Performance Based Building

PeBBu

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PERFORMANCE BASED BUILDING THEMATIC NETWORK 2001-2005

PBB INTERNATIONAL STATE OF THE ART

PeBBu 2nd International SotA Report

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FINAL 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 October 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 organizations worldwide have been participating in the PeBBu Network.

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FOREWORD

At this stage the work of the PeBBu Network is concluded, but implementation of Performance Based Building environments has still a long way ahead.

This network, which was composed of more than 20 operational Tasks, provided some 300 researchers with the opportunity to be part of the Performance Concept in Building thematic melting pot. The Workshops that brought together all Tasks into the same place, and created an informal working environment, enabled fruitful inter-task interactions besides the intra-task activities, and served as an excellent medium for exchanging views and experiences. Hopefully this will yield some interesting future research partnerships.

It is only natural that in such a large network, some tasks face difficulties in achieving the project's goals on time (e.g., the User Platforms, due to insufficient readiness for timely collaboration outside the network), while others terminate their work before the end of the Network due to various task-related reasons (Domains 4, 5, and 9). Despite these minor difficulties, all the tasks have produced the main deliverables they were committed to by the project's scope and program, and submitted their inputs for this Report.

The report includes two parts. The first part is composed of 7 Chapters, intended as a thematic SotA synthesis. The second part is composed of 27 Annexes, which include the individual summary reports of the various Tasks, as well as additional inputs of new activities that were triggered by the PeBBu Network.

The first part of the report was not intended to be a summary of the Task summary reports presented in the second part. This would have been a futile unnecessary task. Its main scope was, besides the presentation of objectives and accomplished work plan, to highlight the SotA of the PBB subject by means of its major inherent ingredients (Chapter 4), elaborate the incentives and barriers for intensive PBB implementation and suggest strategic and operative routes to accomplish it (Chapter 5), and then present a summary of the Network's main outcome, the proposed PBB Research & Development Roadmap (Chapter 6).

I had the pleasure to coordinate the entire Report, and be the main author of the 1st part except Chapter 2 (Scope and Objectives of PeBBu) that was cited from the amended proposal prepared by the PeBBu Secretariat, and Chapter 6 (Summary of Research & Development Roadmap) that was written by Dr. Greg Foliente. Ms. Mansi Jasuja assisted with Chapter 3 (Accomplished Work-Plan and Deliverables). All the Annexes in the 2nd part have been written by their Task Leaders, who first received a general outline of the main titles for their inputs in order to present the different subjects in a common framework.

I would like to acknowledge and express appreciation to all those who contributed to the preparation of this report, despite their probably full-time engagement in the simultaneous preparation of Final Reports and other deliverables they had to produce as part of their own commitment to the PeBBu Project.

PeBBu was mainly a researchers' network. A PBB environment is, if at all, implemented by practitioners. Bridging the gaps between these two communities requires that applied research and practice join efforts. I sincerely hope that this Report may contribute a modest input to advancing this significant dialogue.

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EXECUTIVE SUMMARY

Introduction

Performance Based Building, PBB, is a building market environment in which all the stakeholders involved in the various phases of the building process address the need to ensure performance-in-use of buildings as an explicit target. PBB is expected to facilitate the development and introduction of innovative technologies and building systems into the market, to reduce the technical barriers on free trade, and enhance the overall quality of buildings. Its implementation can be achieved by using innovative, strictly performance-based, procedures and documents in design, construction tendering and procurement, but may also include the more conventional tools and procedures that are based on well documented and approved prescriptive provisions, which are known to supply given levels of performance.

It is believed that the implementation of a PBB environment may actually improve the general performance-in-use of buildings, and supply new opportunities for organisational and technological innovation within and of the building and construction process.

Apparently, the roots of Performance Based Design have been planted more than 2000 years ago in the essay on Architecture written by Vitruvius. However, a wealth of building-related professional literature accumulated since then, was devoted to the specification of material properties and technological details which are known to provide adequate performances. Consequently, the approach adopted in those days, and until less than 50 years ago, was that achievement of building performance targets should be solely based on experience-based validated know-how embedded in clear and strict prescriptions mandated by laws, regulations, codes and standards. By this, assessment of design solutions and construction details turned into a simple technical procedure composed of comparing the proposed design and executed details with their standardised prescriptions. Regarding the building process and economic decisions, this enabled simple tendering, based on detailed design documents, with minimal construction costs playing the main role in contracting decisions.

In the second part of the last decade the more flexible performance-based approach has been developed for application in procurement, design, contracting, delivery, management and maintenance of buildings. It was meant to establish a common language and way of thinking in order to cross borders and reduce the barriers to free trade, while catering for the entire life-cycle performance of building facilities as well as suiting the entire set of interested parties. In its development, some main key-words and concepts have been coined: **Stakeholders, User Needs, Performance Attributes, Performance Requirements, Performance Indicators, Fitness for Use, Assessment Methods, and Cost/Benefit Analysis**.

The PeBBu Network

To supply the European building market with State of the Art knowledge on PBB, the 4-year **Thematic Network PeBBu – Performance Based Building** has been launched in 2001 within the 5th European Program under the umbrella area of Sustainable and Competitive Growth, with CIB as Technical and Managerial Project Coordinator.

The PeBBu network was composed of more than 20 operational Tasks, each handling a different aspect of PBB. Four of the Network Workshops brought together all Tasks into the same place, and created an informal working environment, enabling fruitful inter-task interactions besides the intra-task activities, and served as an excellent medium for exchanging views and experiences. The individual deliverables, main results and specific findings of every Task have been summarized by the Task Leader and are given in the

relevant Annex to this 2nd State of the Art Report (SotA) Report. In addition, 23 fully detailed Final Reports (see section 8.2) and other documents produced by the Task Leader and the Task Members during the network's 4-year period are downloadable from the PeBBu website, at the Task's address as indicated in the specific Annex.

It is only natural that in such a large network, some Tasks face difficulties in achieving the project's goals on time (e.g., the User Platforms, due to insufficient readiness for timely collaboration outside the network), and others terminate their work before the end of the Network due to various task-related reasons (Domains 4, 5, and 9). Despite these minor difficulties, all the Tasks have produced the main deliverables they were committed to by the project's scope and program, and submitted their inputs for this Report.

This 2nd International State of the Art Report includes two parts. The first part is composed of 7 Chapters, intended as a thematic SotA synthesis. The second part is composed of 27 Annexes, which include the individual summary reports of the various Tasks, as well as additional inputs of new activities that were triggered by the PeBBu Network.

The first part of the report was not intended to be a summary of the Task summary reports presented in the second part. This would have been a futile unnecessary task. Its main scope was, besides the presentation of objectives and accomplished work plan, to highlight the SotA of the PBB subject by means of its major inherent ingredients (Chapter 4), elaborate the incentives and barriers for intensive PBB implementation and suggest strategic and operative routes to accomplish it (Chapter 5), and then present a summary of the Network's main outcome, the proposed PBB Research and Development Roadmap (Chapter 6). The contents of the report are based on the vast PBB-relevant existing literature [section 8.1] as well as on the outcomes of the Thematic Network PeBBu [section 8.2].

State of the Art Summary

Chapter 4 of the Report covers the following topics: Definition and Scope of PPB, Conceptual Framework, Stakeholders, User Needs, Performance Requirements and Criteria, Fitness for Use, Design and Assessment Methods, Regulatory Concerns, Standardization, Economic Performance, Decision-Making Tools, Performance Measures and Key Performance Indicators, Risk Analysis, Quality Management, Research Needs. The following sections include a brief summary.

The simplest and most widely cited **definition and scope** of the Performance Concept in Building has been suggested some twenty years ago by CIB Commission W060: "*the practice of thinking and working in terms of ends rather than means*". Some of the PeBBu Tasks have adopted it, or a similar paraphrased version, addressing and emphasizing that the target of enabling specified (usually improved) **performance-in-use** of buildings is the main feature of a Performance Based Building, PBB, environment, whereas working in terms of ends is not an end in itself in the PBB context, but rather a means of implementation, which may be adopted at various points along the process, as needed and suitable.

Numerous general stakeholders who belong to four identified markets (Building, Products, Property, and Capital & investment) are involved in the overall building process in addition to the specific stakeholders concerned with every particular project. Each of the parties regards the building's performance from a different perspective. Some of the stakeholders belong to the demand side and establish the needs' database, while others belong to the supply side and affect the actual performance in use. The list of stakeholders includes: the State or Government; the Municipality and Authority Having Jurisdiction; the professional organisations and institutes engaged in Standardisation, Approval, Certification, and Inspection; the Entrepreneur (also denoted as the Client); the building Owner/s during its service life (not necessarily identical with the entrepreneur), including the facility managers; the direct and indirect human End Users (who inhabit the building, visit it, work in it, enter it for rescue operations, reside nearby or walk around it); the Design Team; the Manufacturers; the Contractor; the Investors and Insurers.

The building facility is regarded as a system with a very long life cycle composed of many interconnected items (materials, products, components, etc.). Its relevant user needs comprise a dynamic set of performance requirements, established by the numerous stakeholders, as well as by the regulatory framework, which addresses also the anonymous users who are not engaged in the building process. It is the task of the regulatory framework and of the knowledge domain to supply the tools for a smooth match between the **performance-demand** and the **solution-supply** sides.

The general performance-based design target may be expressed as "**satisfying most user needs most of the time in all building spaces**". However, some user needs may impose too costly solutions for general implementation in every building. Consequently, a distinction is made between Essential Needs, which are stipulated by the regulatory framework, and Optional Needs, which should be addressed per project, and selected carefully by the relevant stakeholders. User Needs are stated in general terms and refer to the building as a whole, while activities are located within the spaces. Achievement of the conditions needed in every space in order to fulfil its User Needs depends on the building elements separating it from other spaces or from the outside, thus imposing performance requirements on the building fabric as well.

In **the regulatory framework**, User Needs can be transformed directly to **Deemed to Satisfy Solutions, or** presented by clear **performance requirements** amenable to quantification as criteria for design evaluation. The Nordic model, which has been adopted recently by the USA ICC Performance Code, suggests the following sequence for the criteria development process: Objectives (synonymous to User Needs), Functional Statements (qualitative statements addressing the physical building features), and Performance Requirements (detailed statements that provide the professional tools for addressing the objective).

An essential feature in the delineation of user needs into performance requirements is the identification of the **physical factors** that should serve as the **performance indicators**. These factors must be quantifiable, well understood, and preferably amenable to computational analysis in order to enable performance prediction during the generation of design solutions. Statistical data is needed on relations between effects of the physical factors and health, comfort, human response, perception of building performance and satisfaction. This data has to be analysed in order to identify the thresholds of dissatisfying performance and to establish the Design values of satisfactory performance. Unfortunately in many areas of building performance there is a recognised lack in sufficient **dose-effect** data. In parallel, efforts are dedicated to identification of all the agents tending to prevent achievement of the required conditions, and to analysis of the available relevant statistical data in order to derive the Design values of the **generalised Loads**.

Design Tools and accepted **Assessment Methods** are needed in order to provide solutions that respond well to User Needs, Performance Requirements, and Performance Criteria, and to formally ensure at every major step along the process that supplied solutions meet demanded criteria.

The regulators' interests in the context of PBB may be summarized by the following two target statements: 1) Without rendering them prohibitively expensive, buildings should be designed and constructed to be safe and properly performing during their design life, and to prevent excessive damage to the environment. 2) Innovation in construction and free trade are significant to the modernisation and advancement of the building market.

Ways to achieve these targets by means of the **regulatory framework** are now pursued in most **engineering domains**, with major progress made in the areas of structural safety and serviceability, fire safety, energy performance, lighting, and indoor air quality.

PBB concepts have been adopted in some regulatory frameworks, including the Nordic Model, the Dutch Building Decree, the European New Approach and the accompanying CPD Directive, the Building Code of Australia and New-Zealand, the USA new ICC Performance Model Code, and are in the process of adoption in the Canadian Building Code and in the Israeli Regulations. None of these documents is purely

performance-based. In some cases the quantification of performance requirements is incomplete and adversely affects implementation, in others some prescriptive provisions are still stipulated as mandatory solutions instead of performance requirements.

It may seem that there is a need for the preparation of a **European performance-based Model Code for Buildings**, similar to and more comprehensive than the ICC 2003, which will cover all the Performance Attributes. However, given the large differences between the regulatory systems of the various EU countries, this is an extremely difficult task. Taking into account that this sort of decisions requires more than three workshops within a research and scholarly oriented Thematic Network, this option should be pursued more carefully by an adequate dedicated EU Committee, as has been done for the topic of Energy (within the EnPer-Tebuc-Save study).

Although in every country the actual standardisation procedures may be somewhat different, and the produced documents do not have the same format, **standards** in the field of building may be generally divided into five main groups: Materials and components' specification, Test methods, Design evaluation tools, Performance requirements, Construction technology. In a PBB environment, the entire set of standards should comprise a comprehensive inventory of formal documents that can support every specific route chosen for a given project, the prescriptive route as well as the performance-based one.

Some basic parts of the PBB conceptual aspects have been formulated into **ISO** and **ASTM** consensus **Standards**, focusing on the vocabulary, delineation of performance attributes and user needs, methodological aspects of performance requirements derivation, and preparation of performance-based design briefs.

Parts of the scientific disciplinary knowledge have been implemented in ISO and **CEN** Standards that provide performance-based design evaluation tools for specific areas, including structural safety and serviceability, structural fire safety, thermal comfort, energy analysis, day lighting, and service life.

Applied research in the disciplinary areas has been implemented in ISO and ASTM Standards, as well as in **EOTA guides**, which provide comprehensive testing methods for measuring performance properties of building materials, components, and entire building elements in the laboratory and in situ. Most of these documents provide also classification procedures and ranking scales.

The performance assessment of technological **innovations**, new building components or entire systems requires, in addition to design and theoretical evaluation tools, laboratory or in-situ test methods. These are known as **Performance Test Methods**, PTMs. Many of these have been elaborated in ASTM and ISO Standards. There are two main items crucial to ensuring the **fitness for purpose** of industrialised products: Dimensional coordination, and proper classification of performance levels. The main aim of the European **Constructions Products Directive**, CPD, procedures is to ensure that standardised products are recognised as fit for use in all member States, without any additional local tests. The suitable product category for a given work is then chosen according to the required performance for the specific building in the specific place.

Performance-based assessment has been an intrinsic methodology in the evaluation process and procedures for approving innovative building systems and components since the 1950s. There is world wide consensus that it happens to be the most suitable conceptual framework for handling and enabling the safe and economically valid introduction of innovations into the building market. However, although believed that it may, there is no evidence that this in itself promoted innovation and creativity in the building sector.

Although a significant complementary aspect to the implementation of PBB, no PeBBu Task has been devoted to **Economic Performance**. The 2nd SotA Report includes only a short review of decision making tools, performance measures and Key Performance Indicators, and risk analysis. It is recommended to complement the state of the art review of this topic within the agenda of CIB Commission 055 – Building Economics.

Total Quality Management is another significant topic that was not addressed by the PeBBu Network. A review report by Tokaley, which presents the SotA in this field and suggests a research agenda, can be regarded as complementary to the PeBBu outcomes.

Some Specific Observations Outlined by Various Tasks and Research Needs

The first activity of the various Tasks was **mapping of existing relevant knowledge**. Each of the Tasks has gathered, by means of its members and the first series of Workshops, extensive information on PBB-related research activity and implementation efforts ongoing in their countries. The next steps of the Tasks' activities and Workshops were devoted to identification of knowledge gaps and lack of tools for proper implementation of PBB. The entire set of **individual Research Agendas** prepared by the various PeBBu Tasks has been analysed by a dedicated CIB team that has produced the **final PeBBu Research and Development Roadmap for PBB**, and reported it in a separate Synthesis Report, with its summary included in this SotA Report.

Plenty of **conference and workshop papers** have been published hereto by the research community on various conceptual aspects of PBB, and the means for its implementation. Many more **popular articles** are spread in various web sites. In addition to this overwhelming amount of explanatory literature, scientific refereed international journals include a vast amount of relevant **basic knowledge** on health hazards; performance aspects and properties of building materials and components under various conditions; performance and behaviour of whole buildings or their major parts in various areas of the recognised performance attributes as a function of various design variables; performance-based design and evaluation tools in specific areas of the various performance attributes (e.g., serviceability needs and spatial design, performance-based design for structural safety and serviceability, user needs and risk analysis in performance-based fire safety design, indoor air quality and healthy buildings, analysis of hygro-thermal performance and moisture effects, thermal comfort and energy in buildings, room and building acoustics, illumination and visual aspects of spatial design, analytical and testing tools for building materials' durability); as well as on the economic aspects of decision making (e.g., cost-benefit analysis, risk analysis, and multi disciplinary optimisation). In contrast, the amount of quantitative knowledge on human needs at the vicinity of user satisfaction levels is too small, and is regarded as a main handicap in the transformation of User Needs into Performance Requirements and Criteria.

Conceptual aspects, as well as detailed scientific disciplinary knowledge in most areas of the main performance attributes, have been included in the curricula of **professional education** of many Building and Civil Engineering departments in European universities. A similar situation exists in Australia, New-Zealand and Israel. In Canada only a few university departments cover PBB-relevant topics in their curricula. In USA Universities the situation is much worse, with very few Civil Engineering departments carrying some relevant syllabi. The hard core scientific topics are taught at Civil Engineering departments in the NAS countries as well. Architectural departments world wide include some PBB-relevant topics in their syllabi, but these are usually taught at a qualitative level without elaborating the quantitative assessment tools. In the USA PBB-related topics are given in a quantitative manner in some Architectural Engineering departments. As a consequence of the university education situation outlined above, most of the research in the various disciplinary areas of PBB is performed in Europe at universities as well as in Research Institutes, whereas in the USA it is mostly carried out at National Research Institutes and in industry.

Most of the PeBBu Network Tasks have noticed that the basics of the Performance Concept in Building are sufficiently covered in the popular professional literature, bringing them to the attention of other researchers. In contrast, practitioners and other relevant stakeholders in the building market seem to be much less aware of its fundamental principles, and mainly of the associated scientific knowledge. This may explain the low level of implementation. Professional **public relations** are thus necessary, and the **PeBBu Website** is a good starting point, with the ensuing **National platforms and National Thematic Networks** assisting in spreading the knowledge.

Many of the Tasks complained that there is not sufficient documentation of **case studies** in which a PBB environment has been implemented throughout the entire building process and its consequences have been monitored with the required scrutiny. The documentation given by those claiming to proceed along this route is mostly explanatory and of a journalistic nature, rather than professionally detailed. Consequently, it is difficult to analyse the steps, documents, requirements, and assessment methods that have been employed during preparation of design briefs and tendering documents, or during approval and other building performance-relevant decisions. Lack of such information is frustrating in particular with regard to performance-based procurement methods. Objective thorough investigation of some such projects is highly recommended.

Various Tasks stressed the significance of implementing a flexible performance-based regulatory framework, which enables free choice of the performance route when found suitable for to the specific needs of a given project or one of its stages. Since it was envisaged that PBB will not be the main trend for many years to come, the need to leave the prescriptive provisions as approved, deemed to satisfy solutions, has been recognised. Still, once performance requirements are delineated, it may be necessary to **verify some of the standardised solutions** by preliminary research before endorsing them as deemed to satisfy solutions.

Carefully delineated performance requirements and accepted verification and assessment methods are of major significance in a PBB environment in order to ensure, before starting actual construction, that demands are clear and that there is a sufficiently high level of probability that the supplied solutions would meet them. The main difficulty in addressing long term performance is associated with the **dynamic nature of owners' needs**, and the implications of unknown occupancy or usage changes on future fitness for use of the built facility. Literature has very little information on how to handle this topic economically in general, and in a PBB framework in particular.

To be properly implemented during the design process, PBB requires **explicit devotion to the integrated performance of the facility**. This has to be accomplished without sacrificing some performance requirements due to lack of charisma, dominance or leadership of specific team members. **Team work** and some overlap of professional knowledge are essential in performance-based design.

Given the traditional character of the building market, **resistance to change** will probably continue to persist. However, with **Governments** becoming more and more concerned with enabling free trade, as well as being forced to base their own construction contracts on performance-based tenders, they may become the **main drivers** of PBB implementation in the technological part of the building market. Due to the tendency to cut Government expenditure on public works and involve the private sector in building, operating and maintaining the public facilities, Governments are also forced to procure their own projects by means of various new procurement methods in which performance-based design briefs are an inherent feature. This may be a significant driver to implementation of more explicit PBB procedures along the entire building process.

Linkage between performance assessment tools and life cycle economic evaluation tools can be instrumental in optimisation of cost while fulfilling performance requirements at the most effective level. The knowledge and tools for such efforts are available. They are implemented extensively in other industries. However, their implementation in actual building projects is still scarce, but it is envisaged that if PBB will gain momentum, thorough **cost-benefit analysis** and/or overall optimisation will also become part of the new environment.

PeBBu members of the **East European Regional Platform**, as well as **NAS countries** delegates, believe that a PBB environment can be instrumental to enhancing the quality of buildings in their countries and to the competitiveness of their building industries in the European market. This of course has not been substantiated by evidence from similar markets, and thus remains to be verified.

Incentives, Barriers, and Further PBB Implementation

Numerous **incentives** have been pointed out for the implementation of PBB, with a main emphasis on the facilitation of innovations. These include: Reducing barriers on trade; Enhancing innovation; Catering for the users; Providing transparent regulations; Enabling explicit information flow; Predictability of outcomes; Catering for the public sector's procurement restrictions; Organisation's benefits in enhancing worker satisfaction and productivity; Enables tradeoffs and multi disciplinary optimisation; Achieving optimal solutions; Improved prestige; Clarifies responsibilities; Essential to TQM; May reduce costs; May improve performance-in-use; and PBB as an innovation that is an innovation enabler can turn the wheel of building market advancement.

However, the incentives are hampered by a multitude of **barriers**, with the innovative concepts and major procedural changes required in an explicit implementation being a significant deterrent. Others include: Incompleteness of regulations during transition phase; Lack of quantitative user-related data; Requires more profound professional expertise; Lack of experience; Time consuming and costly processes; Requires a holistic approach in a highly fragmented market; Designers do not like the delegation of power to entrepreneurs, owners and users; Conflicting requirements, Reluctance to accept direct responsibility, Uncertainty about risk and liability, Difficulties in separating responsibilities; Undermining of the designers' status; Lack of evidence that PBB may succeed; and last, but not least, Conservatism, Scepticism, prejudice, and resistant to change.

