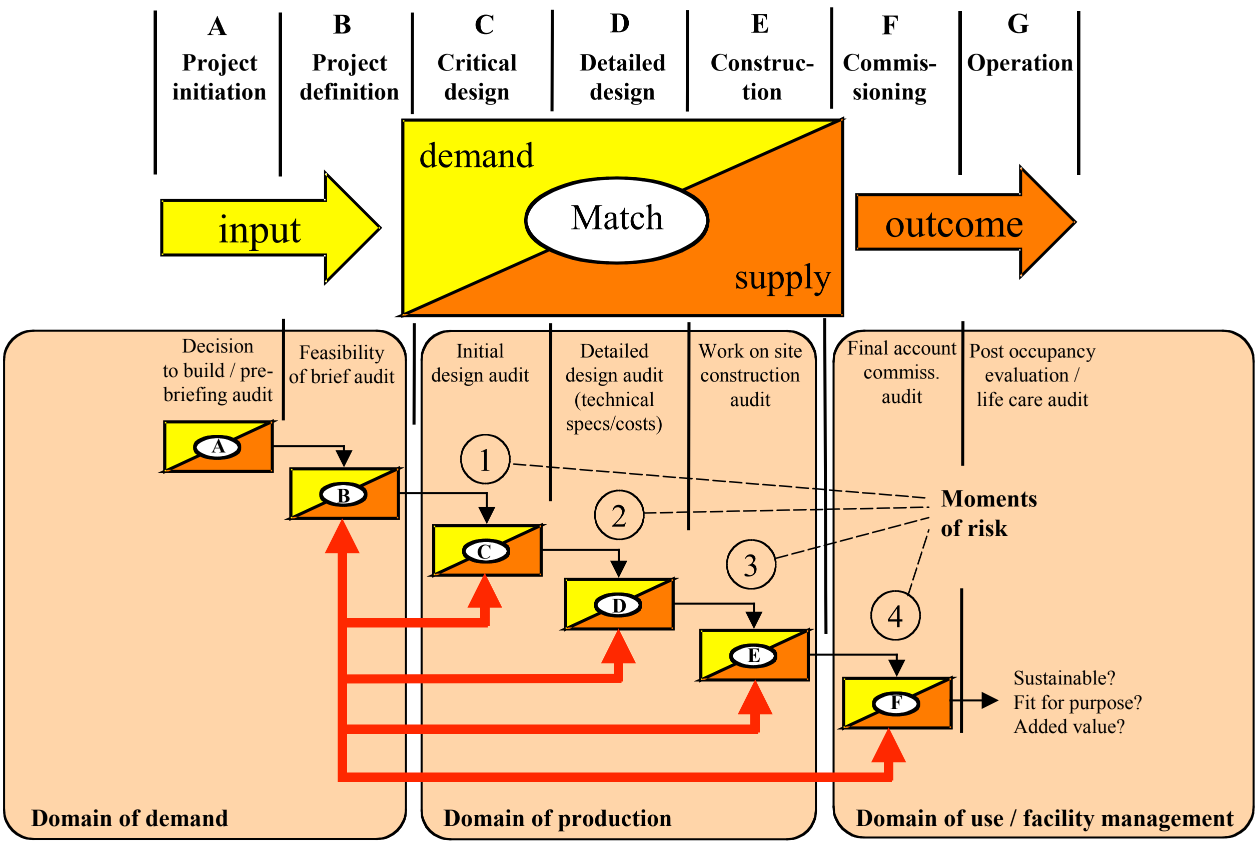

Figure 19: Project assessment loop in the case of performance based procurement
(Wyatt and Ang, CIB 2000)

The diagram in figure 19 was developed in the context of performance-based procurement and is based on the experience of the Dutch Government Building Agency with this type of procurement [2]. This experience taught that – from the client's point of view – there is too much risk for non-conformity when interim results of the design & build process are not assessed properly, also (or rather: especially) after signing the contract with a project supplier.

Assessment methods may vary from simple measuring (e.g. the amount of net square meters offered) via standardized calculating (e.g. the strength and stability of building structures or the energy loss) to simulating certain aspects of the behaviour of the building in-use (e.g. daylight penetration in different seasons and under different weather conditions). In some EU member states national building regulations are more and more performance-based. One of the examples is the Dutch National Building Decree, laying out the technical requirements for all building works, which is completely performance-based. The Dutch National Building Decree often refers to national standards, where not only performance levels for building parts and properties but also the corresponding assessment methods are defined. This often concerns the 'hard', elemental properties and performances of building parts and certain aspects of the total building performance. Aspects for which standardized calculation methods are available.

Also European regulations, that have to be implemented in the national building regulations of all EU member states, are as a rule performance-based. Very well known of course is the Construction Products Directive (CPD). European building regulations as a rule refer to European standards, in which both performance levels and assessment methods are defined.

A recent overview of the State of the Art of the assessment of building performance is given in the book "Assessing Building Performance" edited by Wolfgang F.E. Preiser and Jacqueline C. Vischer (2005).

Assessment methods in European and national standard are mostly aimed at the testing of actual buildings or building products. However, one of the main problems in performance-based design is how to predict the performance of a building on the basis of a design. For many quality aspects the 'total building performance' depends on a complex interaction of many influences. On the one hand there are no validated, standardized assessment methods available to predict the total building performance, but on the other hand this performance will determine the client's perception of the quality delivered to a great extend. The only way to do it is by simulation of the building behaviour, using integrated data models. All over the world institutes and universities are in the process of developing simulation applications to facilitate this. An example of such a development is the <Virtual Environment>. The <Virtual Environment> software uses one integrated data model to carry out a range of analyses, which includes energy performance, value engineering, life cycle analysis, thermal analysis, cost planning, airflow analysis, lighting and occupant safety. The software system is capable of assessing many aspects of building performance, allowing the design team to 'test drive' the building. It is developed by Integrated Environmental Solutions Ltd (IES). IES specialises in advanced computer technology to assist with the design and operation of buildings. Established in 1994 in UK, it is a rapidly expanding company that offers an integrated software system known as the <Virtual Environment>. It consists of a range of software products that enable architects, consulting engineers and developers to evaluate the performance of a building at any stage during the design process. With this software it is possible to evaluate performance of a building throughout the design process:

- Predict comfort conditions
- Examine the visual impact
- Satisfy safety standards

[2] 'Performance-based procurement' is defined here as procurement on the bases of a performance-based brief (e.g. Design & Build) or on the basis of a functional and aesthetic design plus a set of performance requirements. In principle the procurement can take place after the stages B, C or D in diagram 11.

- Design services quickly and accurately
- Optimise energy efficiency
- Control cost

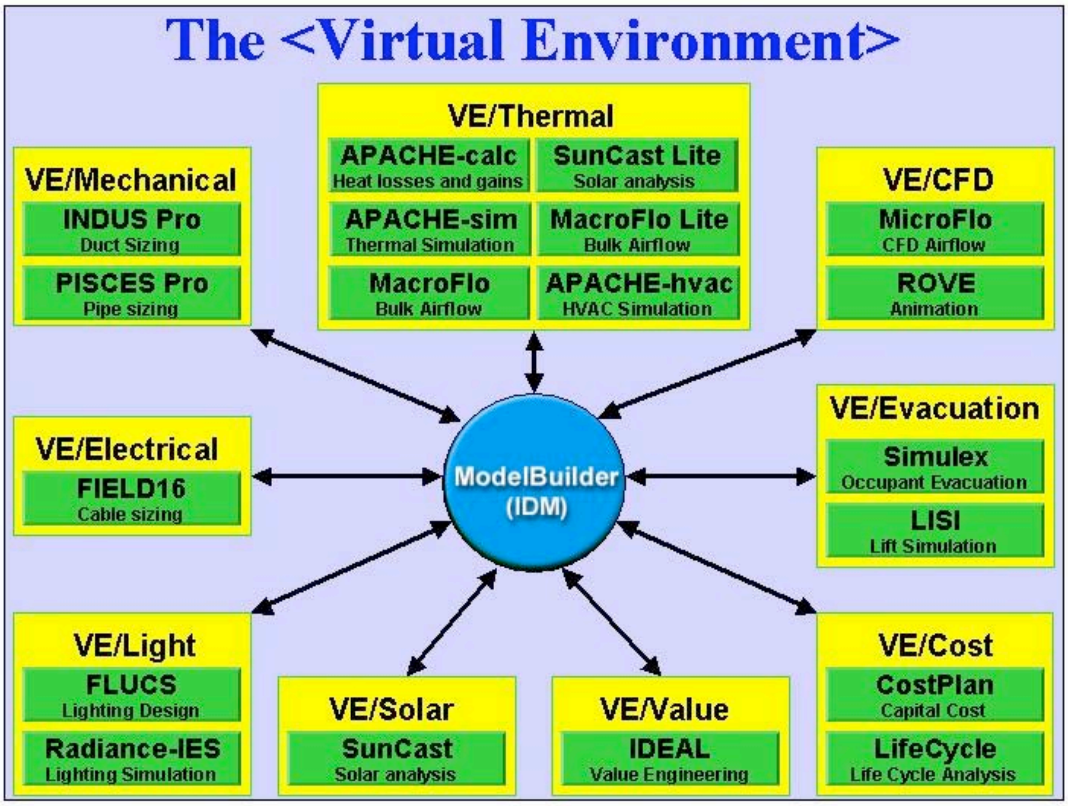

Figure 20: a summary of the products within <Virtual Environment>

The IES <Virtual Environment> consists of integrated software in ten product groups as follows (figure 20):

- VE/ModelBuilder: software capable of creating and modifying the Integrated Data Model from initial concept or by using CAD data.
- VE/Thermal: software for the thermal analysis of a building from heat loss and gains, to thermal simulation and HVAC plant and controls.
- VE/Solar: software to investigate solar shading and insolation as produced by the building and site obstructions.
- VE/Light: software to simulate and design natural and electric lighting systems.
- VE/Value: software to enable Value Engineering analyses to be performed at any stage of the building life cycle/design process.
- VE/Cost: software to perform capital cost and life cycle cost analysis.
- VE/Mechanical: duct and pipe sizing and drafting software.
- VE/Electrical: electrical cable sizing software.
- VE/Evacuation: occupant evacuation and lift simulation software.
- VE/CFD: software to simulate 3D internal and external air flow using computational fluid dynamics techniques.

The <Virtual Environment> software is built around the concept of a single Integrated Data Model (figure 21). Most of the applications use the single building model as much as possible. More information can be found at following website: http://www.ies4d.com/

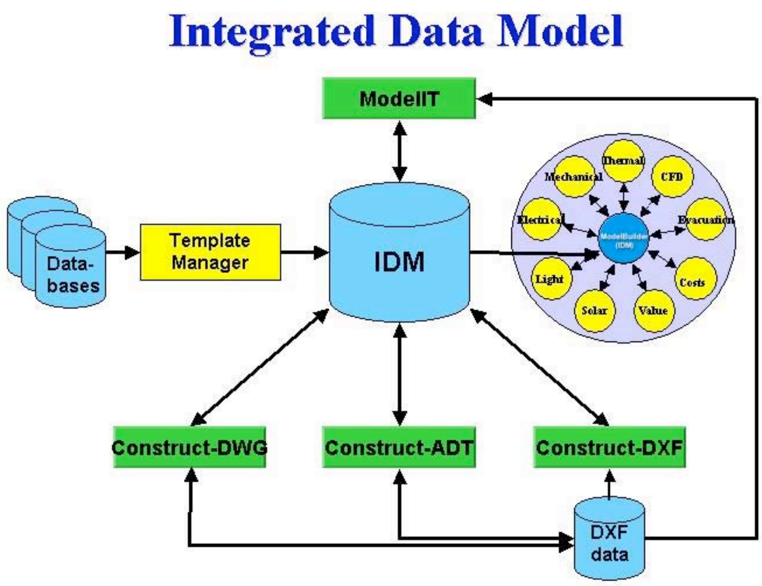

Figure 21: representation of <Virtual Environment> software built around Integrated Data Model

This is just an example; more software companies like IES develop integrated software products similar to <Virtual Environment> or have those products already available. The technology is available, the IES software proves that adequately. The problem is that all these integrated software systems are so called 'closed systems'. As a rule it is not possible to exchange data between different systems.
That means that it will only work, when all participants in a design project use applications of the same integrated software system. In practice however, the participants in a project use different software applications stemming from different sources. Often an important part of their internal operations is based on the software they use. Most project participants will not be ready to invest in an expensive, integrated software system (and as a consequence in training and their internal operations also) on a project level only. After all they can never be sure that they will be able to use it again in the next project, where a different coalition of participants with yet different software systems will be active….

The reason why it is often impossible to exchange digital information between different software systems is that the developers use different definitions for the same 'objects'. As a consequence a door that is defined with certain properties in one application, is not recognized as that door with those properties by another application from a different software house (and the other way around). In several countries organizations have emerged that strive to develop system independent 'object libraries'. An object library is a collection of standardized definitions of building objects and their possible properties. When these system independent libraries are consistently applied in different software systems, it will be possible to exchange digital information between those systems. In other words: object libraries will enable all participants in the building industry to speak a common (digital) language. Examples of object libraries for the building industry are the STABU LexiCon (www.stabu-lexicon.com) and the Industrial Foundation Classes (IFC's) of the International Alliance for Interoperability (IAI) (www.iai-international.org or www.iai-na.org). These are examples of 'standards for interoperability', that definitely need to be developed further and deserve wide support.

The STABU foundation is the Dutch organisation that developed, maintains and exploits the national system of standardized project specifications. All partners in the building industry are represented in the foundation board and the whole Dutch building industry supporting this national standardisation activity.

The IAI is a global standards-setting organization representing widely diverse constituencies—from architects and engineers, to research scientists, to commercial building owners and contractors, to government officials and academia, to facility managers, and to software companies and building product manufacturers. Alliance members are committed to promoting effective means of exchanging information among all software platforms and applications serving the AEC+FM community by adopting a single Building Information Model (BIM). This mission is accomplished by defining, promoting and publishing specifications for Industry Foundation Classes (IFC) as BIM and as a basis for AEC project information sharing through the project life cycle, globally, across disciplines and technical applications.

Most of the organizations that are involved in the development of object libraries, including STABU and IAI, cooperate under the banner of ISO and also within the recently established International Framework for Dictionaries (IFD: www.ifd-international.org). A first result of that is the draft international standard ISO-DIS12006-3, which contains a 'meta data model' for object libraries. This is an indirect, but important and necessary step towards the development of comprehensive, advanced and internationally accepted and applicable simulation software for the assessment of building performance.

Barriers and Incentives for Performance Based Design

CHAPTER 6

6 Barriers and Incentives for Performance Based Design

6.1 Barriers

The main barriers for the further development and implementation of PeBBu in the domain of the design of buildings are:

- the traditional culture of the building process, in which the ability to improvise is still seen as a major merit;
- the suspicion felt by building designers that the application of Performance-based Design will further undermine the design profession;
- the true conviction of most people active in the design process, that the most important quality aspects of buildings cannot possibly be translated into performance specifications;
- the conviction of the same people that the responsibility for the functional and architectural design on the one side cannot be separated from the responsibility for the technical design on the other;
- the segregation and fragmentation of design, engineering and construction;
- the guilds mentality in the industry;
- the low level of R&D investments in the construction industry.

Domain 3 members have been discussing these barriers – and also possible ways to deal with them – in the domain workshops. The main results of this are described in the next paragraph.

6.2 Incentives: ten reasons for Performance Based Design

Performance-based design is not a goal in itself. It is a means to reach 'higher' goals. The Performance-based approach requires a different attitude, a different way of thinking about designing buildings than in the traditional design process. Implementing the Performance-based approach in the design process means a change of culture. Experience teaches that cultural changes do not occur overnight; it takes a lot of effort and a lot of time. Much active and/or passive resistance of professionals in the trade has to be overcome.