Given the **unique features of the building market** (each building is unique; Different supply-demand cultures; Separation of architecture from engineering), PBB is a desired environment, but its implementation should not necessarily be associated with an overall revolution in the entire building process and introduction of explicit new procedures. **Piece-wise implementation** of such procedures in design, tendering or procurement, according to specific needs of a given project should be enabled by the regulatory framework, and remain the free choice of entrepreneurs. Strategies and activities for enhancing implementation should be in **harmony** with the unique features of the building sector.

Identified possible **strategies** include: Public relations; Increasing awareness to the benefits of a PBB environment; Enhancing Government leadership; Enhancing professional knowledge; Making knowledge and information easily available; Standardising objective tools; Simplifying!; Bringing research to practice; Learning from practice; Enhancing team work during design.

These can be accomplished by the following **activities**: Knowledge dissemination; Establishing a PBB enabling regulatory infrastructure; Preparing model performance-based tendering documents; Incorporating PBB knowledge in professional educational curricula; Preparing a structured information source; Preparing an inventory of quantitative performance-based requirements; Standardising accepted design assessment methods; Standardising assessment methods for the built facility; Developing decision-making and assessment tools; Developing an inventory of Key Performance Indicators; Developing tools for the managerial phases; Conducting Post-Occupancy Evaluations; Preparing an inventory of case studies.

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Introduction

1 INTRODUCTION

Performance Based Building, PBB, is a building market environment in which all the stakeholders involved in the various phases of the building process recognise the need to ensure performance-in-use of buildings as an explicit target. One way of implementing PBB is using performance-based explicit and transparent procedures during all the phases of the building process. This is accomplished by replacing prescriptive provisions on the demand side (i.e., in regulations, standards, design briefs and tenders) by performance requirements, and allowing the supply side to provide alternative solutions that meet the requirements, thus enabling the choice of the most suitable solutions by means of cost/benefit analysis or other tools. However, PBB can be implemented implicitly as well, by means of deemed to satisfy prescriptive provisions, as long as professional activities are intension-based (in briefing, design and construction), and the target of performance-in-use of the constructed facility is explicitly recognised.

The Performance Concept in Building has been first defined by the CIB Commission W060 (which was established in 1975 under this name) as "*first and foremost, the practice of thinking and working in terms of ends rather than means*" throughout the entire building process, including its various life cycle stages of design, construction, operation, and maintenance. "*It is concerned with what a building or building product is required to do, and not with prescribing how it is to be constructed*" [Gibson 1982]. This concise definition has been adopted and cited since its first appearance in the CIB Report 64 in almost every article and report dealing with the implementation of the performance concept in building. It reflects so naturally the manner most human activities are planned and carried out, that a person not familiar with the building profession may assume that this is actually the situation prevailing in building as well. However, to those familiar with the profession and its last century developments, it is clear that despite the more than 50 years that have passed since France first introduced the Performance Concept with regard to its Agrèment system [CSTB publications, Blachere 1965], no building market world wide has adopted the entire set of performance-based procedures outlined above. Moreover, it became quite clear nowadays that PBB should be regarded as an overall flexible philosophy and dynamic framework, enabling various equally accepted practical routes for achieving the same societal and organizational targets intended to produce safe, healthy and adequately performing buildings, without dictating procurement and managerial methods or hindering innovation.

Thinking in performance terms in the design stage is much older than it seems from the current literature addressing this subject. Vitruvius, the master teacher of architecture and engineering, wrote in the book he submitted to Imperator Caesar, "*the three departments of architecture, …, the art of building, the making of time-pieces, and the construction of machinery, …. must be built with reference to durability, convenience, and beauty. Durability will be assured when foundations are carried down to the solid ground and materials wisely and liberally selected; convenience, when the arrangement of the apartments is faultless and presents no hindrance to use, and when each class of building is assigned to its suitable and appropriate exposure; and beauty, when the appearance of the work is pleasing and in good taste, and when its members are in due proportion according to correct principles of symmetry.*" [Vitruvius, 1B.C., Book I, Chapter III, section 2]. In nowadays performance-based terminology these targets have been coined into the most widely used terms: **User Needs**, and **Performance Requirements**, and are expressed by the demand that user needs should be identified within the entire set of relevant **Performance Attributes** and performance requirements would then be established for a hierarchical set of the building and its parts [Hattis 2001]. Domain 3 of the PeBBu Network has then defined the performance-based design process by: "*A process in which performance requirements are translated and integrated into a building design*", stating as well: "*Performance requirements should express the real user needs behind the question for a built product*" [Spekkink 2005a].

In addition, when discussing the skills and education required for the architectural profession, Vitruvius states: "*The architect should be equipped with knowledge of many branches of study and varied kinds of learning,* …" [Vitruvius, Book I, Chapter I, section 1] and then continues: "*For without these considerations, the*

healthiness of the dwelling cannot be assured. … And other things of this sort should be known to architects, so that, before they begin upon buildings, they may be careful not to leave disputed points to the householders to settle after the works are finished, and so that in drawing up contracts the interests of both employer and contractor may be wisely safe-guarded." [Vitruvius, Book I, Chapter I, section 10]. The wish this sentence stipulates is coincident with the current emphasis on having all relevant **Stakeholders** involved all along the performance-based process in order to ensure maximum coverage of their needs and interests while enabling accepted resolutions of conflicts [Custer 1997]. Similarly, Domain 2 of the PeBBu Network has defined a 3-D framework for the presentation of performance requirements, which is composed of the three axes: Building phase, Building object, and Stakeholders, stating "*The most important parameter is the performance requirements that are set by the stakeholders*" [Loomans 2005b].

The fundamental principles of architecture according to Vitruvius are stated by: "*architecture depends on Order, Arrangement, Eurythmy, Symmetry, Propriety, and Economy*" [Vitruvius, Book I, Chapter II, section 1]. Propriety is then further elaborated by: "*Propriety is that perfection of style which comes when a work is authoritatively constructed on approved principles. It arises from prescription, from usage, or from nature*" [Vitruvius, Book I, Chapter II, section 5]. The current widely used performance-based term for Propriety is **Fitness for Use**, the main paradigm being that proven compliance with the performance requirements established for a given product (be it a whole building or any of its parts) indicates that the product so tested is usually fit for its intended use. The European New Approach has carried this notion into the regulatory framework, demanding that every building product bearing the CE Marking should be recognized by all member states as fit for its intended use when installed properly in adequately designed buildings. Article 2 in the CPD Directive states: "*Member States shall take all necessary measures to ensure that the products referred to in Article 1, which are intended for use in works, may be placed on the market only if they are fit for this intended use, that is to say they have such characteristics that the works in which they are to be incorporated, assembled, applied or installed, can, if properly designed and built, satisfy, the essential requirements referred to in Article 3 when and where such works are subject to regulations containing such requirements*", and then Article 4 adds: "*Member States shall presume that products are fit for use if they enable works in which they are employed, provided the latter are properly designed and built, to satisfy the essential requirements referred to in Article 3 where such products bear the CE marking indicating that they satisfy all the provisions of this Directive, including the conformity assessment procedures laid down in Chapter V and the procedure laid down in Chapter III*" [CPD 1989].

Economic Performance has been so nicely defined 2000 years ago "*Economy denotes the proper management of materials and of site, as well as a thrifty balancing of cost and common sense in the construction of works*" [Vitruvius, Book I, Chapter II, section 9], and is implemented in modern building design by means of the specific terms **Cost/Benefit Analysis,** and **Performance Measures** or **Key Performance Indicators**. In a recent paper Lützkendorf and his partners distinguish six performance categories, one of them "*Economic Performance*" which they divide into two sub-categories: "*a) Real Estate Performance: Real estate performance is the earnings trend and value of a real estate property. It is especially useful for the decision-making processes of investors and property owners. A performance requirement is likely to be increased revenue and value. b) Cost Performance: Cost and financial performance describes financial expenditures involved in planning, construction, operation, maintenance, demolition or waste disposal at a particular time or within the life cycle of a facility. The current criteria have moved towards LCC (Life Cycle Costing) methods. Cost performance is used by managers, planers, building users and facility managers to monitor and control costs. Investors and property owners especially consider non-allocatable costs*" [Lützkendorf 2005]. Moreover, on February 4, 2004, President Bush signed the Executive Order 13327, Federal Real Property Asset Management. This Order requires that "*the Council shall work with the Administrator of General Services to establish appropriate performance measures to determine the effectiveness of Federal real property management. Such performance measures shall include, but are not limited to, evaluating the costs and benefits involved with acquiring, repairing, maintaining, operating, managing, and disposing of Federal real properties at particular agencies*" [US Government 2004].

Apparently, the roots of Performance Based Design have been planted more than 2000 years ago. However, most of the other text in Vitruvius's book, as well as a wealth of building-related professional

literature accumulated since then, was devoted to the specification of material properties and technological details which are known to provide adequate performances. Consequently, the approach adopted in those days and until less than 50 years ago, was that achievement of building performance targets should be solely based on experience-based validated know-how embedded in clear and strict prescriptions mandated by laws, regulations, codes and standards. By this, assessment of design solutions and construction details turned into a simple technical procedure composed of comparing the proposed design and executed details with their standardized prescriptions. Regarding the building process and economic decisions, this enabled simple tendering based on detailed design documents, with minimal construction costs playing the main role in contracting decisions.

After World War II, with the need for fast reconstruction of some French cities, the safe and satisfactory introduction of innovative building systems has been recognized as a major need in France. During the same period, similar needs emerged in South Africa, the USA and other places where fast construction of multi family housing was urgently needed and triggered the introduction of new technologies into the building markets. Simultaneously, the chemical industries started to introduce many new plastic materials and additives, enabling new solutions for common building components composed hereto of wood and metals, as well as major improvements in the performance of classical materials such as steel, wood and concrete. In order to be able to investigate the fitness for use of the new technologies, yardsticks for their assessment have been needed. These were not part of the existing standard test methods and acceptance criteria. It was thus recognised that the prescriptive approach, which was based on existing experience, could not assist in the assessment of envisaged performance of the newly developed materials and methods. The development of the Agrèment procedure in France followed soon and spread all over, introducing a new concept in those days – Equivalence of Performances, and triggering the development of performance requirements and new performance test and assessment methods [Blachere 1965, Blachere 1988].

During the following 50 years many local building markets experienced the need for more flexibility, enabling more fluent import/export of building goods, as well as fast adoption and assimilation of innovations. A new approach to the procurement, design, contracting, delivery, management and maintenance of buildings has been developing. It aims at crossing borders and reduceing the barriers to free trade, while catering for the entire life-cycle performance of building facilities as well as suiting the entire set of interested parties. In the process of developing this approach some main key-words and concepts have been coined (Stakeholders, User Needs, Performance Attributes, Performance Requirements, Performance Indicators, Fitness for Use, Assessment Methods, and Cost/Benefit Analysis). Obviously, these stem naturally from the essential features of building architecture and engineering, which were so well identified by Vitruvius, but have not been explicitly implemented in a performance-based framework as long as the market could do with the simpler and more convenient prescriptive-based framework. Nonetheless, despite the longevity of the Performance Concept and the multitude of research devoted to its implementation in the last four centuries [Foster 1972, ASTM/CIB/RILEM 1982, CSTB 1988, Davis 1990, Becker 1996b, CIB 2001, Huovila 2005a], only some 15 years ago, when globalization has become more crucial in the building market, the professional decision makers at national and international levels have started to adopt its fundamental modules and essential way of thinking, paving the route for practical routine implementation. Presently some major regulatory acts taken in Europe, Northern America, and Australia, enforcing a performance-based approach to regulations and/or to procurement, stirred the bowl even further and raised the basic question: is the profession well versed with knowledge and tools that enable more profound implementation of Performance Based Building, PBB, and what should be done in order to enhance its applicability in Europe? With the wide spread belief that PBB is instrumental in eliminating barriers to free trade and in promoting innovation in building, the need for a learned response to this question has been recognized in Europe at large and by CIB in particular.

To supply the required answers, the 4-year Thematic Network PeBBu – Performance Based Building has been launched in 2001 within the 5th European Program under the umbrella area of Sustainable and Competitive Growth, with CIB as Technical and Managerial Project Coordinator.

This State of the Art Report is based mainly on the vast PBB-relevant existing literature as well as on the outcomes of the Thematic Network PeBBu.

The next chapter cites the amended scope and objectives of the project as agreed upon with the EU.

Chapter 3 outlines the structure of the thematic network, its various Tasks, and elaborates the accomplished work-plan and its deliverables.

Chapter 4 summarizes the state of the art findings and results in an integrated framework addressing key issues of PBB.

Chapter 5 is devoted to a discussion of the incentives and barriers for intensified implementation of PBB, and suggests some strategies and activities to overcome the barriers.

Chapter 6 introduces the summary of the Research and Development Roadmap Synthesis Report, which has been prepared on the basis of the separate Research Agendas of the various Tasks.

Chapter 7 concludes the report.

Chapter 8 includes two lists of references. 8.1 includes various literature sources, while 8.2 includes the list of all the Final Reports produced by the PeBBu Network.

Annexes I to IX include summary reports of the nine tasks designated as Scientific Domains.

Annexes X to XIII include summary reports of the four tasks designated as Regional Platforms.

Annexes XIV to XVI include summary reports of the tasks designated as User Platforms.

Annexes XVII to XIX include summary reports of three new tasks, designated as Generic Tasks, introduced in the 3rd year of the project (Support on the CPD, Decision making Toolkit for PBB, and CRISP Indicator Analysis).

Annexes XX and XXI include summary reports of two Aligned Tasks (Compendium of PBB Models, Compendium of PBB Statements of Requirements).

Annex XXII includes a summary report of an additional new task, the PeBBu Prototype Interactive Website, which was developed within the project's framework.

Annexes XXIII to XXIV include summary reports of the newly erected Swedish National Platform and the Aligned Australian Regional Platform Aus-PeBBu.

Annex XXV includes a summary report of the newly established Israeli PeBBu Thematic Network ISR-PeBBu.

Annex XXVI includes a summary report of the Newly Associated States of Europe - NAS.

In addition to the current Network, several CIB Commissions have been working in some well defined scientific and disciplinary areas of PBB. Their work is not included in this report, but Annex XXVII includes a list of their titles and current work plans.

Scope & Objectives of the PeBBu Project

CHAPTER 2

2 Scope & Objectives of the PeBBu Project

This chapter is cited from the amended work plan submitted by CIB to the EU in 2004.

2.1 Vision

The application of Performance Based Building in building and construction related regulatory systems, codes and standards and in the organization of and communication within building and construction projects, will enhance both the explicit focus throughout all phases of such projects upon performance requirements of building owners and users and will supply new opportunities for organizational and technological innovation within and of the building and construction process.

2.2 Background: the Construction Industry and Performance Based Building

Traditionally the building and construction market in most industrialized countries over the past decades has been supply driven and consequently the level of customer orientation amongst the building and construction professional has been less than optimal. It is to be expected that consequently the level of fitness for use and of value for money of buildings, as perceived by building owners, users and managers, has been relatively low compared to many other consumer and investment goods.

The traditional fragmented organization of building and construction projects and the prototype characteristics of such projects have in fact resulted in a traditionally far from optimal communication and information transfer between building professionals in such projects, in less than optimal opportunities for technological optimization and innovation by construction firms, in almost no factual opportunities for such firms for technological and organizational specialization, and in a strong emphasize on lowest initial building and construction costs as opposed to lowest user costs over time.

The building and construction descriptive or deemed-to-satisfy regulatory systems, codes and standards, currently in place in almost all industrialized countries, are based upon the traditional attitude and mode of organization in the building and construction industry and thereby implicitly enhance those.

Performance Based Building addresses those problems by using performance requirements to define a building's or building and construction products' fitness for purpose. Performance Based Building means the orientation on ends rather than means by focusing communication between customers and professionals within building and construction projects on required target performances instead of on technical specifications and solutions.

The application of Performance Based Building will have a major impact in the building and construction industry's structure and culture and will provide substantial benefits for both the owners, users and managers of buildings and for the professionals and companies on the industry. Such benefits stem from a better fitness for use of buildings and from substantially enhanced opportunities for technological and organizational innovation within and of the building and construction process.

It is to be expected that an integral application of Performance Based Building in the long term may result in overall cost savings in the magnitude of 25% as compared to the average traditional mode of construction as was considered "normal" during the past say four decades in most industrialized countries.

2.3 Objectives

2.3.1 General

The objective of the Thematic Network PeBBu is to stimulate and pro-actively facilitate the international dissemination and implementation of Performance Based Building, and in that context: a maximization of the contribution to this by the international R&D community.

In this context, the Network aims at combining fragmented knowledge and experience in the respective area, in order to build a systematic approach towards organizational and technological innovation in the building and construction industry and related regulatory communities, and towards applying user requirements as the actual basis for communication throughout the building and construction process.

The Network builds upon various R&D projects and programmes as over the past years have been initiated by CIB – The International Council for Research and Innovation in Building and Construction.

2.3.2 Network Specific Objectives

Stimulation and pro-active facilitation of international dissemination and implementation of Performance Based Building in building and construction practice, and in that context maximisation of the contribution to this by the international R&D community through:

- Stimulation and facilitation of the international programming and coordination of research and implementation projects as concerns Performance Based Building as effectively as possible in order to make optimal use of limited available resources and to prevent unnecessary recurrences.
- Stimulation of actual investments in such research and implementation projects.
- Providing the EU Network Members with an optimal access to knowledge and experience as available in non-EU countries in which respective developments have progressed further than in the EU.
- Coordinated dissemination and implementation of results of international research in the area of Performance Based Building.

The Network aims at combining fragmented knowledge in the area of Performance Based Building in order to build a systematic approach towards innovation of the building industry and applying user requirements throughout the building process. From this, white spots and a coherent future research agenda can be derived. End-users, policy makers, building industry and regulatory communities will be closely involved in this development in order to facilitate dissemination and implementation of research results.

The Network should especially stimulate investments in research that may be expected to produce practical recommendations for the adoption and application of Performance Based Building throughout the building industry and in all phases of the building process.

It is also envisaged that the long period of the network's existence and its broad membership would enhance the collaboration between various members and lead to long lasting International collaboration, well beyond the formal termination of the network and its dedicated EU funding.

Accomplished Work-plan & Deliverables

CHAPTER 3

3 ACCOMPLISHED WORK-PLAN AND DELIVERABLES

3.1 Methodology

An infrastructure has been established for the programming, coordination and facilitation of research and for the dissemination of research results in the area of Performance Based Building. The main components of this program are given below:

- International programming and coordination of research projects in **nine scientific Domains**. As explained later, three of the nine Domains have been terminated at the end of the first two years and **three New Tasks** have been introduced which reflect current important developments in performance based building and the need to address them.
- Involvement of target groups / stakeholders from the start of the programme through **three User Platforms** for i) buildings owners, users and managers, ii) building and construction industry, and iii) the International Standardization and Conformity Community;
- **Mapping** of national and international research as far as related to – aspects of – Performance Based Building;
- **Four Regional Platforms** in Europe to act as the bridge to and the initiator of aligned national activities;
- **Network Management**, including the establishment of a Network Steering Committee, a Technical Committee and a Network Secretariat that among others are to be responsible for: i) annual technical and financial reporting to the EU, ii) final report, iii) designated website including among others a newsletter, and iv) overall project management.

During the course of the project, the following components have been added:

- **Three Generic Tasks** that handle specific professional topics, which have been identified as significant in the framework of PBB implementation, and include i) Support on the CPD, ii) Decision making Toolkit for PBB, and iii) CRISP Indicator Analysis.
- **Two Compendium projects** that serve as a scientific basis for the research projects and establish a common framework, a shared language, and the state of the art in terms of research and best practices in the area of i) Validated Models, and iii) Statements of Requirements[1].
- Launch of the Regional **Australian PeBBu Platform** (Aus-PeBBu).
- Establishment of **National Platforms** (Sweden and Poland).
- Various **R&D projects** related to Performance Based Building, including the about 30 projects that already have been initiated by CIB Task Groups and Working Commissions. The further elaboration of those projects into proposals/request for additional funding has already commenced.

The following figure illustrates the various Network components.

The central part represents the main components as included in the PeBBu Thematic Network, while the outer circle represents the additional / aligned components, which are in operation without EU funding.

The PeBBu Network was planned for and has been operational during a four-year period, from October 2001 to October 2005.

The tasks and deliverables for each of the main components as included in the PeBBu Thematic Network are described in detail in section 3.3 below.

[1] The development of the Compendium of Validated Building Performance Models has already been commissioned in 2000 by CIB, and CIB has also already commissioned preparatory studies for the other two Compendia

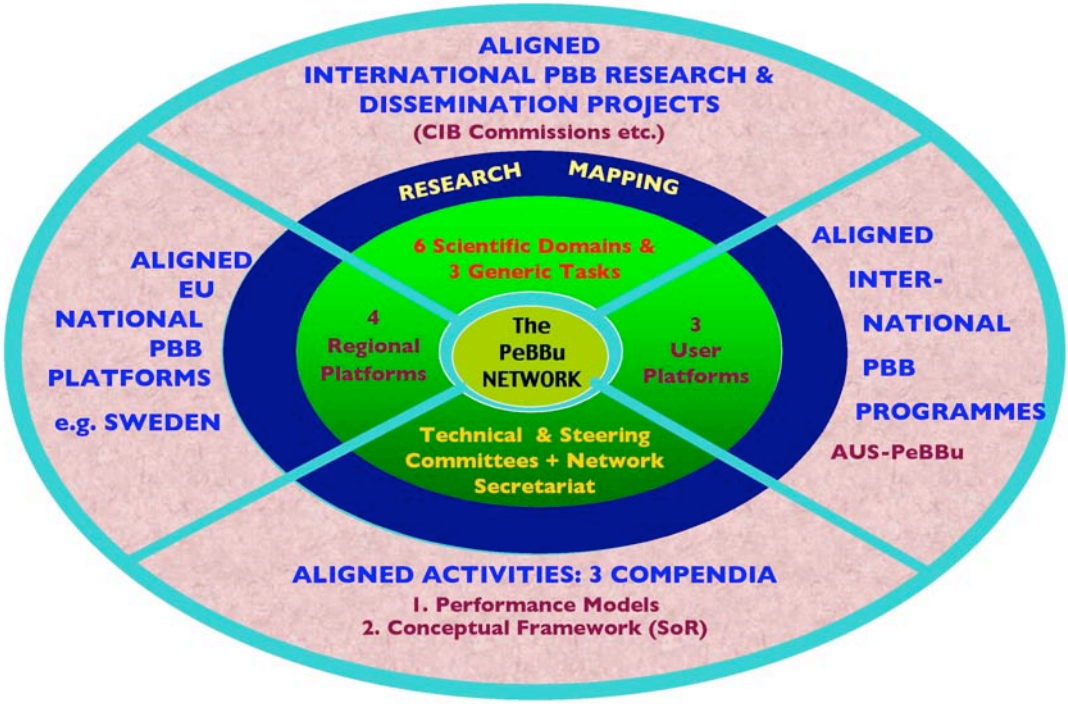


Figure 3.1: Schematic of the PeBBu Network Components

3.2 Members

The PeBBu Network, at the launch of the project, included i) 33 organizations in EU and EU Associated countries and ii) 15 organizations in other countries that committed to participation under the condition that the required funding will become available. Finally, the PeBBu network has grown to include 73 organisations in all from 30 countries, out of which 56 are EU and 17 are non-EU countries. Within the EU, there are 17 organizations from the NAS countries. PeBBu Members which joined in the course of the project were all given an "Observer-member or liaison-member status".