So why do we do it? Why is Performance-based design better than traditional design; what are the 'higher' goals? Why should design professionals be convinced that the performance-based approach is important and a worthwhile cause to put effort in?

Ten reasons for Performance-based design (PBD) are:

1. PBD provides for a more client oriented way of thinking and working in the design process.
2. Performance-based thinking helps clients and designers to gain better knowledge about how a building operates or should operate.
3. PBD leads to cost effectiveness, better quality and better client and user satisfaction.
4. European and national building regulations are more and more performance-based.
5. PBD prevents designers from tumbling into solutions from the very beginning without proper understanding of the real client and user needs.
6. PBD provides architects with the tools to be the integrator in the design process again.
7. PBD offers better conditions for creativity and for generating added value.

8. PBD offers the opportunity to make better use of knowledge and expertise of contractors and suppliers, allowing them to come up with innovative, cost effective solutions.
9. PBD helps to fill in the building industry's responsibility for the environment.
10. PBD is common practice to some extend already.

These reasons are elaborated into more detail as follows.

1. *PBD provides for a more client oriented way of thinking and working in the design process.*
   'The' end user becomes more and more important and he demands quality from his own perspective. During the last few years it has become more and more clear that it is an economic necessity for the building industry as a whole to pay more attention to meeting with user requirements. The performance-based approach is basically a client orientated way of thinking and working, especially in the design process.

2. *Performance-based thinking helps clients and designers to gain better knowledge about how a building operates or should operate.*
   As already was stated in chapter 2, performance-based building primarily has to do with what a building should do for the owners and users (and other stakeholders), rather than with how it should be constructed. This enhances the awareness of how a building-in-use operates or should operate.

3. *PBD leads to cost effectiveness, better quality and better client and user satisfaction.*
   Quality, in client oriented way of working, can be defined as the extend to which a product or service meets with the client's and end users' needs, wishes and expectations. Performance requirements intend to express clients' and users' needs explicitly. A performance-based approach in design offers better conditions for meeting with those needs and – as a result - for better quality and better client and user satisfaction.

4. *European and national building regulations are more and more performance-based.*
   European and national building codes will be more and more performance-oriented (as opposed to prescriptive codes), allowing designers to come up with multiple solutions. Already the European Building Products Directive, that must be implemented in the national building codes of all EU member states, is completely performance-based. Designers will have to prove that their design solutions meet with the legislative requirements. Therefore it is imperative that design professionals adopt the performance-based way of thinking and working.

5. *PBD prevents designers from tumbling into solutions from the very beginning without proper understanding of the real client and user needs.*
   In practice designers often start to develop solutions immediately, without proper understanding of the real questions ('what should the building do for the owner and users?').
   Also owner and user requirements in briefs often seem to be recipes for solutions, rather than descriptions of the performance of the building in-use. This may obscure the real needs behind the owner and user requirements. Moreover it may rule out unexpected creative, innovative and/or cost effective solutions on beforehand. PBD stimulates thinking about 'the question behind the question' before jumping to conclusions.

6. *PBD provides architects with the tools to be the integrator in the design process.*
   Vitruvius already stated ten centuries ago, that architecture is the fusion of functionality, solidity and beauty. With this definition, Vitruvius made a strong plea for integral design. PBD is also all about

integral design. Someone has to do the integration of contributions of all parties involved and the architect is best positioned for that. In many countries the architect lost his integrating role in the building process, because he was not able to cope with all the technical systems. The PBD concept provides him with the tools to be the integrator again. Thus, PBD may give the architect back his lost position.
It has to be taken into account though that there are different legal traditions in the European countries, leading to different positions for architects and different approaches as to who is the integrator. E.g. in Spain, Germany and Belgium architects have a strong legal responsibility for the building design. The building process in the UK is more and more moving towards Design & Build, which causes a shift in the responsibilities of parties involved. In Slovakia a main engineer is appointed for each project (not the architect). Nevertheless, under all circumstances there has to be someone who is responsible for combining all specialist contributions in a design process into one, comprehensive and integrated design. That is essentially the architect's job, irrespective of his legal position. **It's like bringing Vitruvius up to date in a modern setting.**

7. *PBD offers better conditions for creativity and for generating added value*
As performance-based building codes and requirements allow designers, to come up with a variety of solutions, the performance-based approach will enhance creativity and innovation in the design and building process, with more added value for clients and end users as a result..

8. *PBD offers the opportunity to make better use of knowledge and expertise of contractors and suppliers, allowing them to come up with innovative, cost effective solutions.*
Multitudes of building concepts, techniques and products are available for the building industry and more are added every day. It is impossible for designers to have knowledge of all available concepts, techniques, products and new developments. Contractors (and suppliers) often have better knowledge of the market, but also they cannot possibly have mastery of all available concepts and techniques. They have to specialize. But when they are confronted with building designs that are specified in detail, they will often not be able to use their own specializations.
When architects and other designers refrain from giving detailed prescriptive specifications for every building part and complete the functional and aesthetic design with a set of performance specifications for building parts instead, allowing contractors to use their own techniques and market knowledge, that might lead to more cost effective solutions, better quality and more value for money for the owners and users.

9. *PBD helps to fill in the building industry's responsibility for the environment*
The building sector has a responsibility for the environment; future generations also have the right to live in a healthy and sound environment. Legislation in this field is mainly performance-based, leaving the responsibility for how to meet with the legal requirements to the designers to a great extend.

10. *PBD is common practice to some extend already*
In practice most designers already do PBD to some extend, consciously or unconsciously, e.g. in relation to meeting with energy consumption and other environmental requirements. So to most designers PBD is not a completely new concept. Besides that it's important to understand that total systems of performance-based building or design do not exist. PBD can be applied in a more or less extensive form, depending on the circumstances of a project (also see chapter 2). This means that designers do not need to change their 'normal' way of working from one day to another in order to implement PBD.

Knowledge Dissemination and Implementation

CHAPTER 7

7 Knowledge Dissemination and Implementation

7.1 Dissemination

In is commonly agreed that a combination of various tools/methods/activities can lead to most effective knowledge dissemination having as a final result performance-based implementation into general practice. Among these proposed activities are:

- dissemination through the PeBBu website and websites of PeBBu participants
- utilizing the national user platforms and regional platforms that have been established in the PeBBu project
- publications
- national/international events (such as conferences, workshops etc.)
- contribution of members/participants through organizing of workshops/seminars in conjunction with other events for the target groups
- education modules
- training of professionals
- guidelines for performance-based building
- provide clients with case studies and indicate the benefits of performance-based design
- influence local governments and clients with best practices
- providing clients/designers with decision-making/assessment tools
  (in general, the architects are sceptic and afraid that performance-based building can have a negative influence on their profession. Therefore it is needed to address the fear of the architects by showing them on some best practice examples that it is possible to achieve architectural quality and performance-based building at the same time)
- it is necessary to give the right best-practice examples to the right target group
- dissemination of knowledge through best practice examples

7.2 Implementation

This topic differs conceptually from the previous one, even though some of the strategies may be the same.

- make existing projects/design, which already have implemented some of performance-based building, more explicit. In the past, the performance-based building has been already exercised but not necessarily under that name. It is therefore necessary to be more aware of PBB approach, what it actually is and how to implement and exercise
- government leadership
- enhance "total building performance" in a life cycle environment (long term performance)
- performance based regulations
- mutual recognition of the performance assessment methods through standardization
- initiate in education design assignments in terms of performance

Performance Based Design Research Agenda

CHAPTER 8

8 Design of Buildings Research Agenda

8.1 Knowledge gaps

During the Domain workshops some knowledge gaps were pointed out which indicate future research priorities:

- standardized methods for measuring/assessing performance in different fields and in the respective design stages (quantitative measurement and qualitative assessment);
- assessing the subjective, hard to measure performance like 'architecture' and 'image expected' and 'cultural value';
- new fields and problems for which the performance-based design could offer solutions
- structured and systematised data acquisition in order as to develop analytical methods suitable for both quantitative and qualitative data
- state of the art of 3D and 4D modelling systems and computer simulations
- integration of information technology into performance-based building
- specification of user requirements into universal language
- integration of performance-based building in education programmes
- illustration through case studies and benchmarking

8.2 Research priorities

8.2.1 Inventory of design assessment methods

One of the major problems in Performance-based Design is the 'prediction' of a building's performance in-use on the basis of design, or the assessment of design results. Assessment methods may vary from simple counting or measuring from a drawing to advanced ICT-based simulation applications. The Domain 3 State-of-the-Art review shows that many assessment methods and tools are already available, not in the least in ISO and CEN standards, and that many others are being developed all over the world. However, there is no comprehensive overview available. Therefore a project is proposed to make and maintain such an overview, related to decisions designers generally make in the different design stages. This idea is elaborated in further detail in Annex 2 of this report. A matrix is suggested with the 'standard' design stages – masterplan, pre design, final design and technical design – on the horizontal axis and performance aspects (types of requirements on the vertical axis (figure 22).