The final list of PeBBu Members in EU and EU Associated Countries per country is given below. This includes an indication of the organizations' function in the Network.

Organizations involved in the PeBBu Project

	Country	Organisation	Function
1	Australia	Australian Building Codes Board	Observer
2	Australia	CSIRO	Observer
3	Belgium	Belgian Building Research Institute	Principal Contractor
4	Bulgaria	Sofia Energy Centre Ltd.	Member
5	Canada	NRC/CETC	Observer
6	Canada	ICF - International Centre for Facilities	Observer
7	Canada	University of Manitoba	Observer
8	Canada	University of Montreal	Observer
9	Croatia	University of Zagreb	Observer
10	Czech Republic	Brno University of Technology	Member
11	Czech Republic	VSB - Technical University of Ostrava	Member

12	Denmark	Danish Building Research Institute	Member
13	Estonia	TTU - Tallinn Technical University	Observer
14	Finland	Helsinki University of Technology	Member
15	Finland	RTS - Building Information Foundation	Member
16	Finland	VTT Building and Transport	Principal Contractor
17	France	CSTB - Centre Scientifique et Technique du Bâtiment	Principal Contractor
18	France	University of Rochelle	Member
19	Germany	Fraunhofer Institute for Building Physics	Member
20	Germany	University of Karlsruhe	Observer
21	Greece	Aristotle University	Member
22	Hungary	ÉMI	Member
23	Iceland	Building Research Institute of Iceland	Observer
24	India	VIA Architectural Consultants	Observer
25	Ireland	Dublin Institute of Technology	Member
26	Israel	Min. of Int. Div. of Planning and Bldg. Guidelines and Reg.	Member
27	Israel	Technion – Israel Institute of Technology	Member
28	Italy	Architettura Senza Frontiere	Observer
29	Italy	National Research Council	Member
30	Japan	National Institute of Public Health	Observer
31	Lithuania	Vilnius Gediminas Technical University	Member
32	Netherlands	BAM Advies & Engineering	Member
33	Netherlands	CIB	Liaison
34	Netherlands	CIBdf - CIB Development Foundation	Coordinating Contractor
35	Netherlands	EGM Architects - Research Department	Principal Contractor
36	Netherlands	Eindhoven University of Technology	Member
37	Netherlands	Eurocer-Building	Observer
38	Netherlands	Ministry of Housing, Spatial Planning and the Environment	Member
39	Netherlands	SBR	Member
40	Netherlands	STABU - Specification System for the Construction Industry	Member
41	Netherlands	TNO Environment and Geosciences	Principal Contractor
42	New Zealand	Department of Building and Housing	Ex Liaison
43	Norway	Norwegian Building Research Institute	Observer
44	Poland	Architect & Urban Housing Manager	Observer
45	Poland	ASM Market Research & Analysis Centre Ltd.	Member
46	Poland	The Polish National Energy Conservation Agency	Member
47	Poland	Warsaw University of Technology	Member
48	Portugal	IST - Technical University of Lisbon	Member
49	Portugal	University of Porto	Member
50	Saudi Arabia	King Fahd University of Petroleum & Minerals	Observer
51	Slovakia	Institute of Construction and Architecture	Member
52	Slovakia	Slovak University of Technology	Member
53	Slovakia	Technical University - Faculty of Civil Engineering	Member
54	Slovakia	Technical University in Zvolen	Member
55	Slovakia	VVUPS	Member
56	Slovenia	ZAG - Slovenian National Building and Civil Eng. Institute	Member
57	Spain	Instituto de Ciencias de la Construcción Eduardo Torroja	Member
58	Spain	UPC - Polytecnical University of Catalunya	Member
59	Sweden	FORMAS	Member
60	Sweden	KTH - Royal Institute of Technology	Member
61	United Kingdom	Borough Council of Wellingborough	Observer

62	United Kingdom	BRE - Building Research Establishment	Principal Contractor
63	United Kingdom	Glasgow Caledonian University	Observer
64	United Kingdom	Pinsent Masons Solicitors	Liaison
65	United Kingdom	University of Manchester	Principal Contractor
66	United Kingdom	University of Reading	Member
67	United Kingdom	University of Salford	Principal Contractor
68	United Kingdom	University of Strathclyde	Observer
69	United States	ASTM International	Liaison
70	United States	Georgia Institute of Technology	Liaison
71	United States	GSA - US General Services Administration	Liaison
72	United States	NFPA - National Fire Protection Association	EX Observer
73	United States	University of Pennsylvania	Observer

3.3 Details of the Network Tasks and Deliverables

A summary description of the scope and objectives, accomplished work-plan and deliverables of all the PeBBu network Tasks is included in the Annexes. This sub-chapter summarizes briefly the overall framework of the project.

Overall Objectives for the Domains:

During the four year period
- Supply of input into the PeBBu Website (task 20), including: news articles, domain workshop reports, domain reports, information on research and contacts, etc.
- Supply of input into PeBBu Compendia (if and when in place)
- Assessment of proposals for international research and dissemination projects
- Participation (by the Domain leader) in the PeBBu Technical Committee (task 19)
- Provision of domain related input for the activities and workshops of the PeBBu User Platforms and Regional Platforms, and acting upon domain related recommendations from those workshops

Year 1 & 2
- Contribution to the first International PBB State of the Art Report (task 20)
- 1st Domain Workshop, including a workshop preparation report and elaborated workshop minutes
- 1st Domain Report (see under External deliverables for the report's content)

Year 3
- 2nd Domain Workshop, including a workshop preparation report and elaborated workshop minutes
- 2nd Domain Report

Year 4
- Contribution to this Final PeBBu Report (task 20)

Additional Objectives: Apart from these overall objectives, each domain had some additional specific objectives. These are detailed out further in the Task Reports of all domains annexed at the end of this document.

3.3.1 Nine Scientific Domains

For each Scientific Domain, separate international research programming and coordination took place to ensure internationally accepted prioritizing of research, maximum stimulus for international collaboration and a maximum compatibility between the results from the research projects. The following nine separate Scientific Domains were distinguished in the initial planning.

In the area: Building Technique
- **Domain 1: Life Performance of Construction Materials and Components**

- **Domain 2: Indoor Environments (formerly called Building Physics)**

In the area: Buildings and the Built Environment
- **Domain 3: Design of Buildings**
- **Domain 4: Built Environment**

In the area: Building Process
- **Domain 5: Organization and Management**
- **Domain 6: Legal and Procurement Practices**

In the area: Building Industry
- **Domain 7: Regulation**
- **Domain 8: Innovation**
- **Domain 9: Information and Documentation**

The initial work-plan included the flexibility to combine, split up and/or add such Domains if research developments so require. That indeed was necessary during the course of the project. At a Steering Committee Meeting in August 2003, it was concluded that 3 domains (namely domain 4, 5 and 9) are to be terminated due to non availability of relevant research in the international community in these 3 fields and in 2 cases, overlap of work with other domains. However, these domains have produced a domain report as well as an international R & D agenda, as reported in Annexes IV, V, and IX. At the same time, it was realized that certain issues, which are of importance to the work of PeBBu and had not been initially included should be added in the project as New Tasks. These are the three Generic Tasks mentioned above, and clarified in section 3.3.5.

Per Domain the following tasks and deliverables are defined.

3.3.1.1 Contribution to the first International PeBBu State of the Art Report

The Domain Leaders elaborated their initial international State of the Art indication into a formatted contribution to the first official International PeBBu State of the Art Report that has been published by the Network Secretariat in Year 2 of it's operation.

3.3.1.2 Domain Workshops and Domain Reports

The general work-plan for each Domain was identical, but its actual details were of course an outcome of the specific combination of Domain Leader and members. In this section we outline briefly the common agenda. The specifics are given separately in Annexes I to IX.

In each of the nine Domains, two research programming and coordinating workshops, organized by the appointed Domain Leader, were planned to take place. The first workshop of each Domain was actually so organized and took place during the first year of the project. However, a complementary workshop, organized by the network secretariat in Budapest for all those who could not participate in the first workshop, indicated the benefits of having all members in the same place. The 2nd workshop was thus planned as a series of domain meetings held in Manchester, UK, during the same week.

A need for an additional workshop was felt in the course of the project. This additional 3rd domain workshop, was again held as a series for the continuing 6 domains, in November 2004 in Porto, Portugal.

Apart from being responsible for these Domain Workshops, the respective Domain Leaders were responsible for the production of two Domain Reports, which include:
- Conceptual framework for research programming
- Worldwide inventory and assessment of recently finalized, ongoing and planned research in the respective Domain as far as relevant to PBB
- International status and State of the Art report, including best practice examples
- Recommendations for international prioritizing of further research
- Recommendations for international collaboration in future research projects

- Recommendations for international dissemination of research results, for example through training, summer courses, publications, etceteras.

The Domain Leaders stimulated the Domain Members to provide a maximal contribution to the production of such Domain Reports.

3.3.1.3 *Input into the PeBBu Website*

The Domain Leaders supplied the Network Secretariat with input to the PeBBu Website. This includes:

- Workshop Reports
- Bi-annual Domain Reports, as defined above
- In-between articles to be included in the PeBBu Newsletter and in the PeBBu Website
- Information on ongoing research in the respective Domain, as far as available, including information of relevant research results

3.3.1.4 *Communication with PeBBu Compendia*

The Domain Leaders communicated on a regular basis with the contact persons for the PeBBu Compendia, as concerns things like: conceptual framework for and terminology related to Performance Based Building, best practices and State of the Art examples as concerns PeBBu applications to be included in those Compendia.

3.3.1.5 *Participation in PeBBu Technical Committee*

The Task Leaders have participated at the meetings of the Network Technical Committee.

3.3.1.6 *Contribution to Final PeBBu Report*

Each Domain Leader, including the three terminated domains, supplied the state of the art individual summary report for his or her domain, as included in the relevant Annex of this Report.

3.3.1.7 *Production of an International R&D Agenda*

All the domains, including the three terminated domains, produced by the end of their programme an international Research and Development agenda, as reported in their individual Domain Reports and in the relevant Annexes to this report. A synthesis report of the R&D Roadmap has been prepared by a dedicated Task and reported in a separate Report. Its summary is given in Chapter 6.

3.3.1.8 *General Support to the nine Scientific Domains*

Administrative and related types of support to the nine Domain Leaders have been provided by the Network Secretariat, that was also responsible for providing input from all CIB related activities into the Domain Workshops and for distributing the reports of the Domain Workshops and the Domain Reports amongst those participants in the Thematic Network who did not participate at the respective Domain Workshops. The network secretariat had also the responsibility of organizing the series of domain workshops, which took place instead of stand-alone workshops, in coordination with the Domain Leaders.

3.3.2 Three User Platforms

The actual implementation of the principles of Performance Based Building will have a major impact on both the day-to-day and strategic operations of various stakeholders.

In order to stimulate and facilitate the input of those stakeholders' opinions into the programming and execution of the respective research and dissemination projects in all stages of the program, and in order to prepare for their active support for future implementation activities, the following three User Platforms have been established:

User Platform 1:	representing Building Owners, Users and Managers
User Platform 2:	representing the Building and Construction Industry
User Platform 3:	representing the international Standardization and Conformity Community

Per User Platform the following tasks and deliverables have been defined.

3.3.2.1 Platform Workshops and Reports

In the initial work-plan, the Leader of a User Platform was responsible for organizing bi-annual Platform Workshops. For participation at those workshops respective international representing organizations were to be invited to appoint Workshop participants. In preparation of each Workshop, the respective Platform Leader – with support of the Network Secretariat – was to produce and provide the Workshop participants with a report, which included:

- an indication of all programming and research and dissemination activities that are ongoing within the PeBBu Programme

Each such Workshop should have resulted in a Workshop Report that includes:

- An assessment by the participants at the Workshop of presented PeBBu activities. This was to be presented such that the Leaders and Members of the PeBBu Scientific Domains, the three Generic Tasks, the four PeBBu Regional Platforms, and the persons as involved in ongoing or planned PeBBu related research and dissemination projects can use those as meaningful input to their future activities
- A "stake holders" advice as concerns the PeBBu activities in general. The objective of such an advice is to be a means for maximal alignment of PeBBu's activities with the actual need for international R&D as perceived by the participating stake holder representatives in the respective workshops.

Overall Objectives for User Platforms

- To engage high level representatives of actual PBB stakeholders in decision making on the programme as to be performed by the PeBBu Network and in the evaluation of the results of this programme
- To stimulate and facilitate input of the PBB actual stakeholders opinions into the programming and execution of international PBB related research and dissemination projects during all stages of the PeBBu Network programme
- To prepare for the respective stakeholders support to future implementation activities.

Work-plan

Incidental responses at the request of the Network Secretariat to selected strategic network documents, for which the inclusion of the respective stakeholders' opinions is important, including in particular:

- *Strategic programming documents per PeBBu Domain*
- *Definition of the needs for research as to be included in the structure for the PeBBu Mapping activity*

Within the Work-plan of the User Platforms, two workshops were envisaged in the entire duration of the PeBBu Project.

Besides the above tasks and deliverables for the User Platforms, the Standardization Platform had some additional objectives:

- To stimulate and facilitate the transfer of PBB research results and pre-normative knowledge into standardization processes
- To stimulate and facilitate the transfer of actual knowledge about the characteristics of PBB standardization issues into their respective research projects
- To facilitate co-ordination between International, European/regional and National Standards Bodies in standardization processes associated with PBB.

The Standardisation Platform report should thus include:

- International status concerning the inclusion of the principles of PBB in National, European/Regional and International Standards
- An assessment of results available from research on Performance Based Building as concerns possibilities for inclusion in Standards together with an indication of further research required in support of future standardization
- Recommendations to standards organisations.

3.3.2.2 General Support to the three User Platforms

In preparation of the User Platform Workshop, the Network Secretariat provided the respective Platform Leader with selected information on all ongoing and planned PeBBu activities that may be of relevance to the respective User Platform.

The Network Secretariat was responsible – as far as relevant – for the distribution of products of the three User Platforms to i) the Leaders and Members of the nine Scientific Domains for international programming and coordination of the PeBBu research and dissemination projects, and to ii) the Leaders and Members of the four PeBBu Regional Platforms.

3.3.2.3 Changes in Work-plan for User Platforms

There was one information workshop held in year 1 for the User Platform for Standardisation and Conformity.

In this workshop several high level representatives of EU stakeholder organisations were present e.g. representatives of European commission for CPD. In this meeting, there was an agreement to set up a User Platform for Standardisation, to coordinate activities regarding PBB and regulations. At the moment, EU did not commit to this and later it withdrew due to internal reorganisations. This led to a loss of incentive to the other organisations.

After this, another meeting for the User platform was planned to be held in October 2003. However, due to a variety of reasons, this meeting was postponed. The main reason was unexpected cancellations due to illness/holiday. The meetings planned for the other 2 user platforms namely Owners and Industry were also not successful. The main reasons for these were: not being able to attract enough high-level organisations since PeBBu is still in a more theoretical stage of research and development and it was premature to expect such high-level representatives in a meeting without any funding.

In a Technical Committee Meeting held in January 2004, it was agreed that for the Standardisation platform, the idea of a meeting of stakeholders would still be pursued. For the other two platforms, a more individual approach seemed more feasible. The idea of making a PBB-related questionnaire geared specifically to the owners or industry is being developed and then circulated by the national contacts in their network/region. A draft of such a questionnaire for the industry platform was prepared in November 2004 jointly by the task leader of the industry platform, Dr. Luk Vandaele, BBRI, Belgium and an expert commissioned from within the PeBBu network – Assoc. Prof. Rachel Becker, Technion, Israel. This questionnaire aimed in giving local or regional feedback on the main issues surrounding the application and implementation of PBB with respect to those stakeholders. The questionnaire for the User Platform on Owners was prepared by Mr. Tim Yates, BRE, UK and sent to all National contacts for distribution. Several responses were received for this questionnaire.

It was decided by the Steering and Technical Committee in a meeting held in November 2004 in Porto to wait for the results of the Domain 7 on Regulations to see how the results of this domain can help us in making any progress with the work on the User Platform on Standardisation. However, it seems that at this stage the setting up of this User Platform is too ambitious. First, more awareness on PBB principles is needed and steps have to be made to further the PBB approach from a largely theoretical concept to a more applicable concept.

3.3.2.4 Contribution to Final PeBBu Report

The User Platform Leaders supplied the state of the art individual summary report for their platforms, as included in Annexes XIV to XVI of this Report.

3.3.3 Four Regional Platforms

In addition to the international research and dissemination projects that were a part of the PeBBu Programme, national activities are necessary in preparation of the actual implementation of the principles of PBB. It was envisaged from the beginning that such national activities would be aligned as much as possible with the international PeBBu activities.

In order to stimulate and facilitate the programming and coordination of such national activities, in order to facilitate the input of typical national and regional characteristics into the international programming of projects, and in order to prepare for the necessary future national implementation activities, four Regional PeBBu Platforms have been established in the participating EU and EU Associate countries.

The following four EU Regions were defined. Per Region the participating countries as included in the PeBBu Network and funded by the EU, are mentioned and the country that 'supplies' the Leader of the respective Regional Platform is underlined. For three of those Regional Platforms an additional objective was to attract new PeBBu Members in countries in the region to the PeBBu Network. Some changes in the composition of these Regional Platforms have taken place in the course of the project. These are included in the table below. E.g. Slovenia has moved from the East European platform to the Mediterranean platform.

National contact persons participated in the four Regional Platforms as "representatives" of stakeholders in the national communities.

Per Regional Platform the following tasks and deliverables were accomplished:

Overall Objectives for the Regional Platforms

- To stimulate and facilitate a maximal alignment between the international PeBBu activities and national research and dissemination activities concerning the development and implementation of PBB in the countries that participate in PeBBu, through:
  - Stimulation and facilitation of the programming of such national activities
  - Facilitation of the input of typical national and regional characteristics into the international programming of the international PeBBu activities
  - Preparation for future national PBB implementation activities, including the national dissemination of PeBBu results, and in support of achieving those objectives.
- To initiate and facilitate the establishment of National or Trans-national PeBBu Platforms in the region, which includes:
  - Support to defining the scope and objectives of such platforms
  - Support to the establishment of required financial spport structures for such platforms in collaboration with the PeBBu Secretariat and aiming for international financial support from the EU and other international sources
  - Support to regional, trans-national an national PeBBu related events.

Work-plan

- To attract new PeBBu Members/Observers from both already participating and not yet participating countries in the region
- To provide input into the PeBBu website, in terms of data/information/news articles concerning national / trans national / regional PBB related activities and events.

Within the work-plan of the Regional Platforms, three sets of annual workshops took place in the entire duration of the PeBBu Project.

Region 1 (North Europe):	Sweden, Finland, Denmark, Norway, Iceland, Lithuania, Estonia.
Region 2 (West/Central Europe):[2]	Belgium, UK, Ireland, Netherlands, France, Germany,
Region 3 (East Europe):	Hungary, Poland, Czech Republic[3], Slovakia, Bulgaria, and participation of Romania
Region 4 (Mediterranean Europe):	Italy, Spain, Portugal, Greece, Israel, Slovenia, Croatia

3.3.3.1 Contribution to the first International PeBBu State of the Art Report

The Regional Platform Leaders in communication with the respective national Platform Members elaborated the national State of the Art reports into a formatted, following a structure defined by the secretariat, contribution per country, plus an additional, about 1-2 page long, regional synthesis to the 1st International SotA Report that has been published by the Network Secretariat in Year 2 of it's operation.

3.3.3.2 Three Regional Workshops and Reports

The Leader of each of the four Regional PeBBu Platforms organized three annual Regional Platform Workshops. In preparation of each Regional PeBBu Workshop, the Regional Platform Leader in collaboration with the Network Secretariat has produced a report on ongoing and planned international PeBBu activities as far as those might be of importance to the Platform Members.

Immediately after each regional Workshop a Regional PeBBu Report was produced that includes the following:

- The status as concerns i) the envisaged future implementation of PBB in the participating countries, and ii) the national programming and execution of related research and dissemination activities.
- Comments by the Platform Members to the International PeBBu activities and an indication of national of regional requirements as regards future international PeBBu activities in the areas of the International PeBBu Scientific Domains and User Platforms.

3.3.3.3 Contribution to Final PeBBu Report

Each Regional Platform Leader supplied the state of the art individual summary report for his or her platform, as included in Annexes X to XIII of this Report.

3.3.3.4 Initiation & Alignment of and Funding for National PeBBu Activities

The Regional PeBBu Platforms are to function as initiators for aligned national activities in the area of Performance Based Building.

The Regional PeBBu Platforms in collaboration with the Network Secretariat have coordinated and supported possible national programme proposals and request for possible international funding for the included "kick off" activities, as far as those are aimed at establishing a more long term National PeBBu Programme that is sufficiently aligned with international activities of the PeBBu Network. The final aim in this context is to establish permanent National PeBBu Platforms.

The objectives of such National Platforms are:

[2] TNO, Netherlands was in the initial Work-plan, a joint task leader with BBRI, Belgium of the Regional Platform in West / Central Europe. However, at the end of Year 2, the leadership was left to BBRI.