PERFORMANCE GROUP: USE	ASSESMENT METHODS			
Type of requirement	Masterplan	Pre Design	Final Design	Technical Design
Facilities (availability)				
Location				
Availability of public utilities	Inventory / analysis proposed location			
Presence of shops in the neighbourhood	Inventory / analysis proposed location			

Figure 22: Fragment of the proposed Design Assessment Matrix

In the matrix itself assessment methods and tools should be 'plotted' in such a way, that design professionals can see which performance aspects can be assessed in which design stages and which methods and tools are available for that.
This is a project in which many researchers and design professionals from many different countries could participate. A website should be put to service where people can both consult the matrix and give input.

A matrix as proposed here, could serve two goals:
1. it can inform design professionals about which performance assessment tools are available for which purposes at any given moment;
2. the 'white spots' in the matrix may point out subjects for future research.

Apart from this, the Domain 3 members suggested the following subjects for R&D in this field:

- structured and systemized data acquisition in order to develop analytical methods for both quantitative and qualitative data;
- methodologies for optimal design accounting for risk and life cycle cost;
- operational and functional reliability of building components;
- methodologies for the evaluation of building performance.

8.2.2 Development of methods for the translation of user needs into performance requirements and vice versa

Performance-based building is primarily concerned with what a building is required to do for the users and other stakeholders. This includes the entire design life of the building. It is essentially a client oriented way of thinking and working. In order to be able to deliver 'good performance' it is crucial for partners in the building process that they can capture, understand and define user and stakeholder needs before they start thinking about the solutions. The main problem here is that users and other stakeholders on the one side and partners in the building process on the other speak different 'languages'. They look at the same facility from different angles; they have different frames of reference. On the demand side users think in terms of functional concepts, using 'user language' related to the users' own operations. On the supply side building partners tend to think in terms of 'solution concepts', using 'technical language'. Because of these different languages and frames of reference, it is difficult to match supply and demand in practice (figure 23).

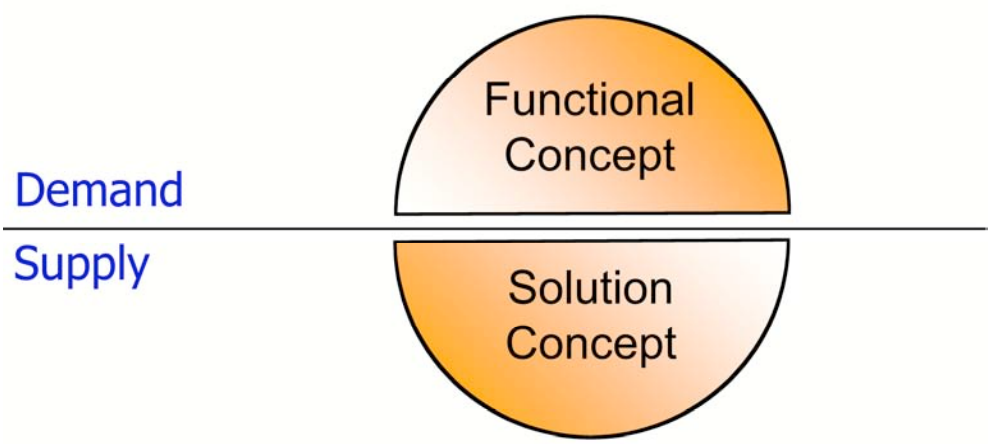

Figure 23: Functional Concept versus Solution Concept (« Hamburger Model »)

Most existing briefing tools tackle this language problem insufficiently, which is one of the reasons that very often built facilities appear not to comply with the real user needs. The performance concept can bring about considerable improvements, as this concept offers an 'intermediate language' that makes it possible to really match demand and supply (figure 24). Thus, existing briefing tools must be improved and/or new tools must be developed using 'performance language' for matching demand and supply. As user and stakeholder needs may vary in time, also tools for the management of user and stakeholder requirements are needed in all stages of a facility's life cycle. Developers of new tools should take into account and/or build upon good examples like the ASTM Standard on Whole Building Functionality and Serviceability and new briefing tools that are being developed by the Dutch Government Building Agency.

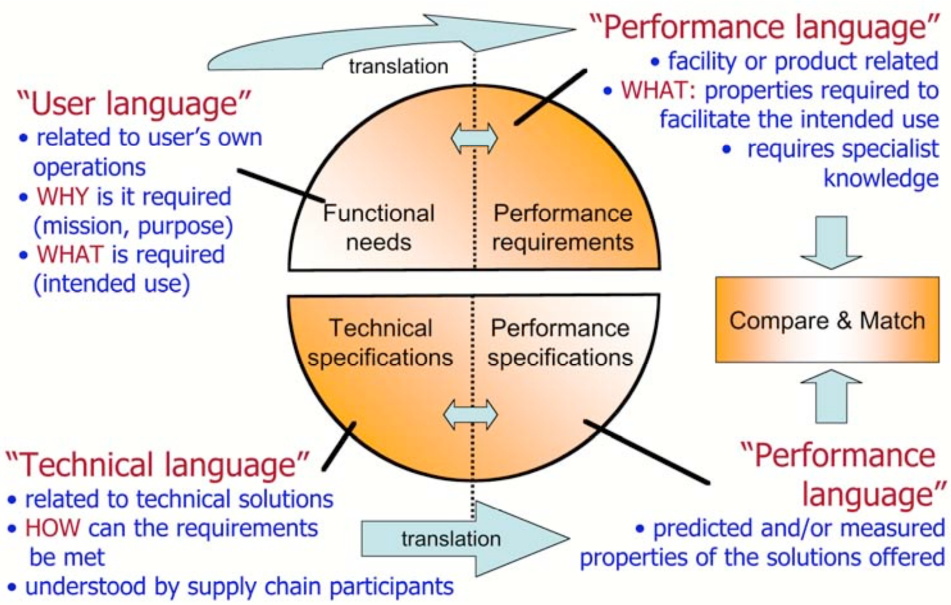

Figure 24: 'Performance language as an intermediate between User language and Technical language

8.2.3 Development of methods for the capture and assessment of 'subjective building performance' (image expected, architectural and cultural value)

Performance requirements express in objective, measurable, solution independent terms the properties of a building, space or building part, that are required to facilitate the intended use. However, some essential aspects of design, such as architectural and cultural value, cannot be expressed in 'hard' measurable performance requirements. Nevertheless this 'subjective building performance' may be quite an important component in a stakeholder's general appreciation of a built asset. This means that also in a performance-based design process, these aspects should be fully taken into account.
There is a great need for methods and tools to capture the 'image expected' of clients and future users concerning architecture, cultural meaning, atmosphere and perception of the built environment. The methods and tools should cover the incorporation of this 'image expected' in the client's brief and also the assessment of the subjective performance during the design stage.

Apart from this, the Domain 3 members suggested the following related R&R topics:
- universal design and accessibility;
- development of global user satisfaction indices;
- the 'human factor' in building design;
- performance assessment of existing buildings (to learn from);
- human behaviour and orientation in complex buildings.

8.2.4 Interoperability standards & incorporation in design & evaluation

The performance of a building is always the result of the interaction between different solutions for different subsystems, like the architectural system, the structural system, the climate system and so on. In order to create integral building performance, design disciplines have to interact very closely. Performance-based approach makes integral design imperative, with parallel, interrelated contributions from all design disciplines involved.

Participants in the design process of facilities produce and exchange a lot of information. Nowadays most of this information is produced digitally with dedicated, sophisticated software applications. In the context of integral design it is essential that design data produced by different project participants, can be digitally exchanged between - and reused in - different software applications without information loss. However, this is not the case already. Software applications from different sources (software developers) still don't communicate, as they use different definitions for the same objects and processes. Man still has to make the 'translations' between different software applications, which implies a lot of (double) work and many chances of misinterpretations and faults. Also, this lack of interoperability it is a big impediment for integral design and thus for the implementation of the performance concept in design and construction. System independent information standards are needed to make software applications interoperable. Existing and new research initiatives for the development and implementation of such standards need to be supported with priority.

One of the main problems in performance-based design is how to predict the performance of a building on the basis of a design. For many quality aspects the 'total building performance' depends on a complex interaction of many influences. On the one hand there are no validated, standardized assessment methods available to predict the total building performance, but on the other hand this performance will determine the client's perception of the quality delivered to a great extend. One of the major ways to improve this situation is the development of applications that can simulate the building behaviour, using integrated data models. All over the world institutes and universities are in the process of developing simulation applications to facilitate this. These developments need to be listed and monitored, favourable developments need to be aligned and new projects have to be started to fill in the white spots. Also for this, interoperability standards need to be in place as soon as possible.

In Domain the following Research and Development projects haven been suggested in this field:

- the development of interoperability standards / integration of IT into PBB/PBD;
- continuous monitoring of the state of the art of 3D and 4D modelling and simulation systems / evaluation and classification of existing computer simulation applications worldwide, in order to list them, find out the limitations that exist nowadays and to propose guidelines for future developments;
- development of integrated building models (using open interoperability standards);
- development of ICT tools for simulation, focused on design and prevention;
- simulating fires in buildings through CFD (Fluid Computational Dynamics) programmes

These projects should link up to the work of e.g. the International Alliance for Interoperability (IAI) and the International Framework for Dictionaries (IFD).

8.2.5 Quantified performance criteria for up to 75% of attributes

Performance criteria should be objectively measurable. However, not all attributes that are important for building design can be expressed in quantified criteria as yet. R&D projects should be started to develop quantified criteria for up to 75% of the essential building attributes by 2010. The Domain 3 Members gave the following suggestions in this field:

- performance criteria for thermal and energy performance, indoor air quality, sustainable planning and construction, building acoustics, fire safety, earth quake resistance;
- performance criteria for special buildings (underground construction, intelligent buildings, tall buildings, office buildings with innovative workspace arrangements);
- universal design and accessibility;
- thermal and energy performance of buildings: requirements for special occupancies (schools, dwellings for challenged people, protected living for the elderly, hospitals, etc.);
- development of urban space and design and construction of buildings, covering sets of criteria in basic areas of sustainability from the CIB 'Agenda 21 on Sustainable Construction': environmental quality, operational reliability and free of maintenance, economic efficiency and constraints, social equity and cultural issues;
- effects of architectural layout on acoustic comfort;
- reliability of structures from new and recycled materials.

8.2.6 Value & benefits assessment & case studies

Performance-based Design implies a relatively new way of thinking and working. Wide spread implementation will not happen overnight. Clients as well as design professionals will have to be convinced of the value and benefits of Performance Concept and PBD. Showcases and best practice examples will be very helpful and instrumental in this. In this context, the Domain 3 Members came up with the following ideas for R&D projects or programmes:

- illustration of PBB/PBD through case studies and benchmarking;
- performance assessment of existing buildings;
- monitoring and evaluation of demonstration projects; risk analysis and optimization;
- short term and long term cost/benefit analyses;
- Life Cycle Assessment analyses.

8.2.7 New Performance-based design tools / renewal of the design process

Further implementation of the Performance Concept in the design practice will induce a growing demand for new design tools and a new design approaches. The following suggestions were made in Domain 3:

- design tools for the implementation of standards in the fields of thermal and energy performance, indoor air quality, structural engineering, fire safety
- methodologies for optimal design accounting for risk and life cycle cost;
- computerized design platforms for overall performance integrated CAD;
- methodologies for the evaluation of building performance;
- re-organization of the regulatory design approval process;
- special design solutions/features geared toward energy conservation;
- performance-based methodology for sustainable building design and environmental impact assessment;
- implementation guidelines for various building occupancies;
- integrated performance approach in the design for fire safety;
- optimization of building evacuation through computer simulation;
- use of renewable energy sources and energy systems;
- PBD of load bearing structures and their optimization; integrated structural design applying optimized design methods.

Conclusions

CHAPTER 9

9 Conclusions

A performance-based design (PBD) is a building design that is based on a set of dedicated performance requirements and that can be evaluated on the basis of solution independent performance indicators. The performance-based design approach is a means to enhance the professionalism and the client orientation of the building design sector. It is aimed at satisfying the real client needs ('answering the question behind the question') and leaves the design process open for creative and innovative solutions. The performance-based approach makes 'integral design', with parallel, interrelated contributions from all design disciplines imperative. PBD offers architects the opportunity to be the integrator in total building design again; PBD is like bringing Vitruvius up to date again in a modern setting.

Although PBD has been put to practice in many countries to some extend, design practitioners appear to be hardly aware of it. Actions need to be undertaken to enhance the awareness of PBD. Clients and end users, who are more and more demanding value for money and fitness for use of the built environment, form the main driver for PBD. Besides that, Performance-based building regulations have proven to be a key success factor in the implementation of PBD. Governmental clients should take the lead in further implementation.

According to the members of Domain 3 the main barriers for further development and implementation of PBD are the traditional culture of the building process, the suspicion of design and engineering professionals that PBD will further undermine the design profession and the conviction of design professionals that the responsibility for the technical design cannot be separated from the responsibility for the functional and architectural design (which is the case in performance based procurement). Also many architects believe that the most important quality aspects of buildings cannot possibly be translated into performance specifications. Other drawbacks that have been mentioned are the segregation and fragmentation of design, engineering and construction, the uncertainty about risk and liability, the (lack of) professionalism of clients, lack of experience. Moreover, during the economical boost of the last ten years, there was little incentive to change. Maybe today, while the whole European building industry suffers from an economic crisis, there is more readiness for innovation. It seems appropriate that actions should be started to enlarge the awareness of Performance-based design. In this respect the participants in PeBBu Domain 3 'Design of Buildings'came up with the following suggestions:

- make existing projects or designs, in which the performance-based approach has already been implemented to some extend, more explicit ('best practices');
- government leadership in the implementation of PBD can be a powerful stimulus;
- incorporate the performance approach in design education;
- enhancement of "total building performance" in a life cycle environment (long term performance);
- performance based building regulations have proven to be a key success factor in the implementation of a performance-based way of thinking in building design;
- mutual recognition of performance assessment methods through standardization.

In order to make PBD successful, new design and assessment tools and methods are needed. All over the world researchers and practitioners have already developed such tools or are in the process of doing so. A project is proposed to develop and maintain an overview of availabele tools and methods. Also new tools and methods are needed for the capture of client and user requirements and for the translation of these requirements into performance requirements (and vice versa). More over, moer effort has to be put into the development of quantifiable performance criteria for – at least – 75% of built facility attributes. Special attention has to be given to the capture and handling of user requirements concerning attributes, that cannot possibly be expressed in objective quantifiable criteria, like perception and architectural and cultural value. Exactly these 'subjective' attributes may to a great extend contribute to the client's and users' appreciation of a built facility.