[3] In Czech Republic, VSB - Technical University of Ostrava was initially the official member of the regional platform. However, another active organization in Czech Republic, Brno University of Technology (PeBBu members of NAS SotA), has been active in the regional platform of east Europe by attending all past meetings, giving input and producing the national SotA.

- to stimulate and facilitate the programming and coordination of national projects, which are necessary in preparation of the actual implementation of the principles of PBB programmes
- to achieve a maximal alignment between those national projects and the international activities as performed in the context of the PeBBu Network.

The participants of each National Platform are typically envisaged to include representatives of building owners, design, construction and regulatory communities as well as research organizations.

At present two National platforms have been established, including Sweden and Australia. These are reported in Annexes XXIII to XXIV. The Australian platform is growing to have a regional focus by including south-Asian countries in its fold. In Poland, a national level platform has been incorporated in setting up the ECTP platform in which PBB is also an issue although of a minor significance. The South African national platform is still under consideration. There were some initiatives for setting up a national platform for PBB in the US but they have faded away.

In order to disseminate the international knowledge and experience in the area of PBB at a national level, an Israeli Thematic Network is being established, as reported in Annex XXV.

The NAS countries, which joined the PeBBu Network during its first year, have prepared an individual report, a summary of which is given in Annex XXVI.

3.3.3.5 *General Support to the three Regional Platforms*

The four Regional Platforms were supported by the Network Secretariat. This support included:

- Distribution of the results of the international programming and coordination of research and dissemination projects to the Leaders of the Regional Platforms
- Distribution of the results of the Regional Platforms, as far as relevant, to the Leaders of the nine Scientific Domains, the three Generic Tasks and to the three PeBBu User Platforms.

3.3.4 Mapping of Research Activities

A separate task of the PeBBu project was:

Mapping of Research Activities in countries that are represented in the PeBBu Network as concerns R&D related to Performance based Building

One of the defined tasks of this activity is the development of a database with information on research and development that is of special relevance to PBB. The aim of such a Mapping is to contribute to future policy making as concerns Performance Based Building. The final objective is to develop this into the world's foremost portal to information on Performance Based Building. It is to be assumed that at that time it will be of strategic importance to various organisations working with PBB principles.

This PeBBu Mapping database contains information on ongoing Research Projects, Publications, (recently published scientific) Papers, Organisations and Contacts (with their expertise) as of special importance to the further development, implementation and application of PBB. The result contains an information system on different levels of detail for the research and for the organisations involved, including: databases in searchable formats, with adequate links to information sources and with several degrees of accessibility.

This mapping task was performed based on the following approach and organisation:

- The Network Secretariat task facilitated and coordinated the respective work
- On the international level information was collected and assessed by the Task Leaders of the nine Scientific Domains, in first instance via the Domain Members
- On the national level information was collected and assessed by the National Contacts who participate in the PeBBu Network, with support by the Regional Platforms
- As concerns the technical infrastructure for this mapping activity, and as concerns formats to be used, the respective PeBBu work was initially planned to be coordinated with the ECORE Network that has the overall coordinating responsibility for the Mapping of Research Activities in the Building and

Construction Sector. However, this did not succeed, which led PeBBu to develop its own mapping infrastructure. This has caused some delay in the mapping work.

The appointed PeBBu Designated Contact in each organisation is responsible in his/her organisation for incorporating as many as possible relevant Projects, Publications and Papers and stimulating other PeBBu members in the organisation to add the papers. Designated contacts can also add more contacts in this database that can further add papers.

This database can be accessed from: http://www.pebbu.nl/maincomponents/mapping/

3.3.5 Three New Generic Tasks

As mentioned before, three New Generic Tasks have been introduced in the PeBBu project during the 3rd year of the network activity. A brief summary of the objectives of each task is given below.

GT1 - PBB & Construction Products Directive (CPD); Support on the CPD

Background:
The Construction Products Directive defines, through a series of interpretative documents, six essential requirements for construction works. For those essential requirements, the European Commission, after consultation of the Member States of the EEA, specifies the regulated characteristics for construction products and kits in mandates to the European Standardisation Committee (CEN) and the European Organisation for Technical Approval (EOTA) to develop harmonized technical product specifications, i.e. harmonized European standards or European Technical Approvals, for the performance assessment of the building products.

The EC New Approach directives in general and the CPD specifically introduce a mandatory system of conformity attestation throughout the construction products sector. Therefore, in this activity, the expected impact of the CPD on the market of construction products will be examined. Besides this new mandatory system, attention will be given to the European voluntary product assessment systems, which exist for many years in most European countries, and are expected to remain in place, although their scope might be very different and as far as they are not in conflict with the CPD and if there is a market driven demand.

At the moment, the CPD is at the end of its first phase, with the first generation of harmonised technical specifications becoming available and being used in the construction sector. The activity will explore domains that the CPD does not cover for the time being and where supporting Standardisation activities are on-going (e.g. dangerous substances, durability, life cycle analysis, environmental declarations, etc.).

On 1 May 2004, the CPD will be applicable in an additional 10 countries, with 28 countries requiring construction products to be CE Marked. This will certainly influence the introduction of CE Marking. Thanks to the CPD, the way technical product specifications are being written has changed. It is expected that the CPD technical specifications should be a driving tool towards performance based works specifications and regulations in a very large part of geographical Europe.

Objectives of the New Task
It has been acknowledged that the CPD should be a basic element in PeBBu work and therefore, the introduction of the CPD is considered to be a horizontal task in PeBBu. The objective of the activity was to provide basic info on the CPD to the PeBBu Domains and Tasks, and to receive and incorporate feedback in a final report that aims at linking PeBBu with the CPD.

The summary report for this Task is given in Annex XVII.

A special emphasis in this activity's scope and objectives was on:
- Providing support regarding the Construction Products Directive (89/106/EEC)
- Analysis of the PBB regulatory systems that are already implemented on a regional, national or local basis, with an understanding as to how those systems are structured

- Analysis of how PBB regulatory systems can incorporate CPD technical specifications.

GT2 - Decision Support Tool-Kit for PBB

Objectives of the New Task
The objective of this activity is to give an overview on decision support tools for performance based building. The most promising ones are presented in detail and their applicability was tested in selected PeBBu Domains using simple software prototype applications. Recommendations for further development were drawn and integration of feasible tools was proposed.

The summary report for this Task is given in Annex XVIII.

GT3 - Sustainability Indicators for PBB: CRISP Indicator Analysis

Objectives of the New Task
The objective of this activity is to report how Performance Based Building can benefit from the EC FP5 CRISP (Construction and City Related Sustainability Indicators) Thematic Network outcome. Within the CRISP project (2000-2003) 24 organizations from 14 countries collected and validated 38 relevant indicator systems using a compatible sustainability framework. This activity aimed at studying and selecting CRISP indicator systems and individual indicators that can add value to PBB.

The summary report for this Task is given in Annex XIX.

3.3.6 Aligned Tasks

Two Aligned Tasks have been introduced in the PeBBu project. The Compendium of PBB Models, and the Compendium of PBB Statements of Requirements. These tasks have been initiated by CIB prior to the establishment of the PeBBu network, and have been recognized as a supplement of significant added value to its deliverables.

A brief summary of the objectives of each task is given below.

AT1 - Compendium of PBB Models

This Task was mandated by CIB in 2000 to CSIRO, Australia, to prepare an international database of Building Performance Models. With the establishment of the PeBBu Thematic Network it was incorporated as an aligned task. The outcome of this Task is the Compendium of models that can provide the professional community with information on existing models, their scope and usage mode, as well as on their scientific background and verification.

The summary report for this Task is given in Annex XX.

AT2 - Compendium of PBB Statements of Requirements

This Task was mandated to prepare a "consensus based conceptual framework" for the PeBBu project overall and to develop documents that would provide examples of how the Performance Based Building (PBB) approach is used during actual building projects.

The primary objective for this Compendium was to provide support to the PeBBu Domains and Tasks so that they would prepare their own conceptual framework within an overall understanding of the PBB approach.

The deliverables of this Task include:
1. Conceptual Framework (articles, papers, presentations, and other documents).
2. Compendium of PBB Statements of Requirements (SoR), including Case Studies.
3. Related Terminology, Bibliography, List of key words to be used for research mapping, and Glossary of related Abbreviations, Acronyms and Initialisms.

The summary report for this Task is given in Annex XXI.

3.3.7 Pilot of Interactive Website for Educational Purposes

It was realised that one of the key contributions of the PeBBu network can be to assist in preparation of materials for education and training related to PBB. Thus it was decided in a Steering Committee Meeting held in June 2005 in Helsinki that part of the budget can be used for preparation of a pilot interactive website or CD for educational purposes. Two domains were chosen for this pilot project namely, Domain 2 on Indoor Environment and Domain 3 on Design of Buildings. The pilot project would begin by putting all the PBB related domains and the building process as well as stakeholders in a matrix in which each intersection can be clicked and leads to a set of educational materials. This may be text, documents, images, PowerPoint presentations or a list of resources. However, at this moment only the parts related to the two identified domains will be populated.

The pilot website is expected to be ready by end of October 2005 and can be accessed via the PeBBu website. The summary report for this Task is given in Annex XXII

3.3.8 Non Funded Tasks

Two additional components, which are a direct outcome of the PeBBu project, have been added to it without any additional funding. These include the newly established National Platform in Sweden, and a new Regional Platform in Australia, which is expanding its efforts to include the entire south-East Asian region.

The summary report for these Tasks is given in Annexes XXIII to XXIV.

3.3.9 Assigned Task Leaders

The listing of all the assigned Task Leaders is given below.

As mentioned before, an overall scientific responsibility for achieving a maximal alignment between the activities that fall under the different tasks was given to the Network Technical Committee, in which the Tasks Leaders participated.

All main tasks were facilitated, and through this facilitation also coordinated, by the Network Secretariat, which was a responsibility of the Coordinating Contractor.

Task	Task Name	Organisation	Task Leader	Support TL	e-mail address
T01-D1	Domain 1: Life Performance of Construction Materials and Components	KTH, Sweden CSTB, France KTH, Germany	Christer Sjöström JL Chevallier	Wolfram Trinius	christer.sjostrom@hig.se jl.chevalier@cstb.fr trinius@trinius.de
T02-D2	Domain 2: Indoor Environment	TNO, Netherlands	Philomena Bluyssen Marcel Loomans		p.bluyssen@bouw.tno.nl marcel.loomans@tno.nl
T03-D3	Domain 3: Design of Buildings	EGM, Netherlands	Dik Spekkink		d.spekkink@spekkink.nl
T04-D4	Domain 4: Built Environment	Univ. of Reading, UK	Colin Gray		c.gray@reading.ac.uk
T05-D5	Domain 5: Organisation and Management	VTT. Finland	Pekka Huovila		pekka.huovila@vtt.fi
T06-D6	Domain 6: Legal and procurement Practices	Univ. of Manchester, UK DBRI, Denmark	Peter Fenn Kim Haugbølle		peter.fenn@umist.ac.uk khh@sbi.dk
T07-D7	Domain 7: Regulations	TECHNION, Israel	David Pilzer		davidpi@moin.gov.il
T08-D8	Domain 8: Innovation	Univ. of Salford, UK	Peter S. Barrett	Martin Sexton Angela Lee	p.s.barrett@salford.ac.uk m.g.sexton@salford.ac.uk a.lee@salford.ac.uk
T09-D9	Domain 9: Information and Documentation	Univ. of Montreal, Canada	Colin Davidson		dav0528@attglobal.net
T10-UP1	Task 10: User Platform: Building Owners, Users and Managers	BRE, UK	Tim Yates		yatest@bre.co.uk
T11-UP2	Task 11: User Platform 2: Building & Construction	BBRI, Belgium	Luk Vandaele		luk.vandaele@bbri.be

	Industry				
T12-UP3	Task 12: User Platform 3: International Standardisation & Conformity Community	BRE, UK	Nigel Smithies		smithiesjn@bre.co.uk
T13-RP1	Task 13: Regional Platform 1 North Europe	KTH, Sweden KTH, Sweden	Christer Sjöström	Wolfram Trinius	christer.sjostrom@hig.se trinius@trinius.de
T14-RP2	Task 14: Regional Platform 2 West/Central Europe	BBRI, Belgium	Luk Vandaele	Johan Parthoens	luk.vandaele@bbri.be johan.parthoens@bbri.be
T15-RP3	Task 15: Regional Platform 3 East Europe	ÉMI, Hungary	Károly Matolcsy	Gábor Tiderenczl	mat.k@mail.emi.hu gtideren@emi.hu
T16-RP4	Task 16: Regional Platform 4 Mediterranean Europe	NRC, Italy	Paolo Cardillo	Giuseppina Varone	paolo.cardillo@itc.cnr.it giuseppina.varone@itc.cnr.it
T17-Map	Task 17: International Mapping PBB Research	CIBdf, Netherlands	Mansi Jasuja		mansijasuja@hotmail.com
T18-NM1	Task 18: Network Management – Steering Committee	CIBdf, Netherlands	Wim Bakens	Mansi Jasuja	wim.bakens@cibworld.nl mansijasuja@hotmail.com
T19-NM2	Task 19: Network Management – Technical Committee	CIBdf, Netherlands	Wim Bakens	Mansi Jasuja	wim.bakens@cibworld.nl mansijasuja@hotmail.com
T20-NM3	Task 20: Network Management – Network Secretariat	CIBdf, Netherlands	Mansi Jasuja		mansijasuja@hotmail.com
T21-NM4	Task 21: Network Management – Financial Coordination	BBRI, Belgium	Bart Michiels		bart.michiels@bbri.be
T23-NAS	Task 23: NAS SotA	EMI, Hungary ICASA, Slovakia EMI, Hungary	Károly Matolcsy Peter Matiasovsky	Gábor Tiderenczl	mat.k@mail.emi.hu usarmat@savba.sk gtideren@emi.hu
T24-GT1	Generic Task 1: PBB & Construction Products Directive	BBRI, Belgium	Winnepenninckx		eric.winnepenninckx@bbri.be
T25-GT2	Generic Task 2: CRISP Indicators	VTT, Finland CSTB, France CSIRO, Australia	Pekka Huovila JL Chevallier Greg Foliente		pekka.huovila@vtt.fi jl.chevalier@cstb.fr Greg.Foliente@csiro.au
T26-GT3	Generic Task 3: Decision Support Toolkit for PBB	VTT, Finland	Pekka Huovila	Janne Porkka	pekka.huovila@vtt.fi Janne.Porkka@vtt.fi
T27-C1	Compendium 1: PBB Models	CSIRO, Australia	Greg Foliente		Greg.Foliente@csiro.au
T28-C2	Compendium 2: Statement of Requirements & PBB Conceptual Framework	ICF, Canada BRE, UK	Françoise Szigeti	Jo Prior, Kathryn Bourke and Tim Yates	fs-gd@icf-cebe.com PriorJ@bre.co.uk
T-29-RTD	RTD Agenda Synthesis	CIBdf, Netherlands CSIRO, Australia VTT, Finland EGM, Netherlands MinistryVROM, NL	Wim Bakens Greg Foliente	Pekka Huovila Dik Spekkink George Ang	wim.bakens@cibworld.nl Greg.Foliente@csiro.au pekka.huovila@vtt.fi d.spekkink@spekkink.nl george.ang@minvrom.nl
T-30-Pilot website	Pilot Interactive website for Educational Purposes	TNO, Netherlands EGM, Netherlands	Marcel Loomans Dik Spekkink		marcel.loomans@tno.nl d.spekkink@spekkink.nl

3.3.10 Network management

The Management of the Thematic Network included the following components:

- Steering Committee
- Technical Committee
- Network Secretariat
- Financial Coordination

3.3.10.1 *Steering Committee*

A Network Steering Committee has been set up whose task was to give overall scientific and managerial guidance on both the strategic and operational level to all activities in the Thematic Network program.

The Steering Committee had the following Members:

- Network Secretariat (that acted as the Committee's Secretariat)
- A high level representative of each of the nine Principal Contractors

The Steering Committee met once a year in the respective four year period.

The Steering Committee has played a very positive 'steering' role in the project. In a meeting in August 2003, several intervention decisions were made which brought about a positive impact on the PeBBu project, including the termination of three Domains, and the launching of three new Generic Tasks.

3.3.10.2 Technical Committee

In conjunction with two of the meetings of the Network Steering Committee, the Network Secretariat organised a meeting of the Network Technical Committee. The members of this Technical Committee were initially the PeBBu Task Leaders who were then joined by the Leaders of the three Generic Tasks, two compendia projects, the aligned Task Leaders, the Aligned Regional Platform Aus-PeBBu, and observers.

The objectives of the Technical Committee were to achieve a maximal technical alignment between the activities as were included in the nine Scientific Domains, the three User Platforms, and the four Regional Platforms. Initially, the Technical Committee was expected to meet once every two years but a decision for the Technical Committee to meet more regularly and to be more active in the PeBBu project's on-goings was made in the Steering Committee meeting held in August 2003, resulting in annual meetings.

3.3.10.3 Network Secretariat

Main tasks for the Network Secretariat related to:

- Annual Technical and Financial Reports
- Regular News articles
- Final report
- Website development and maintenance
- Technical Support Unit
- Project Management
- Organisation of Series of domain meetings

Annual Technical and Financial Report

The Network Secretariat was responsible for producing annual reports according to the respective EU directives on planned and actually achieved activities, deliverables and progress. Those reports were the basis for the respective EU Scientific Officer to make the annual stop/go decisions as concerns continuation of the EU funding of the PeBBu Programme.

Regular News Articles

The Network Secretariat was responsible for producing and distributing regular news articles on issues related to the progress of the PeBBu domains, regional platforms, and user platforms, as well as other publications, news, projects, conferences of interest to PBB. Most of these news articles were sent out electronically and also placed on the PeBBu website.

Final report

The Network Secretariat produced the required Final Report according to the respective EU directives. The report is published in both electronic and paper format.
Apart from the final report, the almost final outcomes of PeBBu were presented in an international conference in Helsinki, Finland in June 2005 [Huovila, 2005a].

Website development and maintenance

The Network Secretariat has set up and was responsible for maintaining the PeBBu website (www.pebbu.nl) during the four years of the duration of the project: This website includes the following components:

- General Information about PeBBu, especially for non PeBBu Members
- Permanently updated data on Members, Scientific Domains, Regional Platforms and User Platforms and their Workshops (in the format of an relational database)
- All Workshop Reports and all State of the Art reports
- Electronic PeBBu Newsletter (this includes various PeBBu Newsgroups that were defined and populated based on a broad and worldwide survey of interests, to which both PeBBu Members and non Members may subscribe)
- Electronic publications from PeBBu related R&D project, as far as made available to the Network Secretariat.

The PeBBu Website has become 'the' portal to information on all PeBBu activities, members and results and was 'the' platform for information transfer between the various defined PeBBu Scientific Domains, Regional Platforms, User Platforms, Steering Committee, Technical Committee and the Network Secretariat.

All above mentioned items included in the PeBBu Website are open to all. In addition, the website includes sections with information that is accessible to the PeBBu Members only.

Project Management

The PeBBu Project Management related to:

- Attracting additional EU (especially from within East Europe) and non-EU Members to the Network and offering support to the new Members as concerns finding funding for their activities. This concerned both new members in general and industry based new members in particular.
- Coordination with other major international Networks and R&D Programmes that are of special importance to achieving the Network's objectives
- Acting as the Network's first contact for the EU respective Scientific Officer
- Supervising the performances of the Network Secretariat

Organising Series of Domain Meetings

In a Steering Committee meeting held in August 2003, it was decided that it is beneficial to have a combined series of domain meetings instead of stand-alone domain meetings, in order to give an opportunity for domains to interact with each other and for the network to really operate as a network. The Network Secretariat was thus responsible for organising and coordinating these meetings with the help of the Domain Leaders.

The first of such meetings was held in Manchester, UK, in January 2004. The second (additional, not in the original Work-plan) series of meetings was held in Porto, Portugal, in November 2004.

3.3.11 Summary Tasks and Deliverables

Annexes I to XXVI include detailed formatted summaries of the above listed tasks. Most of them include the following information, as adequate for the specific Task: Leaders, Members, Website address, Scope and objectives, Conceptual framework, Accomplished work-plan, State of the Art report, Inter-relations with other Domains/Tasks, Incentives and barriers for PBB implementation, Proposed research agenda, Dissemination and implementation, and Conclusions.

State of the Art Findings and Results

CHAPTER 4

4 State of the Art Findings and Results

The PeBBu network included more than twenty defined Tasks, each handling a different aspect of Performance Base Building, PBB. The individual deliverables, main results and specific findings of every Task are summarised in the relevant Annex to this report. In addition, the fully detailed reports and other documents produced by the Task Leader and the Task Members during the network's 4-year period are downloadable from the PeBBu website, at the Task's address as indicated in the specific Annex (See section 8.2 for the list of all Final Reports)

This chapter does not try to further summarise the 26 Annexes. Its main intention was to scan the findings of the separate groups from a bird's eye, trying to integrate them horizontally, while addressing key issues of PBB-related themes. To accomplish this, the chapter handles first some PBB basic concepts (Definition and Scope of PBB, Conceptual Framework, Stakeholders, User Needs, Performance Requirements and Criteria, Fitness for Use, Assessment Methods) and then proceeds to issues related to implementation of PBB in the building process (Regulatory Concerns, Standardisation, Economic Performance, and Research Needs).

The next two chapters (5, 6) then dwell further on some specific findings, which are of major significance for the main topic of more intensive worldwide implementation of PBB.

4.1 Definition and Scope of PBB within the PeBBu Network

The simplest and most widely cited definition of the Performance Concept in Building has been given some twenty years ago by CIB W060 by the phrase "*the practice of thinking and working in terms of ends rather than means*" [Gibson 1982]. This definition, or a similar paraphrased version, has been adopted vastly in literature as well as by many PeBBu Tasks, emphasising that the target of enabling specified (usually improved) performance-in-use of buildings is the main feature of a PBB environment. Some point out, however, that working in terms of ends is not an essential part of all PBB stages, but rather a means of implementation, which may be adopted at various points along the process.

It should be noted that the W060 definition focused mainly on ends relevant to the building's direct users (occupants) and the general public, whereas, according to some of the PeBBu Tasks [Barret 2005a, Gray 2005, Foliente 2005c, Fenn 2005] PBB should address a much wider range of end targets, including also ends related to the overall built environment and the building process itself, as well as ends relevant for other stakeholders, such as the entrepreneur, building owner, investors and insurers, facility managers, and the organisation occupying the building.