References

REFERENCES

- Ang, K.I., Wyatt, D.A. & Hermans, M. (2001): 'A systemic approach to define client expectations of total building performance during the predesign stage, CIB World Building Congress, April 2001, Wellington, New Zealand

- Davis, Gerald & Szigeti, Françoise (2000): 'ASTM Standards on Whole Building Functionality and Serviceavility – 2nd edition, American Society for Testing and Materials (ASTM), West Conshohocken, PA, USA, ISBN 0-8031-2734-0

- Foliente, G., Leister, R. and Pham, L., (1998): 'Development of the CIB Pro-active Program on Performance Based Building Codes and Standards', CSIRO BCE Doc 98/232, CSIRO, Melbourne, Australia

- Foliente, G. (2000): 'Developments in Performance-based Building codes and Standards', Forest Products Journal, 50: 7/8, page 12 - 21

- Gielingh, W.F. (1988): 'General AEC Reference Model (GARM), Report No. IBBC – BI-88-150, TNO, Delft, Netherlands

- Gielingh, W.F. (2005): 'Improving the Performance of Construction bu the Acquisition, Organization and Use of Knowledge. A Theory and Method for Cognitive Engineering, Construction and Lifecycle Management', Technical University of Delft, Netherlands, ISBN 90-810001-1-X

- Gibson, E.J., Coordinator of the CIB Working Commission W060 (1982): 'Working with the performance Approach in Building', CIB State of the Art Report no 64, CIB, Rotterdam, Netherlands

- Huovila, Pekka (ed. 2005): 'Performance Based Building', papers presented in the international CIB Symposium 'Combining Forces' in Helsinki, June 2005. VTT – Technical Research Centre of Finland and RIL – Association of Finnish Civil Engineers, Helsinki, Finland

- Huovila, P. ande Leilonen J. (2001): 'Managing performance in the built environment', paper CLI 18, CIB World Building Congress, Wellington, New Zealand

- Porkka, L., Huovila, P., Gray, C an Al Bizri, S. (2004): Decision support Tools for Performance Based Building, PeBBu report, VTT Building and Transport, Helsinki, Finland

- Preiser, Wolfgang FE & Jacqueline C. Vischer (ed. 2005); ‚Assessing Building Performance', Elsevier Butterworth-Heinemann, Oxford, UK, ISBN 0 7506 6174 7

- Royal Institute of Dutch Architects & Dutch Association of Consulting Engineers (2005): 'De Nieuwe Regeling – Standaardtaakbeschrijving' ('Standard Task Description'), Amsterdam – The Hague, the Netherlands.

- Spekkink, D. et al. (1996): 'Programma van Eisen: Instrument voor kwaliteitsbeheersing' ('The client's brief: tool for quality management in the design process'), SBR, Rotterdam, the Netherlands – 2nd edition

- Spekkink, D. et al. (2004): 'Bringing Vitruvius up to date.' Third state of the art report PeBBu Domain 3 – Design of Buildings (available online at www.pebbu.nl)

- Spekkink, D. en Wijk, M (1998): 'Bouwstenen voor het PvE' ('Materials for the Client's Brief',. a tool for the development of briefs for non residential buildings), SBR, Rotterdam, Netherlands, ISBN 90-5367-231-1

- Szigeti, Françoise & Gerald Davis (2005): 'What is Performance Based Building (PBB): in a Nutshell', PeBBu News Article (available online at www.pebbu.nl)

- Szigeti, Françoise & Gerald Davis (2005): 'Performance Based Building (PBB): An Overview, PeBBu Network Publication (available online at www.pebbu.nl)

- Winnepenninckx, E., Vandael, L. and Vitse, P. (2004: 'Support on the CPD: Performance Based Building and the Construction Products Directive', CPD supporting document, PeBBu Network, Belgian Building Research Institute, Brussels, Belgium

Annexes

Annexes

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Annex 2: Framework Design Assessment Methods

One of the central questions in the PeBBu Domain 3 'Design of Buildings' is: "How to predict the performance of a building on the basis of a design". It is felt that this should also be a leading question in the Domain 3 Research Agenda. For this reason a Framework for Design Assessment Methods is proposed. This framework consists of a matrix, with a list of subjects for which performance requirements can be formulated ('performance issues') on the vertical axis and the most common design stages on the horizontal axis.

The performance issues are classified according to a classification that is based on the publication 'Materials for the Client's Brief' (Bouwstenen voor het PvE), SBR, The Netherlands (1998).

The design stages that are distinguished, are:

- Masterplan;
- Predesign
- Final design
- Technical design

The general idea now is to determine which performance requirements can be assessed in which design stage, given the state of development of the design, and which tools are available for carrying out that assessment. The tools, that may differ from simple measuring from a drawing to sophisticated simulation tools, will be filled in into the corresponding design stage columns. In the following sheets, some of the matrix fields have already been filled in provisionally, just to show the general idea. The rest can be filled in during the next few years.

The result of this exercise will serve two goals:

- it will give design professionals an overview of tools that are already available. This will be an important and practical issue for knowledge dissemination to design practice;
- it will show for which performance subjects decision support tools and/or assessment tools will have to be developed.

Definition of Design Stages

In order to be able to determine which performance aspects can be assessed in which design stage, it is necessary to define in some detail what happens in the different design stages. Underneath a global description is given of the design results per design stage.

Masterplan

- Urban fit in of the building mass
- Placement of (groups of) user functions/activities within the building mass
- Zoning of horizontal and vertical transportation and building services
- First exploration of the structural scheme: pattern measures, floor heights
- First exploration of the building services set-up: principles for the energy provision
- Estimate of building and investment costs on the level of building units and/or functional units (cost index numbers)

Predesign

- Provisional site lay-out (alternative site lay-outs)
- Provisional building layout
- Provisional façade schemes
- Principals of the structural scheme, global dimensionsof the building structure
- Principles of the building services design, global dimensions of technical service rooms and wiring and piping packages
- Estimate of building and investment costs on the level of building elements (floors, facades, inner walls and so on)
- Analysis feasibility delivery date
- First analysis of environmental load, building site labour conditions, social safety

Final design

- Final site plan with measures and infill
- Final building mass design and measures
- Final building lay out, including place and measures of building parts and infill elements
- Materials and colors of building parts that determine the architectural image
- Dimensioning and global detailing of foundations and building structure
- Determination of building service capacities, dimensioning of service installations
- Estimate of building and investment costs on the level of building elements (floors, facades, inner walls and so on)
- Analysis feasibility delivery date
- More detailed analysis of environmental load, building site labour conditions, social safety

Technical design

- Building site: final lay-out with specifications of spaces, components and/or materials
- Final lay-out with specification of spaces/rooms, components and/or materials, finishing and colors
- Architectural and constructional detailing
- Final calculations, drawings, detailing and specifications of the building structure and building structure components
- Final lay-out, capacity calculations and dimensioning of service installations
- Estimate of building and investment costs on the level of building components and materials

Detailed analyses of environmental load, energy consumption, social safety; risk assessment of building site labour conditions.

PERFORMANCE GROUP: USE	ASSESMENT METHODS			
Type of requirement	Masterplan	Pre Design	Final Design	Technical Design
Facilities (availability)				
Location				
Availability of public utilities	Inventory / analysis proposed location			
Presence of shops in the neighbourhood	Inventory / analysis proposed location			
Presence of (supporting) business activity in the neighbourhood	Inventory / analysis proposed location			
Housing facilities in the neighbourhoood	Inventory / analysis proposed location			
Availability of personnel in the neighbourhood	Inventory / analysis proposed location			
Development possibilities in the area	Inventory / analysis proposed location			
Energy supply system	Inventory / analysis / site plan / capacity	Total energy concept / energy flow diagram	Main energy system structure	Specification of system parts
Water supply system	Inventory / analysis / site plan / capacity	Total water concept / water flow diagram	Main water system structure	Specification of system parts
Sewer system	Inventory / analysis / site plan / capacity	Total waste concept / waste flow diagram	Main waste system structure	Specification of system parts
Building				
Availability of functions	Inventory / analysis available building(s)	Provisional building layout		
Availability of (inter) relations between functions	Inventory / analysis available building(s)	Provisional building layout		
Specific installations / systems per function	Inventory / analysis available building(s)	Provisional building layout		
Rooms				
Availability of specific facilities per room	Inventory / analysis available rooms	Provisional building layout / room book	Final design layout / room book	Specification of room facilities / room book
Elements				
Availability of specific elements	Inventory / analysis available elements	Inventory list	Principle details	Specification of specific elements
Space requirements				
Location				
Site area	Inventory / analysis / site plan			
Parking space	Inventory / analysis / site plan	Predesign drawing building and site	Final design drawing building and site	
Building				
Net useable area	Inventory / analysis / masterplan drawing	Provisional building layout - measures	Final building layout - measures	
Net surface of services	Inventory / analysis /	Provisional building	Final building layout -	