Apparently, the scope of PBB in the PeBBu Network is very wide, encompassing the complexity of interactive relations arising between the three C's: Concept, Content and Context. It consists of the full set of actors relevant along the entire building process (denoted by the general term Stakeholders), the specific Building and the general Building Market, with the Performance Concept applied as a basis for the various professional activities, such as regulation, standardisation, procurement, design, contacting, operation and maintenance.

4.2 Conceptual Framework

PBB is regarded as an alternative framework to the long lasting prescriptive-based framework that dominated the building market until the middle of the 20th century. Its manifestation in explicit procedures can be implemented as a coherent all encompassing framework for all the stages in the building project's life cycle, or alternatively as a local methodology for a specific task at one given point.

The introduction to the 3rd International CIB-ASTM-ISO-RILEM Symposium on Applications of the Performance Concept in Building reads "*The Performance Concept provides a flexible and technically non-prescriptive framework for building design and construction. Its application in building consists of translating human needs to user requirements (for serviceability, safety, security, comfort and functionality within the building's spaces, and for an adequate life expectancy of the building and its parts); transforming them into technical performance requirements and criteria; implementing them in the various stages of conceptual, preliminary and detailed design, to enable cost-effective construction of buildings that provide long-term satisfactory performance. In addition it is applied in the regulatory framework, via building codes, standards and performance specifications; in the processes of evaluation and assessment of innovative building materials, components and whole building systems; and lately as the underlining definition of quality for the modern approach to quality assurance according to ISO 9000*" [Becker 1996b]. These general statements re-appear in most of the PeBBu Tasks' reports, but the details of the elaborated individual PBB frameworks are usually different, each proposing a fragment relevant to the specific Task.

Combining the various fragments into the main frameworks suggested by Domains 2, 6 and Aligned Task 2 seems to yield an integrated framework, which suitably represents the PeBBu Network context for PBB implementation, as illustrated in Figure 4.1 below. Each particular building project resides in the inner yellow circle. The building facility is regarded as a system with a very long life cycle composed of many interconnected items (materials, products, components, etc.). Its relevant user needs comprise a dynamic set of performance requirements established by numerous stakeholders, who belong to the four identified markets, as well as by the regulatory framework, which addresses also the anonymous users who are not engaged in the building process. The various stakeholders engaged in the different stages of the building process supply the final outcomes and establish the actual performance-in-use. In the context of the PeBBu Network, it is the task of the regulatory framework and knowledge domain to supply the tools for a smooth match between the performance-demand and the building-supply sides.

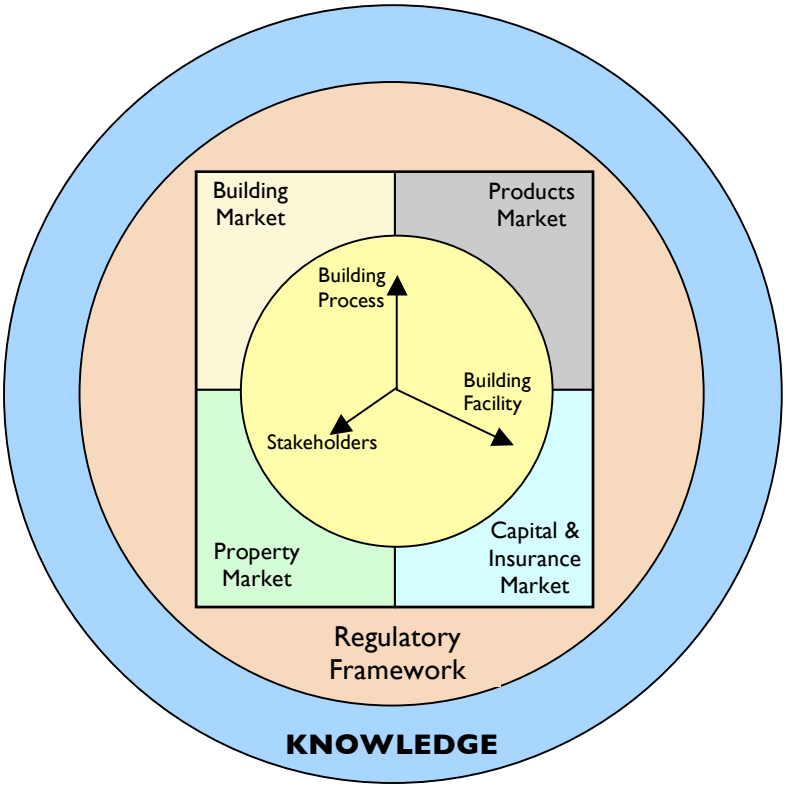


Figure 4.1: Conceptual Framework for PBB Implementation

Although the benefits may be significant, it is well accepted that using a performance-based approach at any stage in the building process is more complex and demanding than going the simpler prescriptive route. Consequently, applying this approach should not be regarded as an end in itself. Moreover, it is recognized that in most common situations (mainly when simple buildings are concerned and well experienced technologies are used) the prescriptive routine is faster, less costly, and more reliable for ensuring the building's performance-in-use. On the other hand, when innovations are concerned, the utilization of the performance-based route at almost every link and stage is indispensable. The PBB framework presented above thus enables both, the prescriptive-based as well as the performance-based approaches to be followed at any point in the multi dimensional space of the building market. The choice of using one or the other should be made by the relevant stakeholders, based on cost/benefit evaluation as to which way is more suitable at that particular point for ensuring proper performance of the building in use. The infra-structure needed for allowing and enabling a learned choice must be embedded in the regulatory framework (see sub-chapter 4.8). Scientific and applied research should prepare the knowledge infra-structure necessary to evaluate the costs and benefits of applying either approach, as well as the more technical knowledge needed when any of them is chosen (see sub-chapter 4.12 and Chapter 6).

4.3 Stakeholders

Numerous general stakeholders are involved in the overall building process in addition to the specific stakeholders concerned with every particular project. Each of the parties regards the building's performance from a different perspective. Some of the stakeholders belong to the demand side and establish the needs' database, while others belong to the supply side and affect the actual performance in use.

The list of stakeholders addressed explicitly or implicitly in PBB-related literature includes:

- the **State or Government** (represented usually by law makers, state officials, and civil servants) whose main involvement is in the regulatory, Standardisation and enforcement frameworks;
- the **Municipality** and **Authority Having Jurisdiction** (represented usually by the City Engineer and/or municipal Building Official);
- the professional organisations and institutes engaged in **Standardisation**, **Approval**, **Certification**, and **Inspection**.
- the **Entrepreneur** (also denoted as the Client);
- the **Owner**/s during the building's service life (not necessarily identical with the entrepreneur), including the **facility managers** who operate and mange the facility on behalf of the owner/s;
- the direct and indirect human **End Users** (who inhabit the building, visit it, work in it, enter it for rescue operations, reside nearby or walk around it);
- the various members of the project's **Design Team**;
- the various **Manufacturers**;
- the **Contractor** (including sub-contractors);
- the **Investors** and **Insurers**.

The State is concerned first and foremost with ensuring the basic needs (health, safety, security, hygiene, comfort, habitability, durability) of the direct and indirect end human users and small owners who do not participate in the design and construction stages of the building facility but are the main group affected by its performance. The State's main concern is the duty of care – i.e., addressing true needs, which market forces may neglect to take care of properly or to the adequate extent. For some industrial occupancies, where building performance may affect the products manufactured in the building and subsequently bear on the health of people using them (such as public kitchens, food production industry, pharmaceutical industries, etc.), the State is also concerned with special minimal cleanliness and hygiene needs. In addition, the State is concerned with the long term protection of the environment from the building's direct and indirect impacts during its entire life cycle from cradle to grave (including effects stemming from depletion of resources, emissions, energy consumption, etc.).

Besides protecting the needy, the State is interested in maintaining a vital and economically stable building market, in promoting export, and in preventing raised building costs due to unjustified barriers on imports, excessive mandatory demands, or complex regulatory procedures.

In addition, the State is called upon when natural or man-made disasters occur. It bears the financial burden for rescue and immediate help, as well as for compensation when insurance does not cover the event.

Consequently, the State is usually involved in the stages of setting concepts for and writing/adoption of regulations, codes, standards, and any other formal documents that dictate the overall mandatory procedures and the levels of overall mandatory requirements (see section 4.8 below). The decision to enable a performance-based regulatory framework in the country, as well as providing conditions for performance-based procurement is usually obtained at the level of Government in order to facilitate the introduction of innovations and to somewhat eliminate the barriers to free trade. Government is also engaged in setting the proper procedures for enabling performance-based regulations, and for assessment and approval of design solutions that are based on such regulations.

In order to have all these accomplished without imposing a prohibitive economic burden on the building processes, most countries avoid a revolutionary change from a prescriptive based framework into a solely performance-based one, and enable the daily use of the commonly accepted prescriptive documents under the title of "Deemed-to-Satisfy Solutions" or "Approved Documents". The performance-based approach is then kept as an option for those parts in the process when innovations are introduced, or when the entrepreneur, a member of the design team, or the contractor are interested in an alternative solution to that enabled by the common approach.

In some countries, the performance-based part of the regulatory framework does not stipulate the values of performance criteria neither the way to obtain them, and enables this to be settled by negotiation between the entrepreneur (and his team) and the authority having jurisdiction (e.g., Australia, and USA). In other countries, the tendency is to avoid negotiable requirements, and a need is recognised for tools which enable translating the qualitatively defined user needs into quantitative criteria (e.g., The Nordic countries, Israel). Acknowledging the gaps in knowledge and lack of scientific tools for such translation in many areas of building performance (e.g., indoor air quality, fire safety) and for adequate and reliable assessment methods for the design and delivery stages, governments interested in more profound implementation of PBB should also engage in the promotion of research intended to bridge these gaps.

The State also establishes rules and restrictions on the procedures utilised for tendering in general and particularly for tendering of construction works by the public sector. The American mandatory new rules enforce performance-based contracting of facility management, stating " *Performance-based contracting" means structuring all aspects of an acquisition around the purpose of the work to be performed with the contract requirements set forth in clear, specific, and objective terms with measurable outcomes as opposed to either the manner by which the work is to be performed or broad and imprecise statements of work.*" [US Government 2000]. This pioneering approach has not yet been adopted in Europe. However, the intents for barrier-free trade, equal opportunity options and international validity of products, which are the underlining explicit intension of the New Approach directives, may lead in the future to similar decisions and regulations for the European public sector. It is not foreseen that such regulations will be imposed on the private sector, but when a private entrepreneur prefers to adopt performance-based contracting, the lessons learned from the public sector's usage of the relevant legal procedures and documentation may be helpful. Gathering the information on experience gained by USA governmental and other public entrepreneurs may thus be a significant information source for successful implementation of performance-based contracting in Europe.

The Municipality is usually concerned with overall aspects of the built environment, with the direct effects of the building on the public infra-structure and service systems (water and gas supply, sewage, transportation and parking, etc) and on other buildings and public areas in its vicinity, and with the effect

of the built environment on the general public. Domain 4 of the PeBBu Network has been devoted to the Built Environment, and gathered information on these aspects (see Annex IV for details).

In addition, concepts embedded in the zoning ordinance and urban planning documents issued by the Municipality may affect the performance of individual buildings (e.g., the orientation and size of land lots, as well as aesthetic requirements for building facades may prevent the employment of solar systems; proximity of building facades to traffic carrying roads affects acoustic criteria for the building envelope; distance between buildings affects the fire resistance required for the exterior walls and the maximal dimensions of windows). These inter-relations between urban planning and performance-based design of individual buildings call for deeper involvement of City Engineers and members of the City Council in the national and international processes of establishing performance criteria.

The Authority Having Jurisdiction, which may be identified with the Municipality or another municipal authority, is usually not well equipped to cope with PBB, mainly due to lack of adequate professionals. In order to overcome this deficiency when innovative building systems and technologies are concerned, most countries introduced an innovations' approval system based on evaluation reports produced by professional bodies (usually affiliated with research-oriented institutes). Lately, in order to enable within a PBB environment the use of alternative scientifically-based analysis and design methods (e.g., for structural fire design according to the Eurocodes), Notified Bodies have been empowered to evaluate such designs. Based on their evaluation the alternative design method is then accepted by the Authority Having Jurisdiction. In the USA the building officials have lately established the International Code Council, ICC (replacing the previous three separate bodies BOCA, ICBO and SBCCI), and have devised in 2003 the first full Performance-based model Code [ICC 2003].

The Standardisation, Approval, Certification, and Inspection bodies are the main bridge between the authority having jurisdiction and the newly enabled performance-based approach. Standards that reflect envisaged performances of products, and those supplying the relevant performance test methods can be adopted in performance-based regulations. Prescriptive standards can be adopted in the part that delineates the approved solutions. Evaluation Reports and Approvals of innovative building systems and technologies provide the basis for granting a building permit, as well as for specific additional inspection steps, when such innovations are introduced in a given project. All these documents can also be used within the framework of performance-based programmes and tendering briefs.

Writing of standards has changed its scope during the last twenty years. Previously, most standards prescribed the composition of materials or building components, and the tests to be used for classification and quality control. Standardisation Committees were thus composed mainly of manufacturers. With the introduction of performance-based thinking, standards are expected to supply the tools for assessing a wide range of similar products intended for the same use, enabling a variety of manufacturing techniques and material formulations. Standardisation Committees cannot be composed any longer of manufacturers only, and must include professionals familiar with the usage patterns and the long term performance of the components in which the product is used, as well as the user needs relevant to the particular components. ASTM and ISO, as well as national standardisation bodies, have recognised this needs, and established committees or sub-committees responsible for building performance related standards [ASTM E06, ISO SC 03, ISO SC 15].

The professionals engaged in assessment of innovations or of alternative design methods utilise the performance-based approach as a routine framework for their activities [WFTAO, UEAtc, EOTA]. The gaps in knowledge Agrement organisations and Notified Bodies identify can thus be a significant input to the broader scope of PBB research needs, but, as innovations are sometimes highly esoteric, these gaps may sometimes be of little interest to the profession at large.

Certification and Inspection bodies perform tests, inspect work, and certify products or works according to standards and against specified documents and drawings. The nature of their activities is and will remain prescriptive based. However, when innovative systems or technologies are incorporated in a given

project, they must address the additional tests and inspection procedures requested in the Evaluation Reports and Approval documents.

The Entrepreneur is the initiator and main stakeholder in every given project (in the UK and some other European countries he is called the Client). His interests are expressed by a variety of targets that motivated the initiation and affect all the project stages. Performance of the building in use is not always an essential part of these targets, mainly when the entrepreneur does not intend to remain the building owner or its main user. On the other hand, he will always prefer the building process that ensures value/money more reliably without risking excessive delays in the delivery of the finished building and/or excessive litigations upon its occupation. Application of a PBB environment implies that, despite the specific preferences of a given entrepreneur and despite the specific process he chooses, the entire building framework he acts in should lead to the provision of adequately performing buildings in use.

A distinction should be made at this point between a public and private entrepreneur.

When a Governmental Agency or any other public entity initiates a building project, the specific function is always the building's raison d'etre. A similar situation exists when a private entrepreneur builds a facility for his own use. Consequently, adequate performance of the building in use is part of the main targets these entrepreneurs would be committed to achieve. In addition, the public entrepreneur is obliged by law to refrain from specifying products by the name of their manufacturers in order to enable free competition. Subsequently, although not always addressed explicitly, the need to ensure adequate performance without specifying the exact products has a significant impact on the framework chosen for the various stages of the building process [US Government 2000]. Until some 20 years ago, conceptual and detailed design was always performed by the design team chosen by the entrepreneur, while performance-based contracting has been a frequent choice for the actual construction process. In the last 25 years, increased request for explicit responsibility for the adequate performance and maintenance of public works, side by side with major cuts imposed on public expenditure evoked various procurement methods for design, construction, operation and maintenance of infra-structure facilities and governmental office buildings, where the private sector is recruited into the project not as a mere contractor, but rather as a partner who takes part in the financing of the project as well as in its operation. A multitude of procurement methods is addressed by Domain 6, including: Design and Build, D&B; Design Build Fund Operate, DBFO; Build Operate Transfer, BOT; Build Operate Own Transfer, BOOT; Private Finance Initiatives, PFIs; and Public Private Partnership, PPP. All these methods require the establishment of a Performance Based Design Brief, PBDB, as an integral part of the tender. However, most of them have been applied to infrastructure works, which are engineering type projects with a limited number of well established design rules, and still the main handicap pointed out by the entrepreneurs' professionals is the difficulty in establishing as early as possible the exhaustive set of performance requirements. The number of building projects commissioned by the procurement methods listed above is still very scarce, and there is no sufficient information on the PBDBs used in their commissioning, except general outlines [Ang 2005, PBSRG Newsletter]. The Wilhelminahof Tax Office in Rotterdam commissioned by the Dutch Building Agency (RGD) by means of a performance-based D&B tender is an important example of such a building project, as presented from unpublished literature in the reports of Aligned Task 2 - Compendium of Statements and requirements. An objective follow-up of this project brought forward some key lessons learned from the entrepreneurs' experience during the various stages of design, construction and operation, as well as from the post occupancy evaluation in the occupied facility, which investigated its actual achieved performances and compared them to the performance requirements stated in the design Programme (for details see Annex XXI). The ISO Sub-Committee for Functional/User Requirements and Performance in Building Construction, TC59/SC3, has recognised the difficulty encountered with identification of needs and performance requirements at the project initiation stage, and prepared a template for preparing PBDBs that can be used under various procurement procedures [ISO 9699 1994]. Consistent gathering of information and objective follow-up of projects commissioned using such performance-based methods is of major significance in identifying the details of knowledge gaps and in establishing proper tools for performance-based procurement methods [PBSRG Newsletter].

When a private entrepreneur initiates a building project that he does not intend to use, the specific function of the building is not necessarily his main target. Long-term financial investment or short term fast profits may be dominant factors, each leading to a different approach towards the building's performance in use. The shorter the period that the entrepreneur would remain attached to the facility, the lesser is his natural devotion to ensuring its adequate long-term performance. Consequently, unless improved performance can promote sales, the entrepreneur will in this case prefer to provide the minimal performance levels stipulated by the regulatory framework, and build the "best selling" building. This entrepreneur has no use for an explicit PBB framework, and will usually prefer the more secure investment enabled by the traditional prescriptive-based design and construction processes.

When the private entrepreneur remains the owner he is concerned with the long term performance of the facility, depending if he uses it or rents it out, as explained below. These different scenarios may affect his preferences and lead to setting elevated performance levels for some aspects, and mainly for the durability of the building's infrastructure and facades.

Independent of the long term relations between the entrepreneur and the built facility, the project's scope and main targets need to be defined and transferred to the design team together with the design brief. A systematic tool for this stage, denoted as Project Definition Rating Index, PDRI, has been developed in the USA under the guidance of the Construction Industry Institute, CII [Dumont 1997] in order to improve communication of the entrepreneur's needs and ensure the completeness of transferred information and its control.

The Building Owners are concerned with the long term everyday performance of the building when they are also its main users. When an owner rents out his property to others, he would usually be concerned with those performance aspects that affect the renting rates, as well as with durability and maintenance of all those parts that he remains responsible for. However, when the potential owner is not the entrepreneur who initiated and constructed the facility, he could not be involved in the design process and had no ability to affect the building's performance level. For him, when looking for a facility, using an explicit weighted set of performance requirements established according to his own preferences, together with objective but simple assessment tools, may be instrumental in making the proper choice. The performance concept and terminology are thus very helpful in communicating the buyer's needs and demands.

During the service life of the facility, the owner manages, maintains and operates it with the assistance of a **Facility Manager**. The latter is the most direct person responsible for the building's actual performance in use. However, facility managers are hired for their task at a very late stage along the building process, and have no influence on its design. Learning from their experience in existing buildings and structuring this information into the tools for establishing PBDBs is one of the most important areas for applied PBB research. At later stages of the building life cycle, and mainly when repair, refurbishment and internal changes are considered, the facility manager is instrumental in assessing the existing performance levels, determining the needs for actions and establishing the new performance criteria for their outcomes. Using a performance-based approach at this stage, by means of relevant Key Performance Indicators (KPIs) and a cost benefit analysis, seems to be very helpful in ensuring the long term proper functioning of the facility [Shohet 2003, Davis 2004, Elley 2005].

The End Users of buildings are the largest and most anonymous group of stakeholders. They are usually not represented in the early stages of an actual building process. However, they generate most of the needs that should be addressed in design and operation of building facilities, and PBB implies an explicit consideration of these in order to ensure an adequately performing building in use. User Needs are usually generated by combinations of User-Activity modules (e.g., Person-Sleeping, Pupil-Listening, etc.). Identification of the relevant modules in a given building project is an essential step in the preparation of a PBDB. The knowledge base for attaching User Needs to User-Activity modules, and for translating them into tools that can be incorporated in design and operation of buildings is being developed in research institutes by means of controlled laboratory studies, field investigations, and Post

Occupancy Evaluations (POE). The implementation of this knowledge into the design process is an essential feature of PBB [Fanger 1970, Blacherre 1987, Becker 1993].

Safeguarding the fulfilment of end user minimal needs for safety, security, comfort and serviceability in every building is the task of the regulatory framework. As explained above, it is assumed that an implicit role of the State representatives in the relevant regulatory committees is to take care of these minimal user needs. In Standardisation Committees the interpretation of the regulatory intentions depends on the user-relevant knowledge and data bases provided mainly by the research professionals. Lately, it has also become customary to include Consumers representatives In Standardisation Committees, assuming they represent the needs and interests of the end users. The participation of the last two groups in committees preparing performance-based standards and codes is much more significant than in those preparing the prescriptive documents.

In a given project, when the entrepreneur intends to remain the building owner as well as its main user, he may be interested in ensuring improved performance levels regarding safety, security, comfort and serviceability conditions. His motives for improving performance may stem from various targets, including increased prestige and image of the facility, increased employees motivation, increased efficiency and productivity, preparing for future upgrading of requirements, prevention of accelerated deterioration, increased flexibility of space utilisation, etc. In each of these cases, he may have different preferences for the various parts of the facility, with different priorities for the various performance attributes. Moreover, according to his main target, the entrepreneur's personal priorities would not necessarily coincide with those of the actual end users. Improving performance levels above the minimal ones stipulated by the regulatory framework is thus a per-project task, which cannot be framed into a standardised routine.