PERFORMANCE GROUP: USE	ASSESMENT METHODS			
Type of requirement	Masterplan	Pre Design	Final Design	Technical Design
areas	masterplan drawing	layout - measures	measures	
Net surface of common areas	Inventory / analysis / masterplan drawing	Provisional building layout - measures	Final building layout - measures	
Surface of other areas	Inventory / analysis / masterplan drawing	Provisional building layout - measures	Final building layout - measures	
Rooms / work spaces				
Net surface of wor spaces	Inventory / analysis / inventory list	Provisional building layout - measures	Final building layout - measures	
Net height of rooms / work spaces	Inventory / analysis / inventory list	Provisional cross-section / room book	Final cross-section / room book	
Logistics				
Location				
Availability and frequency of public transportation	Inventory / analysis proposed location			
Accessibility to airport	Inventory / analysis proposed location			
Light transportation	Inventory / analysis proposed location			
Public bicycle paths and roads in the area	Inventory / analysis proposed location / site plan			
Vehicular access to site	Inventory / analysis proposed location / site plan			
Acces and parking for deliveries and services	Inventory / analysis proposed location / site plan			
Company provided transport	Inventory / analysis proposed location			
Building				
Internal flows	Inventory / analysis available building(s)			
Accessibility	Inventory / analysis available building(s) / masterplan drawing	Pre design layout and cross sections / handbook	Final design layout and cross sections / handbook	
Findability of facilities	Inventory / analysis available building(s) / masterplan drawing	Pre design layout	Final design layout	
Rooms				
Accessibility, net measures	Inventory / analysis available rooms / handbook	Pre design layout and cross sections / handbook	Final design layout and cross sections / handbook	
Elements				
Accessibility of installations / systems	Inventory / analysis available installations / systems / handbook	Pre design layout and cross sections / handbook	Final design layout and cross sections / handbook	

PERFORMANCE GROUP: USE	ASSESMENT METHODS			
Type of requirement	Masterplan	Pre Design	Final Design	Technical Design
Communications				
Location				
Data network	Inventory / analysis proposed location			
Telephone network	Inventory / analysis proposed location			
Cable system	Inventory / analysis proposed location			
Building				
Data & telephone structure	Inventory / analysis available structure		Zones for data & telephone	Drawings data & telephone structure
Network	Inventory / analysis available network		Zones for cable network	Drawings cable network
Public address system	Inventory / analysis available system		Zones for public address system	Drawings public address system
Rooms				
Connections for data, telephone, images, ..	Inventory / analysis available rooms		Roombook	Drawings rooms and specifications
Elements				
Door bell	Inventory available elements			Drawing and Specifications
Personal locating system	Inventory available elements			Specifications
Phone operating principles	Inventory available elements			Drawings and specifications
Suitability / workability				
Location				
Suitability of facilities	Inventory / analysis proposed location			
Suitability of personnel	Inventory / analysis proposed location			
Building				
Building management facilities	Inventory / analysis available building(s)			
Main electrical structure	Inventory / analysis available building(s)			
Main heating structure	Inventory / analysis available building(s)			
Main water supply structure	Inventory / analysis available building(s)			
Switchability of artificial lighting	Inventory / analysis available building(s)			
Rooms				
Floor-loadings				
Technical areas				
Connections (e.g. electricity grid)				

PERFORMANCE GROUP: USE	ASSESSMENT METHODS			
Type of requirement	Masterplan	Pre Design	Final Design	Technical Design
Setup of specific rooms like archive, restaurant, kitchen, ….				
Elements				
Finish of walls, floors and ceilings				
Operability of elements, systems, installations				
Adaptability / flexibility				
Location				
Posibilities of extension in situ				
Building				
Posibilities of extending the building				
Posibilities of subdivision				
Internal flexibility of construction and installations				
Rooms				
Internal flexibility				
Elements				
Industrial / removable				
Flexible, changeable				

PERFORMANCE GROUP: CONDITIONS	ASSESSMENT METHODS			
Type of requirement	Masterplan	Pre Design	Final Design	Technical Design
Hygro thermal conditions				
Location				
Sun heat				
Wind attack				
Building				
Temperature zones				
Predicted Mean Vote				
Different temperatures per area				
Rooms				
Room temperature				
Temperature gradient				
Floor temperature				

PERFORMANCE GROUP: CONDITIONS	ASSESSMENT METHODS			
Type of requirement	Masterplan	Pre Design	Final Design	Technical Design
Radiation asymmetry				
Relative air humidity				
Air flow				
Individual control of room temperature				
Elements				
Heat storage				
Insulation				
Sun blinding				
Wind tightness				
Surface condensation				
Interstitial condensation				
Air (quality) conditions				
Location				
Air pollution: SO2, CO2, O3, NO2, …				
Air velocity (wind)				
Building				
Ventilation per area or function				
Air quality flow (air pressure differences)				
Natural ventilation (chimney effect)				
Rooms				
Ventilation per room				
Relative humidity per room				
Max concentrations of ……… (MAC)				
Odor intensity				
Natural ventilation, individual control				
Elements				
Emission class of building materials				
Air tightness of facade				
Smooth, easy to clean, minimal allergens				
Visual conditions				
Location				
Space, movement, natural elements, ..				
Outdoor illuminances				

PERFORMANCE GROUP: CONDITIONS	ASSESSMENT METHODS			
Type of requirement	Masterplan	Pre Design	Final Design	Technical Design
Glare				
Shadow formation				
Building				
Quality of view from different areas				
Daylight for different areas / functions				
Rooms				
Daylight				
View				
Glare				
Indoor illuminance				
Luminance distribution				
Light spectrum				
Individual control / adjustability				
Elements				
Reflections				
Contrasts				
Color rendering				
Color temperature				
Acoustical conditions				
Location				
Outdoor area noise level				
Outdoor area noise peaks / frequency				
Building				
Base noise level				
Foot sound noise level				
Noise of installations (HVAC)				
Rooms				
Airborne noise levels between rooms				
Contact noise levels				
Reverberation times				
Elements				
Sound insulation				
Sound absorption				
Vibration conditions				
Location				
Vibrations of traffic, trains, industry, ..				

PERFORMANCE GROUP: CONDITIONS	ASSESSMENT METHODS			
Type of requirement	Masterplan	Pre Design	Final Design	Technical Design
Building				
Max vibrations of installations				
Rooms				
…….				
Elements				
Absorption of vibrations				
Hygiene / allergens				
Location				
Cleanliness of surface water, soil and air				
Building				
Hot water facilities				
Showers				
Sanitary and other facilities				
Food preparation				
Rooms				
Minimum of air flow				
Low temperature heating				
Elements				
Floors, walls and ceilings easy to clean				
No places collecting dust				
Combating allergens				

PERFORMANCE GROUP: SAFETY & SECURITY	ASSESSMENT METHODS			
Type of requirement	Masterplan	Pre Design	Final Design	Technical Design
Safety with calamities				
Location				
Earthquakes				
Floods				
Explosion danger				
Hurricanes ….				
Lightning				
Firestorms				
Building				
Resistance to earthquakes				

PERFORMANCE GROUP: SAFETY & SECURITY	ASSESSMENT METHODS			
Type of requirement	Masterplan	Pre Design	Final Design	Technical Design
Resistance to floods				
Resistance to hurricanes ….				
Rooms				
Emergency lighting				
Escape routes				
Elements				
s Alarm system				
Lightning conductor				
Rescue facilities				
Firefight equipment				
Earthing				
User safety				
Location				
Traffic situation				
Height differences				
Building				
First aid provision				
Rooms				
Safety requirements for special functions				
Elements				
Sign posting				
Glass partitionings				
Social safety				
Location				
Roads and entrances				
Tunnels				
Corners, hiding places				
Vandalism				
Building				
Entrance to building				
Safety rings / shields				
Choice of route				
Rooms				
Entrance to spaces / areas				
Lay-out (views, back covering, ..)				
Elements				
Tracking system / cameras / TV				
Anti graffiti				