The end users are also generators of a large part of the Generalized Loads (e.g., generated internal heat gains, noise level created by the pupils during Free lessons, dynamic features of feet impact during dancing), which should be addressed in a performance-based design routine. These loads stem again from User-Activity modules, which not necessarily coincide with the Needs-generating modules.

The Design Team is composed of numerous professionals, including architects and engineers. The architect is usually the team leader, and is always hired directly by the entrepreneur. According to the specific setup, the other professionals may be chosen by the entrepreneur as well, or by the architect.

In the traditional framework, the architects are considered as the building's designers while the rest of the team is regarded as "Consultants". Without explicit performance requirements, the consequences of the engineers' design are assessed by measuring conformity with the prescribed regulatory provisions, or with other prescribed requirements made by the entrepreneur and/or the architect. This process is based on an implicit assumption that using the prescribed provisions ensures the adequate performance in use of the facility being designed.

In the framework of PBB the role of the various team members is altered, and their responsibility for the direct results of their work is enhanced. This framework implies that each member of the design team should explicitly consider the performance levels required by the regulatory framework and the additional ones imposed by the entrepreneur, and choose the solutions that meet them. In addition it implies that one area is not solved on the expense of others, and that the basic assumptions which affect performance in use (e.g., service conditions, occupants' behaviour, modes of the facility operation and maintenance, etc.) suitably represent the expected occupancy and are not conflicting each other. The flexibility of design and the ability to introduce innovative solutions may be attractive to creative professionals, but it usually requires more profound analysis and verification of the results. Even when one uses the previously outlined scenario, and bases the design solutions on prescriptive provisions, his design may be assessed against its outcomes and the actual performance in use, and not against the provisions he chose. The level of responsibility associated with the PBB approach may thus deter professionals from using it in areas where the actual performance depends strongly on maintenance or occupants' behaviour, when the theoretical performance evaluation tools are not well established, or when reliable solutions can be derived only by means of sophisticated analysis and very complicated calculations. Consequently, when the

entrepreneur chooses the PBB route, acceptance of this responsibility should be part of the contract he makes with each of the design team members, inflicting on the costs of design due to the extended design hours and the increased professional insurance rates.

Three areas of engineering design (Structural, Fire Safety, and Energy) have adopted a performance-based approach during the last decade, and prepared some standardised infrastructure for its implementation in the design process.

The semi-probabilistic approach adopted in the Structural Eurocodes [CEN] is the most comprehensive set of design documents that is based on performance concepts. It is predicated upon the notion that from the User's viewpoint a building should be safe and feel safe (damage should not be excessively disproportionate to the size of the event causing it, and under regular service conditions no threat to safety should be felt). It sets safety and serviceability targets in physical terms related to the factors that adversely affect the building performance from the users' viewpoint (deformations, vibrations, cracks, ultimate failure). It provides the characteristic limit values for these physical factors when they are unique (e.g., displacement, crack width), or the method of generating them when they depend on other factors (e.g., capacity). It lists the types of loads to be considered while addressing every Need, and supplies the information on how to derive their values, including the partial safety factors associated with the loading combinations. And, finally, it lists the accepted analysis algorithms and calculation methods for evaluating the design. There are hardly any prescriptive provisions in the Eurocodes (even minimal thickness of concrete columns has been removed, although this provision still appears in some local codes that have otherwise adopted the Eurocodes). Structural engineers got used to develop the solutions in terms of achieving targets (preventing serviceability and ultimate limit states) and to suggest alternative solutions that provide the same level of safety.

Structural Fire safety engineering is developing in Europe in similar lines, with the Eurocodes devoting particular parts for performance-based design options in this area. The American Society of Fire Protection Engineering, SFPE, is also trying to generalize a performance-based approach to the overall Fire Safety design process [SFPE 2004, Rosenbaum 2005]. The documents produced hereto by SFPE can serve as conceptual guidelines but do not yet include the comprehensive set of design tools incorporated in the Eurocodes. Consequently, Fire Safety engineers trying to use a performance-based approach in their design have to develop individually the criteria, loads and design tools, a situation that increases their personal professional risk. It thus seems that this group of professionals is ready for the adoption of a performance-based approach in its design but lacks the supportive infrastructure that is needed for a reliable actual implementation.

Energy design of buildings is the third area in which a performance-based approach has been implemented in various countries, and mainly in the USA. The Energy Codes that were adopted by most American States include two design options. The prescriptive option follows the traditional provisions for thermal resistance of envelope elements, sizing of windows, etc. The performance option requires analysis of energy demand and its comparison to a calculated energy budget. While following the first option does not require highly specified knowledge beyond the regular architectural or building engineering education, the second option can be applied only by professionals who are well versed in the area of energy analysis and engineering [DOE 2005a, DOE 2005b].

Other design fields that are developing tools for performance-based design include Acoustics, Moisture Protection, Durability, and Indoor Air Quality. In regular design routine whenever a non-trivial problem occurs in the first area, it is handled by an expert (Acoustic Consultant), who may individually use a performance-based approach. Despite the lack of formalized performance-based codes, criteria stemming from User Needs are set in these cases by the expert and his decisions are derived by means of analysis and knowledge based tools, and performance in use is assessed by means of well-defined ISO Standard Test methods. However, in order to apply performance-based design in this area as a regular routine there is a need to develop and formalize accepted standardized methods for establishing criteria, as well as for the evaluation and assessment of the design solutions. In the area of Moisture Protection there is

now an ongoing international effort under the umbrella of IEA to prepare the professional and standard infrastructure for applying a performance-based engineering approach to design [MoistEng 2005]. In the areas of Durability, and Indoor Air Quality, the ongoing activity in applying a performance-based approach has been summarised by the dedicated Domains I & II (see Annexes I, II). The last three areas are in the domain knowledge of the "Building Physics Engineer". However, despite the advancements in scientific knowledge and the ongoing endeavours to develop tools for performance-based analysis in the last three areas, the professional setup of a regular design team does not include this expert, except in a few European countries (Germany, The Netherlands). Consequently, it is expected that even under a PBB framework, these areas will continue to be handled by means of prescriptive provisions until the need for adding the proper experts into the design team is well recognized.

PBB calls not only for performance-based design in every separate discipline, but rather for coordinated design and teamwork all along the design process. Moreover, in order to ensure the final long-term results (performance-in-use), it implies collaboration between the design team and the other stakeholders, or at least between the design team and the knowledge-base representing the potential inputs of the other stakeholders have they been known and present during the design process. In particular, the design team is expected to take into account the technological aspects of constructability, as well as the technical and behavioural aspects of maintenance.

The Manufacturers of building materials, products, components, and entire building systems become significant stakeholders in the PBB framework only when innovations or changes to a standardized product are concerned.

In their regular everyday manufacturing routine they produce the same series of products by means of the established process and materials, testing samples of the products regularly by means of simple quality control tests. The PBB framework accepts products as deemed to satisfy solutions when they are standardised, assuming implicitly that the standardisation committees have considered the envisaged performances and prescribed the provisions that ensure fulfilment of the requirements. The European CPD is based on this assumption, and utilizes the CE marking as a means for communicating the "fitness for use" information implied by the standard procedures.

When a manufacturer introduces major changes in the material formulation, or structure of the product, or when he designs a new component or entire building system, he cannot use any longer the standard testing methods for checking his own ideas before marketing them, neither do these tests provide a means for proving to others that his innovation meets their needs. The creative manufacturer is thus interested in a flexible performance-based framework that supplies the tools for checking the performance of his innovation, and enables its safe introduction into the building market. It is not surprising thus that the evaluation processes offered by professional bodies such as Agrement and Avis Technique organisations have been adopted by manufacturers as a means for proving the validity of their products. Although not mandatory in most countries, European manufacturers approached these organisations voluntarily in order to assess their innovations much before the CE marking has become mandatory. In South Africa, Canada, the USA and Israel the equivalent of a CE marking is not a mandatory requirement, and Evaluation of innovations is still pursued by their manufacturers voluntarily. Moreover, even in Europe, with the CPD enabling assessment of innovative products by Notified Bodies according to EOTA Directives, it is still expected that Agrement certificates will continue to be pursued by the manufacturers, since the Agrement assessment procedure addresses more aspects of performance in comparison with the minimal set of standard safety and health requirements addressed by the mandatory documents.

The creative manufacturer is the main user of Performance Test Methods for prototype testing. His involvement in the development of such tests is instrumental in establishing tests that are relevant to the specific product and detection of its weaknesses. It is, however, even more significant that committees developing such tests be familiar with the service conditions in buildings, as well as with the deteriorative mechanisms affecting the particular materials under local conditions.

The Contractor becomes an explicitly relevant stakeholder to PBB only when performance-based contracting is employed.

In performance-based contracting, the flexibility of solutions enabled by the tendering documents will be different for each project, but conceptually, in every such project the contractor can consider a wider range of products and technologies in order to produce the same construction works. In comparison to regular prescriptive briefs, this requests deeper knowledge and familiarity with products' properties and the ability to judge their suitability for the specific applications. For large contracting firms, who employ several engineers and probably a few architects as well, this tasks can be usually performed with due regard to the preferred construction technologies of the specific firm, and the flexibility is an asset, enabling optimisation of the construction process. When the adequate knowledge does not exist in the contracting firm, there is a higher risk of making wrong decisions, and small firms would thus usually prefer the fully prescriptive tendering procedure.

When the design-built option is used, the contracting firm is engaged in detailed design and not only in the construction of the facility. Firms engaged in such projects employ design teams highly familiar with the technologies preferred by the construction team of the same firm, thus aiming at optimisation of the entire process. Consequently, the contractor will prefer in this case to receive a detailed PBDB, listing carefully the envisaged performances and assessment methods, with as little as possible prescriptive decisions made by the entrepreneur's team. The ability of the contractor to detect ambiguities regarding envisaged performances as early as possible in the design process, and their clarification with the entrepreneur's team are instrumental in ensuring a finally well performing facility.

The Investors are interested first and foremost in the profits made by their investment. The success of a building project to meet its targets and fulfil its performance requirements is a cardinal prerequisite for ensuring the sales, rent and satisfactory operation of the facility. Meeting user requirement can also promote user satisfaction and positively affect workers' productivity. Proper performance of a facility thus becomes an asset to the entrepreneur, owners, renters, as well as to the investors, whose risk for reduced profits due to unpaid debts diminishes. When PBB is applied properly, the risk these stakeholders face is not greater than in a regular project and the chance for larger profits due to faster sales or renting of the facility is increased. However, when this framework is applied without the required rigour and the envisaged performance in use is not met, all the concerned stakeholders, including the investors, may suffer losses. Despite their role in the building market, investors are not familiar with the building's professional tools and frameworks. They do not participate in writing of regulations, standards, programmes or tenders. They can thus be regarded as silent stakeholders, who may be affected by the process taken for the execution of the project, but who hardly have the opportunity to affect it.

The Insurers provide the financial backup to erroneous decisions taken by the design team, as well as to poor workmanship of the contractors. In a prescriptive environment, it is easier to decide if the design was according to the standard provisions or faulty, and if the construction was performed according to the prescribed documents or not. Still, many cases end up in court, with the judge having to decide how to split the responsibility for the faults, which have occurred in the building. In most cases, the financial penalties imposed on the designer will be paid by his insurance company, whereas the contractor may sometimes choose to absorb the extra costs associated with the repair works without looking for reimbursement by the insurance company.

In a PBB environment, it is less obvious whose fault led to the mal function or violation of a performance requirement. In the event that the court accuses the design team in erroneous decisions, the official assessor of the design, who approved it and accepted it as a valid response to the performance requirements, may be regarded as a responsible party as well. Insurance rates for designers and approval bodies who participate in performance based design and assessment may thus be higher than those imposed on professionals engaged solely in prescriptive based routines.

A special insurance system exists in France, where each building has to be insured by the contractor (for ten years at least after its delivery) against any building faults that occur during this period. The insurance

company is directly responsible for the immediate remediation of any fault. By this system, the insurers have a major interest to verify that precautions were taken during the design and construction stages to ensure proper performance of the built facility, which also explains the early introduction of Agrement into the French building market. Such compulsory insurance strategy can play a major role in enhancing short-term building performance. However, as the extension of obligatory insurance beyond ten years is not economically feasible, this system cannot be recruited for enhancing building durability and long term performance.

Building owners may insure their property against natural disasters such as earthquakes, storms and floods, as well as against fire. Insurance companies base the premium rates on the existing local regulatory framework, design standards, quality of workmanship, and location, type, and age of the building. Moving from a prescriptive regulatory framework to a performance-based one may affect these insurance rates, as well as the assessment methods and scales appraisers use.

4.4 User Needs

The term User Needs is all encompassing, and even with relation to buildings covers many areas in which humans experience needs but building design alone cannot supply them. In the present context of PBB, this term is thus restricted to needs that may impose design and construction requirements on the building as a facility, on its specific delivery process, and on its inter-relations with the adjacent built and natural environment (e. g., solar rights, acoustic separation, fire spread), but not on its social urban location (e. g., proximity to schools or parks), or its final internal decor.

In qualitative terms, from the occupants' point of view, a building performs well along its entire life cycle when the functional spaces can be furnished and equipped to suit the activities taking place in them at first occupancy, as well as during refurbishment; thermal, visual and acoustic conditions needed for all these activities are adequate; indoor air quality is pleasant and causes no sickness syndromes; energy costs are not excessive; there are no building-related disturbances that interfere with any activity; under regular use and climatic conditions the building fabric does not deteriorate excessively, no visible cracks develop and there is no build up of dampness or moisture stains; operation and maintenance are easily enabled and are not too costly; safety in fire is ensured so that evacuation is enabled within a short period, fire does not spread easily beyond the room of origin, and in case of flashover the building structure does not collapse; structural serviceability is ensured, so that under regular service conditions structural deformations and displacements are not noticeable, and structural vibrations are not observed; structural safety is ensured, so that under the strongest wind or earthquake that may occur on the given site during the building's life cycle no severe structural damage is caused. The Owner may wish that the well performing building would include a few additional features, which are not directly relevant to the occupants' needs, such as: re-adjustment of the internal division of spaces is easily enabled; building features do not prohibit rehabilitation or change of occupancy; the building's visual features are impressive and attractive to renters; etc. The State may have some additional expectations from a well performing building, which are of no concern to the occupants or owner, including: minimizing the building-related environmental impacts; the life of emergency and rescue personnel should not be excessively threatened in case of fire; under extremely severe winds or earthquakes, which have a return period much larger than buildings' life expectancies, structures would not collapse; etc.

The entire set of above expectations is seldom achieved throughout a given building's entire life cycle. Even when design and construction have followed all the provisions stipulated in the codes and standards decreased levels of performance may occur at various stages. This is due to the stochastic nature of the various main factors affecting performance in use, such as the actual occupants hosting an actual building, the magnitude of the actual driving forces, the occurrence of unforeseeable exceptionally severe events, the actual variation of material and component properties, the actual quality of the workmanship details, and the evolution of expectations with time. The explicit elaboration and exhaustive listing of presently known and future foreseeable Needs, as well as of the expected events and driving forces that tend to

disturb their achievement, decreases the risk of overlooking random combinations which may be harmful to the building's performance. It is thus believed that, in the context of PBB, identifying the multitude of needs and integrating them into engineering-type design tools may decrease the probability of occurrence of situations when adequate performance is not achieved.

The Systems approach utilised in the 1970's in the USA for the development of performance specification for housing and for office buildings within the framework of the Operation Breakthrough project [NBS 1970], established a list of areas in which user needs should be identified and performance requirements should be stated. These areas were denoted by the term Performance Attributes. The list has been extended afterwards by various groups [Blachere 1987, Jaegermann, 1978, ISO 6241 1984, ASTM E2351 2005], and in most documents it includes several or all of the following: Spatial Characteristics, Serviceability, Operation and Maintenance, Structural Safety, Fire Safety, Accident Safety, Health and Hygiene, Indoor Climate, Indoor Air Quality, Acoustics, Illumination, Structural Serviceability, Moisture Safety, Energy efficiency, Durability, Sustainability.

User Needs are usually expressed in colloquial terms, which are easily understood by all the stakeholders, but lack the professional scrutiny needed for producing the actual design details. In essence, they should be regarded as a list of statements that should be further elaborated into a working tool for the professional design team. Various models have been suggested for this task. The most famous ones are the Nordic model developed as early as 1978 by the Nordic Committee for Building Regulations, and the Systems Approach model [Hattis 2001]. Both suggest a systematic algorithm for deriving the quantitative criteria from the qualitative statements (see section 4.5), while the Systems model suggests also an algorithm for the systemic derivation of the User Needs, as outlined also by ISO 6241.

The general performance-based design target may be expressed as "satisfying most user needs most of the time in all building spaces". However, some user needs may impose too costly solutions for general implementation in every building. It is thus recognised that a distinction should be made between Essential Needs, which are stipulated by the regulatory framework, and Optional Needs, which should be addressed per project, and selected carefully by all the relevant stakeholders. For many years, the titles of Essential Needs are stated explicitly by most Building Laws, delegating the responsibility for implementation by means of regulations or codes to a specific Ministry. Details in these regulations and codes have then been given in prescriptive terms, without explicitly ensuring a one-to-one match between the provisions and the intents of the Law. On the other hand, when the regulations and codes are written in a performance-based approach, they elaborate the needs into a hierarchical structure, which ensures that all the detailed requirements stem transparently from clear needs at its root (e.g., the American ICC Performance Code, [ICC 2003]).

In the PeBBu Network, only Domains 1 and 2 have been devoted to specific Performance Attributes – Durability and the Indoor Environment, respectively. The Reports of these Domains [Chevalier 2005, Loomans 2005b] present relevant State of the Art information on user needs and include rich bibliographies. In addition, the Aligned Task 2 - Compendium of Statements of Requirements [Szigeti 2005b] includes an exhaustive list of User Needs found to date in literature and performance-based design briefs.

Systematic derivation of User Needs for the design process can be achieved by means of a top-down hierarchical procedure. The project may be regarded as a platform intended to host numerous User-Activity combinations with various diurnal, weekly, monthly, and annual schedules. These User-Activity modules are usually aggregated into functional spaces, which are accommodated in the total building layout. User Needs are stated in general terms and refer to the building as a whole, while activities are located within the spaces. Achievement of the conditions necessary in order to fulfil the Needs depends on the building components separating the given space form other spaces or from the outside. The transformation of Needs starts thus at the level of the building as a whole moving down to building spaces, then to building parts and systems, to components and connective details, and finally to materials and accessories. Still, some Needs may be directly related to the building fabric (e.g., moisture tightness)

and not to the users' activities within the spaces. Their elaboration will thus start at the relevant intermediate level and proceed downwards from here on. At every level Needs can be elaborate in a general manner, addressing building as a virtual entity (as in codes and standards), as well as in a specialized manner, addressing the specific building project (as should be in the case of writing a PBDB). The three parts of the ISO Standards 6242 [ISO 6242 1992] delineate this procedure for the topics of thermal comfort, indoor air quality, and acoustics.

4.5 Performance Requirements and Criteria

User Needs can be implemented in design briefs by requesting specified solutions that are known for sure to satisfy these needs (denoted in Codes by Deemed to Satisfy Solutions, or Approved Documents), or by clear performance requirements amenable to quantification as criteria for design evaluation. When the regulatory system provides these requirements and associated minimal criteria the entrepreneur can still choose to specify more stringent demands due to his specific preferences, while the authority having jurisdiction has usually no right in these cases to increase the requirements per project. When a decision was made to use the performance-based route but the requirements or criteria or both are not specified by formal documents, they should be elaborated by the design team members and approved by the relevant stakeholders (Entrepreneur, State, Municipality).

The Nordic model, which has been adopted recently by the ICC Performance Code [ICC 2003], suggests the following sequence for the criteria development process: Objectives (which may be regarded as synonymous to User Needs), Functional Statements (qualitative statements addressing the physical building features that should be considered in order to fulfil the objectives), and Performance Requirements (detailed statements that provide the professional tools for addressing the objective in the design process). A similar approach has been adopted by the Australian-NZ Building Code, and is now under implementation in the Canadian Code as well. The ISO Sub-Committee for Functional/User Requirements and Performance in Building Construction, TC59/SC3, has first standardised this procedure conceptually [ISO 6240 1980], then elaborated the procedure for establishing requirements [ISO 6241 1984], and finally illustrated it for several topics [ISO 6242 1992].

Conceptually, the writing of performance requirements should follow the same hierarchy outlined for User Needs, i.e., relevant performance requirements should be stated for the highest level in which a Need appears. Each requirement is then elaborated in detail into technical Performance Criteria that provide all the necessary information for assessing the design and checking if it ensures the stipulated requirement. Based on the set of requirements and criteria at the higher level, more specific requirements can be developed, if necessary, at the relevant lower levels. A building-code's acoustic requirements can serve as an example for this procedure: The user need for continuous and undisturbed sleep in a residential building is made at the level of the building as a whole. However, requirements should be stated at the level of building spaces, identifying and addressing all the spaces which are expected to host this activity. The limit values of the maximal short term and long term noise levels to be tolerated in these rooms should be stated, as well as the maximal short term and long term noise levels that may be created in adjacent rooms, including the combinations of noise sources that should be addressed simultaneously. In addition the code should elaborate the accepted methodology for evaluating the level of noise sources outside the building envelope according to the type of roads and other activities in the building's vicinity. The code can then proceed to the next level (partitions, floors, external walls, and windows) and state requirements for minimal noise reduction values that are coordinated with the higher level spatial requirement. In the PBB conceptual context, these lower level requirements are not actual performance requirements, but rather "deemed to satisfy solutions" provided in terms of acoustic properties rather than in technical solutions. However, at this stage of PBB implementation, building codes tend to regard coordinated noise reduction requirements as performance requirements (see also ISO 6242-3), and prescribed construction details of wall and floor cross-sections as "approved" or "deemed to satisfy" solutions.

An essential feature in the delineation of user needs into performance requirements is the identification of the physical factors that should serve as the performance indicators. These factors must be quantifiable, well understood, and preferably amenable to computational analysis in order to enable performance prediction during the generation of design solutions. Statistical data on health and comfort, as well as on human response to the effects of the physical factors on perception of building performance and satisfaction, has to be analysed in order to derive thresholds of dissatisfying performance and Design values of satisfactory performance. In parallel, identification and statistical analysis are needed for agents tending to prevent the achievement of the required conditions in order to derive the Design values of the generalised Loads (see Figure 4.2 in Sub-chapter 4.7 below) [Fanger 1970, Becker 1993, CIB TG42 2004]. Some efforts to prepare performance requirements in various disciplinary areas of the performance attributes are listed below. Other areas are expected to proceed in the same route, but in many instances the necessary databases are prohibitively incomplete, and research on human needs is first required.

The area of structural engineering can serve as a mature model for the implementation of performance requirements and criteria in design standards. The Eurocodes, as well as many other local codes or standards, request first that overall structural stability be established under various loading combinations stipulated in the document by means of characteristic loads, partial safety factors, and design loading combinations. In addition, the documents state criteria for ultimate limit state prevention as well as limit displacements and crack width for adequate serviceability. Statements of performance requirements are not given explicitly in these codes, but the assessment methods elaborated in them reflect the intents of such requirements. They are based on the desire to ensure a defined level of safety against reaching an ultimate state under the action of loads with a given probability of occurrence during the design life of the building, and to ensure that there is a high level of probability that a serviceability limit state would not occur under the action of the characteristic loads. Explicit performance-based requirements for earthquake resistance have not yet been finally implemented in codes, but are based on the following procedure: several levels of events are recognized, according to their return periods. Requirements at each level are adjusted to the probability that this event will be exceeded during a period relevant to the life time of buildings. The more frequent quakes (say, 50% probability of being exceeded in 50 years) should not cause damage that impairs serviceability, a most severe quake (5% probability of being exceeded in 50 years) may impair serviceability but should not cause an ultimate state, and for a rare event (3% probability of being exceeded in 75) the only requirement is that it should not cause total collapse [Soulages 1995, Bozorgnia 2004].

The Need for improved building energy efficiency can serve as an example for the significance of stating requirements at the highest relevant level instead of moving directly to lower levels: the first statement in this case can obviously be made at the level of the building as a whole. If a pure performance-based approach is used, the requirement and criteria can remain at this level, requesting an optimal building, which yields the lowest life cycle cost for a given life expectancy (calculated by adding initial costs and the present value of electricity and fuel consumption for heating, cooling, ventilation, illumination, and hot water during the stated design life). The reference point for optimization should be set in the criterion and may be, for example, a building with the same layout designed according to the prescriptive standards. Another way for stating a performance requirement at this level is providing the design team with information on the requested total annual energy savings (compared, say, to the building designed according to the regular standards) for all the energy consuming functions (heating, cooling, ventilation, illumination, and hot water) and the maximal initial cost increase permitted for this purpose. In these cases, no further detailing of other requirements follows, and the design team is free to suggest any integrated solution that meets the criteria. When the writer of the requirements (entrepreneur, State, or Municipality) prefers to state (in addition) requirements for items at lower levels (say minimal thermal insulation of the roof and walls, minimal or maximal size of windows, etc.), the latter are restrictions that should be addressed simultaneously when searching for the optimal solution. Obviously, in this case the energy efficiency of the chosen solution may be lower than that of the solution derived in the first case. The American building codes have recognized the significance of this hierarchical approach, and most of the Energy Codes adopted in the various States, enable the choice between a prescriptive approach and a

Performance Based Whole Building approach. In the first route requirements include minimal values for thermal resistance and other factors. In the second route tradeoffs are enabled, and the designer is expected to calculate the total maximal energy budget (based on a building with the same layout and designed according to the standard values) and suggest a solution within this budget [DOE 2005a,b].

Several model documents that list a comprehensive set of performance specifications for various building occupancies have been developed since the early 1970's to be used by the public sector [NBS 1970, Jaegermann 1978, Becker 1990, ICC 2003, ASTM E2351-04a 2004]. The older American documents have been used in the procurement of buildings within the Operation Breakthrough project. The Israeli documents have been used during the assessment of innovative building systems, as well as by specific standardisation committees. There is no evidence in literature that any of these or similarly detailed documents have been used in privately owned projects.

The ICC Performance Code [ICC 2003] is actually the first comprehensive document that transformed all the provisions included initially in the regular prescriptive building code into statements of performance requirements, using the systematic procedure outlined above. Experience gained with this document has not yet been recorded, and it would be valid to follow such literature when it appears, and add it to the PeBBu research mapping website.

Recently the ISIAQ-CIB task group TG42, has issued a Guideline on Performance Criteria of Buildings for Health and Comfort [CIB TG42 2004]. This guideline includes performance criteria for the design and construction of adequately performing indoor environments and healthy buildings, which may serve as a basis for modifying the more prescriptive standards that prevail in this area in the USA [ASHRAE 1999] and in Europe [CEN 1999]. In addition, the Committees to Assess Health Risks from Exposure to Radon and Low Level of Ionizing Radiation, established by the American National Research Council have issued recently the results of their work in two reports on these subjects [Samet 1999, Monson 2005]. The reports supply the background information on the subject. Using performance-based reasoning, this profound source of information can now be used to reach conclusions with regard to recommended performance requirements and criteria, which can be adopted internationally.

The American Society of Fire Protection Engineering, SFPE, has prepared a draft of SFPE Engineering Guide to Performance-based Fire Protection Analysis and Design of buildings [Rosenbaum 2005]. This guide includes thorough explanations of the methodological procedure for performance-based design and conceptual elaborations on issues of equivalence and prevention of redundancy in solutions, as well as general statements of the Fire Safety Needs. It elaborates the conceptual framework for moving from Stakeholders' needs to quantitative criteria, but does not transform the needs into detailed performance requirements and criteria, neither provides the tools for doing so in the various areas of fire safety design.

4.6 Fitness for Use

The building market has progressed during the last fifty years, from a mostly in-situ workmanship area to an industrial branch of national and international economies. The flow of products produced in various factories into the building site requires a different way of handling the design and assessment processes than when most items are produced, cut or cast on site and adjusted to the specific conditions and dimensions. The current main concern of the builder, as well as of the producer, is that the supplied product would be Fit for its Purpose (one may denote this statement as a User Need in the demand-supply chain between these two stakeholders). In addition, to enable reasonable market prices, production should be based on large series of the same product, whereas supplying a new small series of specially designed products to every building project may render industrialisation prohibitively expensive. On the other hand, to accommodate the different needs in various projects (as well as in different parts of the same project) production should include several prototypes of similar products, from which the designer can choose according to the specific needs of the design. The properties of the various products

are usually detailed in the producer's catalogue, and the designer (or entrepreneur or contractor) chooses the one that is the most suitable for the specific purpose.

There are two main items crucial to ensuring the fitness for purpose of industrialised products:

Dimensional coordination, mainly at the connections to and interfaces with other items. This need has been recognised first in the plumbing and electrical supply industries, and has been solved by means of prescriptive standardisation and classification of dimensions (of pipes, knees, inserts, threads, and the numerous accessories' connective parts). A similar approach has been taken in other industries, such as the steel industry, standardising dimensions of structural cross-sections (Profiles), the gypsum wall board industry, standardising dimensions of boards, etc'. This prescriptive approach to dimensional coordination has proven to be very effective, without inflicting too many restrictions on design. Consequently, although not always required by the regulatory or formal Standards, it is adopted in most building-related industries. It will not be wise, neither welcome by most producers, to recommend replacing it by a performance-based approach that enables "a free choice of dimensions as long as the ends are met". However, with the advancement of technological sophistication, one can foresee a future scenario, where the mechanism of operation of a specific item is altered, and its connections to other items do not require any longer the coordination of dimensions. The need to facilitate such innovations without imposing restrictions stemming from mandatory prescriptive dimensional coordination requirements is at the basis of a PBB environment.

Performance levels of the various prototypes of a similar product should cover the entire range of envisaged requirements' levels in most building projects that may use the given product, while the intervals between categories should not be too large in order to enable (for every given design situation) a reasonable choice of the most suitable product without excessive over-design, but sufficiently large from the producer's viewpoint to enable economically reasonable production series. To ensure that supply may meet demand, national and international standards for various building products try to bridge this gap by **classification** of performance levels on an accepted discrete scale. Some of these Standards use the tested physical properties as part of the class designation (e.g., the Israeli Standard IS5 for concrete blocks designates their classes by the strength and thermal insulation indicators, in addition to shape and weight categories. The strength indicator includes a letter followed by the strength in Pascals, and the thermal resistance is then indicated by a numerical indicator, which is the thermal resistance in m^2K/W multiplied by a hundred. The recognised strength levels are on a scale between 2.5 Pa to 10 Pa with 1.0 and 2.5 Pa intervals. The recognised insulation levels are on a scale between 0.40 to 1.15 m^2K/W with 0.05 m^2K/W intervals). Another group of Standards uses a verbal indicator to portray the differences in specific performance properties (e.g., "regular", "water repellent", "water resistant", "fire Resistant" in various standards for gypsum wall boards to indicate differences in surface water absorption, total water absorption and fire resistance [ASTM C36 1995]). A third group uses a pictorial symbol for designating the classification categories according to the product's intended use, without revealing the actual physical property that enabled the sorting (boot or hand or snowflake in the ISO standard for ceramic tiles [ISO 13006 1998]). The fourth group of Standards uses neutral letters or numbers for designating the classification (e.g., letters for fire classification of building materials [EN 13501-1 2002]), where the ascending or descending order implies improved performance.

An underlying assumption in such standardisation procedures is that the classification supplies sufficient information for enabling the most suitable specification of the product during the design stage, and that the contractor or the entrepreneur is then free to choose any product they prefer with the given classification, as each of the standardised products so chosen is fit for its purpose.

The European CPD procedures are intended to ensure that standardised products are recognised as fit for use in all member States, without requiring any additional tests by means of local national documents, where the choice of the suitable product category for a given work is made according to the required performance in the specific place and building (see Annex XVII).

It is recognised that existing standards may not be suitable for classifying innovative products intended for the same functions, as some of the classification indicators or tests, may have been established based on the known products weaknesses (e.g., durability), and not only on the envisaged functional targets, while for similar products composed of different materials other weaknesses may be relevant, and other tests should be used. Consequently, the preparation of EOTA Guidelines has been included as part of the harmonisation process in the European building market. These are written for generic components (e.g., Partition Kits), trying to formulate performance requirements and criteria in a more general manner, so that various components intended for the same function, with different composition and structure, can be assessed, classified, certified, and thus recognised as fit for use.

Although it is significant to use in building construction only components that have approved performance levels, this does not necessarily ensure automatically the fitness for use of the entire facility. The interactions between the various building spaces and the building fabric are non-linear and non-additive. Consequently, performance of the building as a whole and its adequacy for the intended use are much more complex concepts than the aggregation of its components' performances. The facility's fitness for use stems from the year round conditions established within the spaces and the simultaneous lack of faults experienced by the various components. The ASTM Committee E06 on Performance of Buildings has identified Serviceability as the main item occupants, owners and facility managers of office buildings may be concerned with in order to assess the facility's fitness for use. It thus established serviceability classification scales for offices addressing most of the relevant User-Activity modules and Performance Attributes, including: support for office work [ASTM E1660-95a 2005], meetings and group effectiveness [ASTM E1661-95a 2005], sound and visual environment [ASTM E1662-95a 2005], typical office information technology [ASTM E1663 2003], layout and building factors [ASTM E1664-95a 2005], facility protection [ASTM E1665-95a 2005], work outside normal hours or conditions [ASTM E1666-95a 2005], image to the public and occupants [ASTM E1667-95a 2005], amenities to attract and retain staff [ASTM E1668-95a 2005], location, access and way-finding [ASTM E1669-95a 2005], management of operations and maintenance [ASTM E1670-95a 2005], cleanliness [ASTM E1671-95a 2005], change and churn by occupants [ASTM E1692-95a 2005], protection of occupant assets [ASTM E1693-95 2005], special facilities and technologies [ASTM E1694-95a 2005], structure and building envelope [ASTM E1700-95 2005], manageability [ASTM E1701-95 2005], and thermal environment and indoor air conditions [ASTM E2320 2004].

4.7 Design and Assessment Methods

User Needs, Performance Requirements, and Performance Criteria express the demand side of the chain. The supply side provides the design solutions as well as the finally constructed facility. To provide solutions, Design Tools are needed. In order to ensure at every major step along the process that supply meets demand, accepted Assessment Methods are needed.

A distinction is drawn between design tools and assessment methods. A major difference between the tools required for design and its assessment stems from the different nature of these complementary activities. During design, answers are sought for every set of given performance requirement by the specific professional who is in charge of responding to them. The different preferred solutions are checked superficially against other requirements and solutions obviously conflicting with the other requirements are discarded. The architect combines all the remaining solutions into the seemingly most favourable combination, and in some rare cases may even prepare some alternative combinations of seemingly equivalently valid solutions. Every single decision made by each of the various professionals may have affected to some extent performance in other areas that are not in his direct responsibility. Consequently, the finally chosen combination has now to be assessed by every design team member in order to verify that it fulfils the entire set of requirements he is responsible for.

Parts of the design process are highly intuitive and non-structured. During these stages performance-based design relies mainly on basic knowledge and physical principles, but does not address the

quantitative values of the requirements. Adequate tools for this stage are informative Guides explaining general trends and inter-relations between the design variables and the performance indicators [Ruck 1989]. At the more advanced stages of design, when quantitative decisions are made, some assessment methods can also be used as direct design tools, using a recursive process. However, the more sophisticated assessment methods, which are based on computer simulations of large building parts, can only be used for predicting the results of a given design combination. They can thus be used as evaluation and assessment tools upon completion of the design process. In addition, they can be incorporated in the design process for deriving the most suitable solution by performing systematic parametric investigations or by evaluating the results of numerous different alternatives.

When a prescriptive approach is employed in linking the demand and supply sides under a PBB environment, assessment is simple and does not require special skills. The details in the design documents are checked against the deemed to satisfy provisions given in the prescriptive Regulations, Codes, Standards, or Approved Documents. When the entrepreneur has some doubts with regard to the solutions provided by his design team, he may ask for specific expert opinion and assessment of the specific details, but in most cases he assumes that the provided solutions meet the performance requirements. In addition, in most countries the authority having jurisdiction performs some sort of partial or full checking of the design documents before granting a building permit, and the entrepreneur relies on this procedure as an additional step in ensuring that the design fulfils the requirements. Prescriptive based design leads to prescriptive based contracting, and enables simple inspection routines along the on site construction works, so that upon delivery only final visual checks are performed. Any faults developing before or after delivery are usually attributed to a lacking match between the prescribed provisions and the design documents, to a mismatch between the design documents and the constructed details, or to poor workmanship. However, in case of litigations for mal-performance, experts engaged by both sides have to assess the relevant specific design and construction details against the basic relevant performance requirement. To do that they cannot rely any longer on the prescriptive documents, and need relevant performance-based assessment tools.

When a performance-based process is employed along the demand-supply chain, the design team needs assessment methods in order to evaluate the design alternatives it considers before offering the valid preferred solutions. The entrepreneur also needs preliminary assessment methods in order to check that the design solutions meet his requirements, but in addition he may need methods for assessing the end product upon delivery. The authority having jurisdiction needs assessment tools as well, in order to grant the building permit. The methods used by these different stakeholders need not necessarily be identical, but those used by the authority having jurisdiction must be elaborated in the regulatory documents, and those used by the entrepreneur must be clarified in the performance-based contracts (with the design team as well as with the contractor). This ensures that when other tools are used by the designer to produce the suggested solution combination, its in-house assessment can still be performed before delivery of the design documents. Similarly, the contractor should be able to verify that his proposed technological solutions can pass the tests they will have to undergo does the entrepreneur choose to use such tests. Consequently, when a PBDB is used at any stage in the process, assessment methods utilised by the entrepreneur should be elaborated in it. When the assessment methods have been part of the performance-based contract, tracing the cause of faults developing in the built facility seems to be, at first glance, much simpler than in the prescriptive case. This would probably include: screening all the documents, utilising the accepted assessment methods along the entire chain, and if all checks returned positive results, blaming workmanship as the main cause. However, due to oversimplification embedded in most today's design and assessment tools, positive results in the evaluation process of a building that suffers from mal performance do not necessarily imply that workmanship went wrong. It should not be excluded that the utilised assessment methods are not sufficiently thorough and as such could not predict faulty performance. Embedded in a performance-based design contract is thus the design team's precautionary need to employ more accurate and reliable assessment methods, which are usually scientifically based sophisticated tools. Moreover, as long as these tools are not standardised, designers

have to make their own choice of tools, and undertake the risk of making a wrong decision at this stage as well.

The performance assessment of new building components or entire systems requires, in addition to design and theoretical evaluation tools, laboratory or in-situ test methods. These are known as Performance Test Methods, PTMs [Gibson 1982, Becker 1996a]. Despite the diversity of performance attributes and topics for which compliance needs assessment, the common approach to the development of performance criteria enables also an integrated common approach to the development of PTMs, their outputs, the procedure for assessing compliance and the incorporation of their results into the design process. The main features of a PTM include [Becker 2001]: Identifying the actual actions imposed on the building and its parts, and establishing their simulating generalized Loads; Understanding the macroscopic and microscopic response mechanisms of the tested building part to each specific action; Identifying, for each response factor and for their combinations, whether they might disturb the users or processes within the building. The limit values of these factors should be established so that this level of response will not aggravate most users (e.g., 70% to 100% should remain "satisfied"); Devising a test set-up that simulates and triggers the same mechanisms of response under the relevant generalized Loads; Devising means for measuring the Response Curve of the built part during the process of increasing the severity of the generalized Load; Studying the response curve and its behaviour in the vicinity of the limit values of the performance criterion. In general, solutions with convex Response Curves would indicate better performance than those with concave or linear behaviour. Solutions with a "brittle"-type behaviour (concave trend lines) should usually be avoided, unless a well-defined margin of safety with regard to the relevant generalized Load is ensured. Obviously, performance requirements that are not yet amenable to some quantification of the generalized Loads and the limit values of the performance criteria, cannot be objectively assessed by means of a PTM. On the other hand, when statistical data for establishing Design values for these factors is limited, but personal judgement of an expert, an assessor, or the end user, may be an acceptable means for deriving the criterion, a PTM can still be part of the assessment tool.

In some areas, Standards have been developed to bridge this gap. Structural Engineering is again the leading discipline, with the Eurocodes 1 to 9 together with the loading test standards serving as an example for how such documents can pave the way for a well streamlined performance-based procedure. However, even in this discipline, when innovative structural systems are used, the Eurocodes may not be sufficient for the design evaluation, and the classical loading tests may not be suitable for evaluating safety and serviceability of the built object, and deeper more sophisticated knowledge-based tools should be pursued. To overcome the handicaps and intrinsic difficulties stemming from the sometimes insufficient level of knowledge, entrepreneurs and building officials prefer in these cases to rely on third body opinion as to the suitability of the utilised tools. The Notified Bodies in Europe, as well as the Building Code Councils in the USA serve as publicly accepted objective and qualified bodies for this purpose.

The Eurocodes include also performance-based tools for evaluating the structural integrity under fire conditions. However, they still do not elaborate the entire rigorous procedure needed at the initial design stage for the establishment of the fire scenarios. The SFPE Engineering Guide to Performance-based Fire Protection Analysis and Design of buildings [Rosenbaum 2005] does not include these either.

In the area of illumination, assessment of day lighting has been standardised by ISO [ISO 15469 2004], utilising the simple Day Light Factor, DLF, Indicator. More sophisticated tools, accounting for internal and external reflections, enabled with the increased performance of computers, have not yet been standardised, although they are implemented in the wide spread utilised computer programs, such as Radiance [Ward 1994] and EnergyPlus [DOE 2005].

In other areas the performance-based assessment methods have not yet been standardised, but work is going on to provide the infrastructure for such standardisation. In most of these areas scientifically based assessment models have been developed and computer programs have been written by various authors. The International Building Performance Simulation Association, IBPSA, is organising bi-annual symposia in which such tools are presented and discussed [IBPSA 2005].

The following are some European endeavours towards additional standardisation of assessment methods for PBD:

In the European project on Energy Performance, EnPer, assessment methods have been pursued for performance-based energy design of buildings in cold as well as in warm climates [van Dijk 2004]. In the EU 5th FW Project HOPE (Health Optimisation Protocol for Energy-Efficient Buildings) a procedure has been developed to assess the health and energy performance of existing office and apartment buildings [HOPE 2005].

Initial tools for the assessment of moisture effects have been established by the EU 5th FW Project HAMSTAD (Determination of liquid water transfer properties of porous building materials and development of numerical assessment methods) [HAMSTAD 2002], and are now further pursued by the international IEA Annex 41 MoistEng [MoistEng 2005].

Design for durability is one of the more difficult areas for implementing a performance-based approach. A joint CIB and RILEM technical committee on Service Life Methodology - Methods of Service Life Prediction of Building Materials and Components (CIB W080 / RILEM 175 SLM) has devoted its work to this subject since 1996. Lately it produced a report suggesting operational performance-based assessment tools for the design stage [CIB 2004]. The report covers two main types of methods for service life prediction: the Factor methods, which have been standardised in ISO Standard 15686 [ISO 15686 2001], and the more basic Engineering methods, which incorporate probabilistic data analysis instead of utilising simplified factors. Domain 1, intended initially to cover a range of topics relevant to building materials and technology, recognised also the difficulty that still exists in PBD for durability, and decided to dedicate its activity solely to this area, changing its Domain name to Life Performance of Building Components and Materials (for details see Annex I).

A more advanced method for design assessment is based on Risk Analysis, which is linked to Economic Performance as well. There are some pioneering examples for this application in the areas of Fire Safety, Earthquake engineering, and Durability, as outlined in section 4.10.3.

The trends outlined above indicate that the conceptual framework of intention based design embedded in PBB has triggered the systematic development of an Engineering Approach in most areas of building performance, including those considered essentially prescriptive until a few years ago (fire safety and durability). Schematic features of the common engineering approach that can be applied to performance-based design in most performance areas and their inter-relation with the required knowledge-based information and tools are outlined in Figure 4.2 below.

4.8 Regulatory Concerns

The rules for operation between and within the four main markets, building, manufacturing, property, and capital & insurance, are settled by the regulatory framework in which they function. This framework is not identical in the different countries. There are, however, two common features that enable discussing the topic in a generalised manner, without losing accuracy despite neglecting the specific differences: The hierarchical structure, and the underlining philosophy and targets.