PERFORMANCE GROUP: SAFETY & SECURITY	ASSESSMENT METHODS			
Type of requirement	Masterplan	Pre Design	Final Design	Technical Design
Operational reliability				
Location				
Risks of breakdown electricity supply, gas supply, …..				
Building				
Management system technical installations				
Emergency power supply				
Rooms				
Emergency lighting				
Monitoring systems				
Elements				
Overvoltage protection				
Anti burglar security				
Location				
Limited access to the site				
Building				
Partitioning of areas				
Security control system				
Rooms				
Partitioning of rooms				
Alarm system				
Elements				
Key and lock system				
Safety on harmful influences				
Location				
Risks like kerosene dumps, magnetic fields, toxic gasses, ..				
Building				
Safety requirements for special indoor processes				
Areas for arrangement of computer hardware				
Rooms				
Safety requirements for special functions				
Elements				
Restrictions on emissions of materials				

PERFORMANCE GROUP: SAFETY & SECURITY	ASSESSMENT METHODS			
Type of requirement	Masterplan	Pre Design	Final Design	Technical Design
(MAC)				
Requirements regarding to growth of fungi, microbes, …				

IMAGE EXPECTATIONS: CULTURAL VALUE	ASSESSMENT METHODS			
Type of requirement	Masterplan	Pre Design	Final Design	Technical Design
Characteristics & values				
Location				
Urban characteristics				
Social characteristics				
Cultural characteristics				
Architectural value				
Historical value				
Archeological value				
Building				
Architectural meaning, style				
Rooms				
Interior design, cultural expression				
Elements				
Interior design, cultural expression				
Visual arts				

IMAGE EXPECTATIONS: IDENTITY	ASSESSMENT METHODS			
Type of requirement	Masterplan	Pre Design	Final Design	Technical Design
Characteristics & values				
Location				
Urban characteristics				
Social characteristics				
Cultural characteristics				
Architectural characteristics				
Status / type of location				
Building				
Recognizable, e.g. house style				
Representative				

IMAGE EXPECTATIONS: IDENTITY	ASSESSMENT METHODS			
Type of requirement	Masterplan	Pre Design	Final Design	Technical Design
(company culture, style)				
Unique or anonymous				
Rooms				
Recognizable on the level of functions, areas, rooms				
Representative on the level of functions, areas, rooms				
Elements				
House style elements				
Specific color usage				
Representative materials, finishes				

IMAGE EXPECTATIONS: PERCEPTION	ASSESSMENT METHODS			
Type of requirement	Masterplan	Pre Design	Final Design	Technical Design
Characteristics & values				
Location				
Urban characteristics				
Social characteristics				
Cultural characteristics				
Architectural characteristics				
Building				
Expression of the building (open - closed, formal - informal, light - heavy, etc)				
Illumination of the building (night architecture)				
Transparency, readability of the building (independency)				
Social / psychological preferences (introvert - extrovert, individual - group, etc)				
Rooms				
Social / psychological preferences (daylight-artificial light, seing and being seen, etc)				
Views on the environment, relation outside – inside				

IMAGE EXPECTATIONS: PERCEPTION	ASSESSMENT METHODS			
Type of requirement	Masterplan	Pre Design	Final Design	Technical Design
Elements				
Functional use of colors, textures of materials				

CONSTRAINTS GROUP: COSTS	ASSESSMENT METHODS			
Type of requirement	Masterplan	Pre Design	Final Design	Technical Design
Investment				
Location				
Land costs				
Demolition costs				
Soil sanitation costs				
Foundation costs				
Costs of terrain facilities				
Taxes, subsidies, etc				
Building				
Building costs				
Rooms				
Interior costs (choice of quality level)				
Elements				
Costs of materials, finishes & labour (choice of quality level)				
Operational costs				
Location				
Level of upkeep				
Physical, chemical and biological characteristics				
Maintenance costs of terrain facilities				
Building				
Level of upkeep				
Exterior maintenance costs i.r.t. physical, chemical, biological and mechanical aspects				
Rooms				
Level of upkeep				
Interior maintenance costs				
Elements				

CONSTRAINTS GROUP: COSTS	ASSESSMENT METHODS			
Type of requirement	Masterplan	Pre Design	Final Design	Technical Design
Durability / quality of materials and finishes				
Supplementary maintenance requirements				

CONSTRAINTS GROUP: ENVIRONMENT	ASSESSMENT METHODS			
Type of requirements	Masterplan	Pre Design	Final Design	Technical Design
Energy				
Location				
Mobility / transportation				
Use of natural resources: sun, wind, soil, water				
Industrial rest heat				
Energy distribution system				
Total energy solutions				
Building				
Minimal energy demand				
Sustainable energy resources				
Efficient energy techniques				
Energy monitoring system				
Rooms				
Temperature clustering				
Group and individual control (temperature, heat, light, ventilation)				
Elements				
Thermal insulation				
Thermal accumulation				
Materials				
Location				
Local materials				
Possibilities recycling				
Building				
Minimal material demand				
Sustainable materials (with attest like FSC)				
Efficient building				

CONSTRAINTS GROUP: ENVIRONMENT	ASSESSMENT METHODS			
Type of requirements	Masterplan	Pre Design	Final Design	Technical Design
techniques, minimal waste				
Rooms				
Optimized material usage, prefabrication				
Elements				
Prefabrication				
Minimized finish materials				
Sustainable materials				
Water				
Location				
(Closed) surface water system				
Flow from clean water to polluted water				
Old valuable streams				
Rain water storage				
Buildings				
Minimal drink water demand				
Rain water and / or waste water usage				
Water saving techniques				
Water use measuring				
Rooms				
Wet cells (clusters of rooms), short pipes				
Elements				
Water cleaning flow forms, art				
Rain or waste water storage				
Plants & animals				
Location				
Bio diversity				
Vitality				
Protected species				
Valuable old trees, …				
Micro climate				
Building				
Space and place for valuable plants and animals				
Space and place for				

CONSTRAINTS GROUP: ENVIRONMENT		ASSESSMENT METHODS			
Type of requirements		Masterplan	Pre Design	Final Design	Technical Design
	development of new green area (dry - wet, sun - shade, …)				
	Rooms				
	View at green areas				
	Windows to green areas (sound, fresh air)				
	Elements				
	Natural elements, vegetation roof, bird nest blocks, ….				
Soil					
	Location				
	Soil pollution, cleaning				
	Fertility				
	Ground water level, dryness				
	Water storage capacity				
	Strength				
	Building				
	Minimal ground usage (surface)				
	Minimal ground movement (m3)				
	No ground disposal				
	Rooms				
	Efficient space usage				
	Multifunctional ground usage				
	Elements				
	Soil as one of the raw materials => clay, lime, sand, pebbles, ….				

CONSTRAINTS GROUP: LABOUR CONDITIONS		ASSESSMENT METHODS			
Type of requirements		Masterplan	Pre Design	Final Design	Technical Design
Safety					
	Location				
	Safety risks				
	Enough space for safety measures				
	Building				
	Safety risks, like working on height				

CONSTRAINTS GROUP: LABOUR CONDITIONS	ASSESSMENT METHODS			
Type of requirements	Masterplan	Pre Design	Final Design	Technical Design
Facilities for maintenance				
Rooms				
Working in (closed) spaces				
Elements				
Working between building disposal				
Health				
Location				
Weather conditions, climate				
Building				
Health risks				
Rooms				
Working in dusty, noisy places				
Elements				
Working with dangerous (stoffen)				
Handling of heavy or large components				
Well-being				
Location				
Building site facilities				
Building				
Time schedule				
Rooms / elements				

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