Building regulatory frameworks consist of a hierarchical structure that stems from the general characteristics of the legislative framework in the country. In most cases there would be an upper level of documents, which are issued by the legislative body (such as parliament or Senate), and are known as Laws or Acts. The rules for their implementation and interpretation, as well as for their administration and enforcement, are documented in Regulations or Building Codes, which are issued by a government official (Minister) designated in the Law or Act to be in charge of the implementation. Regulations or Building Codes refer then to technical documents, such as Standards or Approved Documents.

In most Western countries, the government is not involved in the market as an entrepreneur or builder, except for its own buildings and some specific and unique projects. It is thus regarded as an objective

body, and usually assumed to be the most adequate representative of the general public's interests. These interests may be summarised in the present context by the following two target statements: 1) Without rendering them prohibitively expensive, buildings should be designed and constructed to be safe and properly performing during their design life, and to prevent excessive damage to the environment. 2) Innovation in construction and free trade are significant to the modernisation and advancement of the building market.

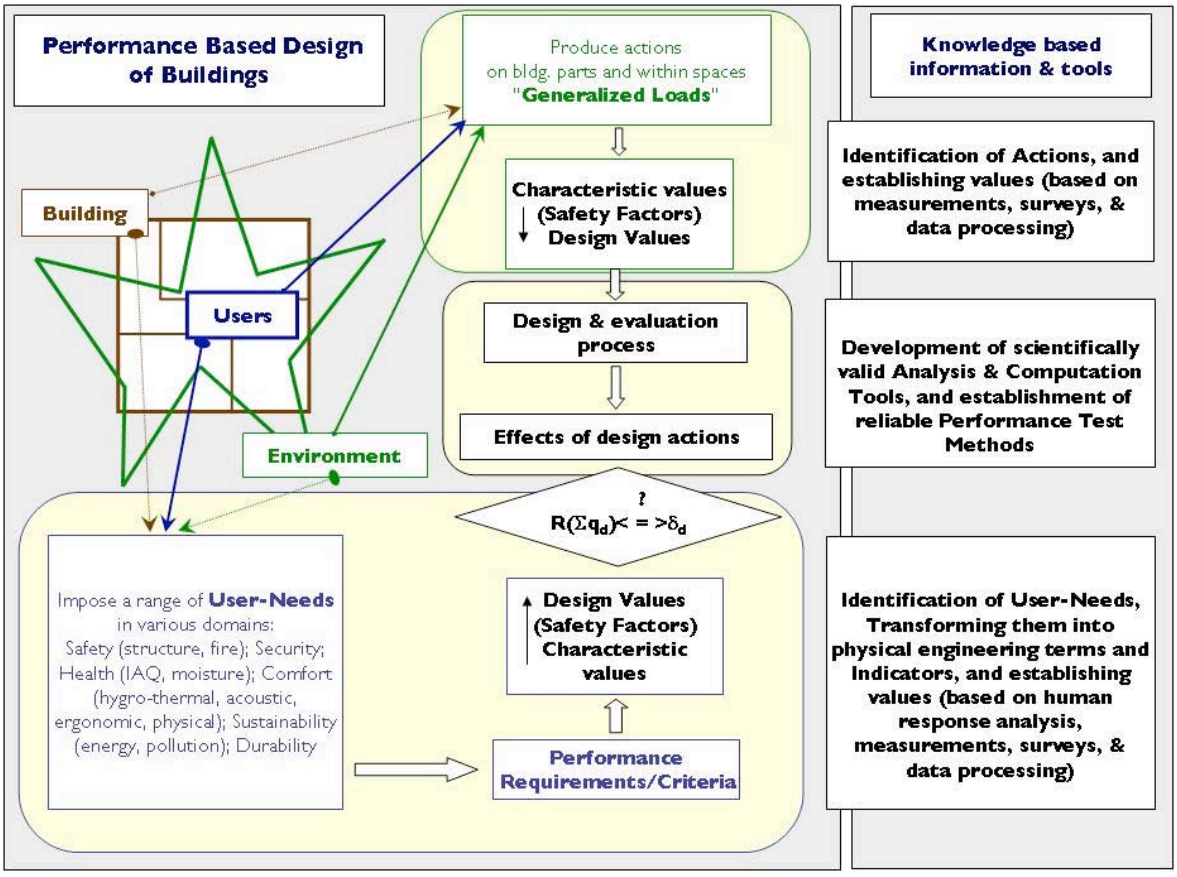


Figure 4.2: Schematic of Performance Based Design and Required Knowledge-Based Information and Tools

Building laws express the underlining philosophy that a given government and parliament hold with regard to the extent of their intervention in the building market in general and in the quality of its buildings in particular. Despite the differences in culture and socio economic levels, the above mentioned two basic paradigms can be traced and recognised in most building laws, independent of their specific wording.

The European Community Council Resolution of May 1985, which adopted the so called New Approach in order to ensure harmonisation of the European regulatory frameworks for products and services, uses the notion of Essential Requirements, and states that for all products *"legislative harmonization should be limited to the essential requirements (or other requirements in the general interest), these being obligatory and formulated in general terms. Establishment of the technical specifications necessary for the implementation of directives should be entrusted to the voluntary standards organizations. The standards would not be mandatory. There would be a presumption of conformity with the essential requirements for products manufactured according to harmonized standards*". Then, the European Council Directive of 21 December 1988 on the approximation of laws, regulations and administrative provisions of the Member States (89/106/EEC),

issued by the Council of the European Communities, includes in its annex I the following statements of the Essential Requirements for building products:

"The products must be suitable for construction works which (as a whole and in their separate parts) are fit for their intended use, account being taken of economy, and in this connection satisfy the following essential requirements where the works are subject to regulations containing such requirements. Such requirements must, subject to normal maintenance, be satisfied for an economically reasonable working life. The requirements generally concern actions, which are foreseeable.

1. Mechanical resistance and stability

The construction works must be designed and built in such a way that the loadings that are liable to act on it during its constructions and use will not lead to any of the following:
(a) collapse of the whole or part of the work:
(b) major deformations to an inadmissible degree;
(c) damage to other parts of the works or to fittings or installed equipment as a result of major deformation of the load-bearing construction;
(d) damage by an event to an extent disproportionate to the original cause.

2. Safety in case of fire

The construction works must be designed and built in such a way that in the event of an outbreak of fire:
- the load-bearing capacity of the construction can be assumed for a specific period of time,
- the generation and spread of fire and smoke within the works are limited,
- the spread of the fire to neighbouring construction works is limited,
- the safety of rescue teams is taken into consideration.

3. Hygiene, health and the environment

The construction work must be designed and built in such a way that it will not be a threat to the hygiene or health of the occupants or neighbours, in particular as a result of any of the following:
- the giving-off of toxic gas,
- the presence of dangerous particles or gases in the air,
- the emission of dangerous radiation,
- pollution or poisoning of the water or soil,
- faulty elimination of waste water, smoke, solid or liquid wastes,
- the Presence of damp in parts of the works or on surfaces within the works

4. Safety in use

The construction work must be designed and built in such a way that it does not present unacceptable risks of accidents in service or in operation such as slipping, falling, collision, burns, electrocution, injury from explosion.

5. Protection against noise

The construction works must be designed and built in such a way that noise perceived by the occupants or people nearby is kept down to a level that will not threaten their health and will allow them to sleep, rest and work in satisfactory conditions.

6. Energy economy and heat retention

The construction works and its heating, cooling and ventilation installations must be designed and built in such a way that the amount of energy required in use shall be low, having regard to the climatic conditions of the location and the occupants."

A similar situation exists in the USA, Canada, Australia and New-Zealand, and Israel.

As stated explicitly in most Building Laws or Acts, the rules for implementation of their intentions should be formulated by Building Regulations or Codes. The methods of preparing the latter documents, as well as their format and status are again different in the various countries. However, the following common

features may be recognised: They are designed to ensure that the health and safety of people using and working in and around buildings is adequately provided for, and that the quality of construction of all permanent and temporary buildings is sufficiently controlled.

Historically these documents supplied descriptive specifications of the materials and works that were considered adequate according to the gained long-term experience of the local building market. In the 1970's it was recognised that regulations should not excessively restrict technological developments, and many of these provisions have been exchanged by prescriptions of building components' performance properties (thermal resistance, fire resistance, acoustic separation, etc.), thus enabling various solutions for the same purpose. In the 1990's most Western countries acknowledged the fact that ensuring whole building performance requires more than prescribing performance properties of building components. They thus started to produce more basic performance-based documents, which stipulate performance requirements and the associated criteria, and relocate the previous descriptive as well as prescriptive specifications into a non-mandatory status of deemed to satisfy solutions.

Australia and The Netherlands were the first to officially publish and implement performance-based regulations (see Annex VII and Domain 7 Report for details [Pilzer 2005]). The committees writing these documents did not follow the entire procedure of developing User Needs into performance criteria, but rather preferred to state the principles of the performance requirements in a qualitative manner, without delineating the quantitative values of the various criteria nor the assessment methods for verification of compliance with the stipulated needs. The main identified handicap and documented criticism of these documents, as presented in the Domain 7 Workshop [Carson 2004, Scholten 2004] is the lack of quantification, which leads to uncertainty during the design stage as well as to sensitivity of the design review and negotiation process on the knowledge and skills of building officials or other assessors.

Apparently, one of the main difficulties that regulation and code developers face occurs at the stage of establishing the mandatory minimal level of performance. As most documents they have developed hereto were not based on an explicit answer to this specific topic, but rather stemmed from experience with solutions that proved to be adequate (possibly due to over design), the notion of Equivalence emerged as a possible yardstick for the definition of a minimal mandatory performance level. Compliance with the performance criterion is then evaluated in a two stage procedure: 1) the minimal required level of the performance indicator is established on a reference building, usually by analysing it by means of an approved standard tool or by means of a PTM; 2) the proposed solution is analysed by the same tool. The proposed solution is acceptable only if its resultant performance indicator is at least as good as that of the reference solution.

A conceptually preferred method for establishing the minimal mandatory performance levels would be going back to basics, and addressing for every type of building-occupancy all the items presented in the following ten-step algorithm, which is also reflected in the performance-based design framework presented in Figure 4.2:

Step 1 - Definition of potential User/Activity groups.
Step 2 - Establishing all the relevant agents that tend to adversely affect building performance (denoted by the term generalized Loads).
Step 3 - Identification of all the relevant Performance Indicators.
Step 4 - Establishing the building-related definition of the term Dissatisfaction or performance failure for every performance indicator.
Step 5 - Establishing the accepted percentage of dissatisfied or the conceptual level of failure.
Step 6 - Establishing the Characteristic values of the generalized Loads.
Step 7 - Establishing the Characteristic limit values of the performance indicators.
Step 8 - Establishing Safety Factors for transforming Characteristic values to Design values.
Step 9 - Establishing acceptable evaluation tools that reliably predict the loads' consequences.
Step 10 - Establishing methods for deriving Design values for all the relevant material or component properties that are needed in the evaluation process.

Most of the procedures established in these steps may be formulated in Standards, enabling the production of concise regulations or Codes, which outline the basic principles and then refer to the specific Standards for the detailed explicit information.

The ways for implementing a comprehensive performance-based approach in the regulatory framework, in order to ensure adequate building performance without restricting the industrial development of the relevant markets, are now pursued in most engineering domains, with major emphasis in the areas of structural safety and serviceability, fire safety, energy performance, lighting, and indoor air quality. The SFPE definition of a performance-based Code illustrates this approach: "*A code or standard that specifically states its fire safety goals and references acceptable methods that can be used to demonstrate compliance with its requirements*" [SFPE 2004]. However, spatial aspects, acoustics, durability, security, and other areas of building performance are still stipulated by means of descriptive or prescriptive provisions although performance-based assessment methods have already been developed and some of them even standardised (see section 4.7 above).

It may seem that there is a need for the preparation of a European performance-based Model Code for Buildings, similar to and more comprehensive than the ICC 2003, which will cover all the Performance Attributes, and for administrative documents, which will address all the links between the four markets when such a code is applied. However, given the large differences between the regulatory systems of the various EU countries, this is an extremely difficult task. Domain 7 reached thus the conclusion that they cannot recommend such action. Taking into account that this sort of decisions requires more than three workshops within a research and scholarly oriented Thematic Network, this option should be pursued more carefully by an adequate dedicated EU Committee, as has been done the topic of Energy.

4.9 Standardization

As clarified earlier, the role of standards in the regulatory framework has changed during the years. From mandatory documents, by adoption in descriptive and prescriptive building regulations and codes, they are now gaining the status of "Deemed to satisfy solutions" or "Approved documents".

Disregarding the specific status, standards are the main technical documents used by producers, engineers and builders when regular and conventional technologies are concerned. Laboratories and other third party evaluators use them for testing and compliance assessment. Building owners assume that any design issue solved according to a standard, and every building product complying with a standard, will ensure proper performance of the building during its concerned lifetime. Builders assume that standard labels on ordered building products ensure their expected quality and their proper performance in the finished building during the entire warranty period and beyond. Authorities having jurisdiction assume that compliance with standards implies fulfilment of the expected level of safety, health, comfort, durability, and acceptable quality. In lawsuits, compliance with standards assists designers and builders in proving that they did their best to prevent the specific fault. In summary, when no innovative design or new technologies are applied, most stakeholders assume that the role of standards is dominant in ensuring proper physical performance of the building and its parts.

Consequently, in most countries standardisation activity has long been considered a main vehicle for settling the essential conflicts of interests between the various parties involved in the building market. The procedures of standards' development, which are very similar in most countries, reflect this need for consensus.

Standards are usually developed by professional committees, which are composed of a few experts in the specific area of the given standard. The proposed document is then reviewed by the public (mostly professionals in the given and related areas) and after relevant revisions approved by a public committee representing most concerned sectors (stakeholders). It is assumed that this consensus process ensures the objectivity and professional validity of the standard, on one hand, and the feasibility and acceptance of

its implementation, on the other hand. Standards represent State of the Art acceptable knowledge, and only when adopted within the framework of regulatory documents they become mandatory.

Although in every country the actual standardisation procedures may be somewhat different, and the produced documents do not have the same format, standards in the field of building may be generally divided into five main groups:

Materials and components - these standards are based on existing knowledge and state the required test results (mainly quality control tests, but sometimes prototype tests as well) for ensuring proper performance of these items under various use conditions. These standards prescribe usually the Characteristic (denoted sometimes by the term Nominal or Basic) values of the typical properties and occasionally they also include the standardised Design (denoted sometimes by the term Practical or Computational) values that may be used at the design and performance evaluation stage (e.g., the ISO Technical Report 9165 for determination of Practical Thermal Properties of Building Materials and Products [ISO 9165 1988]).

Test methods - these standards describe the test procedures for quality control testing, physical properties' measuring, or performance prototype testing (e.g., a multitude of ASTM and ISO Standards).

Design - these standards outline the technical rules for the design of buildings in the various domains of building's performance, and provide the details of acceptable tools for analysis, computations, design, and performance evaluation (e.g., the Structural Eurocodes [CEN]).

Performance requirements - these standards are composed of two sub-groups: 1) those establishing the required levels of various properties for building components, whole elements, building sub-systems, and in some cases even entire systems, and 2) those establishing the required levels of various physical properties within a given space in order to ensure a specific activity.

Construction technology - these standards establish the performance criteria for acceptance of the final works, and may include references to descriptions of the conventional and most acceptable methods for performing the specific work. In a performance-based regulatory framework, the descriptive parts are included as "Deemed to Satisfy" or as "Approved" procedures, and are not mandatory.

Every country has at least one standardisation institute or organisation involved in writing of building standards. In some countries there are even more than one body that writes standards in the same area (e.g., in the USA full versions of various fire test method have been published by at least three different organisations: ASTM - American Standards Test Method, NFPA – National Fire Protection Association, UL – Underwriters Laboratories. The texts of these documents are different not only in the phrasing used, but also in some quantitative aspects).

The diversity of non-identical standards' documents for similar subjects is highly prohibitive to harmonisation of the regulatory framework in an open market environment. To overcome this difficulty in Europe, an overall international harmonisation endeavour is invested in global standardisation of terminology, performance requirements, product specification, test methods, design rules, and guidelines for building innovations, with the tasks shared among the following three main organizations: ISO - International Organisation for Standardisation, CEN - European Committee for Standardisation, and EOTA - European Organisation for Technical Approvals. The activity of ISO started in 1947 but a commitment to harmonisation has emerged only in 1985 with the European Communities' Council Resolution mentioned above. This European resolution actually adopts a performance-based attitude in every commercial sector, with the building sector not being exempt. Consequently, activities in the area of building standardisation have been coordinated between CEN, EOTA and ISO in order to prevent duplication of efforts, and it is expected that within a few years most national standards will be based on the same international model-documents.

Standardisation activity is knowledge-based. As such, it is also a significant vehicle for identifying knowledge gaps and research needs. Unfortunately, within the PeBBu Network project, the Task dealing with this subject, User Platform 3 on "Standardisation and Conformity" failed to produce a research agenda.

4.10 Economic Performance

A key issue in the success of every project is its economic performance from the various stakeholders' viewpoints. Although a significant complementary aspect to the implementation of PBB, no PeBBu Task has been devoted to this topic. Consequently, the PeBBu deliverables do not cover its state of the art as related to PBB. The following three Sections highlight briefly the main economic performance evaluation tools that correspond well with the PBB framework. It is recommended to complement the state of the art review of this topic within the agenda of CIB Commission 055 – Building Economics.

4.10.1 Decision-Making Tools

The regulatory framework takes care of ensuring minimal levels of performance-in-use in the areas denoted as Essential Requirements, but the success of a project and the levels of owner and user satisfaction may require elevated levels as well as consideration of additional topics, which are denoted as Optional Requirements. Supplying the added values involves elevated costs that have to be justified by the ensuing benefits. In complex building projects there is an extremely large number of variables on one hand and elevated performance requirements on the other hand. Making the most proper decision with regard to every variable in order to obtain the optimal combination which yields the lowest total cost is the aim of various decision-making tools that have been developed outside the arena of PBB research.

The simplest way by which structured decisions are made in small projects imitates the intuitive non-structured pros and cons decision-making routine undertaken by non-professionals. This is known as the Weighted Score method [Belanger 1984, Griffith 1997]. By this method, each alternative option for a given variable is graded against the entire list of performance requirements that are affected by it. Grades are established according to the added value enabled by the given alternative with regard to the specific requirement's threshold mandatory level, or according to its level of supporting the requirement when there are no such minimal thresholds (e.g., appearance) [Becker 1993]. Weights reflecting priority levels associated with the various requirements are assigned by the grader intuitively, or by means of data processed from surveys of relevant stakeholders [Becker 1985]. A much more sophisticated and mathematically based method for priority setting and derivation of the weighting factors is the method developed by Thomas Saaty, best known as the Paired Comparison method [Saaty 1982], but it has not been used in the PBB context. Finally, every alternative scores a total weighted grade, with the highest grade yielding the best performance-related choice. Some applications of this method were extended to include costs (initial, or total life cycle) as one of the criteria [US Government 2004], with the option achieving the best score comprising the preferred choice.

A more advanced series of tools for selecting the best choice is denoted by the general name Cost-Benefit analysis [Marshall 1990]. There are several alternative methods for performing cost-benefit analysis of multi variable systems, which are intended to derive the optimal solution combination, all based on a similar conceptual methodology, by which the benefits of added performance levels are expressed in monetary terms for every alternative option. The most common one is the net benefit technique that is based on subtracting the total cost increment from the total monetary benefit of the added performances. This yields the net monetary benefit of the various alternatives. The option with the highest net benefit is distinguished as the best choice, while alternatives with negative monetary benefit are recognised as wasteful. Another possibility is to address the cost per unit score (cost-benefit ratio technique) as an indicator of worth. The lower the unit cost, the more attractive is the alternative.

A key issue to be addressed when seeking optimization of a new building project is whose benefits and whose costs should be accounted for. According to the chosen stakeholder, the same perspective should be used for setting the monetary values of both, the costs and the benefits, as illustrated in the table below.

Optimisation Perspective	Benefit	Cost
An occupant who rents a facility	Occupant-related sum of added values of performance-in-use	Increased renting fee
The entrepreneur who rents out the facility	Total added rents to be received	Increased sum of building costs plus service life costs
An owner who intends to occupy the facility	Occupant-related sum of added values of performance-in-use plus increased resale price	Increased sum of purchase cost plus service life costs
The entrepreneur who sells the facility	Total added income from sales	Increased building costs

4.10.2 Performance Measures and Key Performance Indicators

Management, maintenance and operation of existing facilities require continuous investments in various works intended to provide envisaged performance levels. The target performances may consist of continuously decreasing levels adapted to the age and life expectancy of the facility, the same level set out at the initial design stage, or enhanced levels required by changing general standards and/or user expectations. Independent of the chosen target, constant monitoring of the facility's performance level is required in order to establish the timing and sorts of most adequate maintenance and/or remedial works. In order to enable strategic decisions by managerial staff and owners, monitored performances need to be expressed by means of simplified indicators. This led to the adoption of the notion Key Performance Indicator, KPI, which is used in the area of business administration for defining and measuring organisational goals, in order to express the level of existing, targeted or potential performance of the built facility. A KPI is usually a quantitative entity, not necessarily the physically measured one, representing the performance topic in terms convenient for managers, e.g., a grade on the scale of 0 to 10, the number of injuries per year, the number of complaints, etc. In the area of business administration benchmarking of KPIs is used in order to enable comparative investigation of a given situation to the commonly existing cases. Databases of business oriented KPIs are now available for various topics, including those relevant to the construction sector [DTI-KPI]. KPIs have also been adopted by the manufacturing industry for monitoring and upgrading production, as well as for monitoring and up keeping maintenance and operation of the machines and production lines [Milen 2002, Scharpf 1999].

In recent years, some efforts have been devoted to the identification of facility management related KPIs for various occupancies [GSA-RPM, Shohet 2003], as well as for benchmarking their values in existing buildings. Linking the difference between measured KPIs and target values to the costs involved in achieving the targets, in a cost-benefit analysis scheme, is expected to enable simple and fast decision making with regard to maintenance scheduling and tasks.

The use of KPIs in facility management is a young phenomenon, and there is not sufficient follow-up of its ability to produce satisfactory decisions. The fact that the USA Government continues to implement it since 1998 using the obtained data for benchmarking purposes [GSA-RPM] is a promising sign but needs substantiation by objective research and quantitative monitoring of the physical factors as well in order to establish the links between the KPIs and the applied solutions.

4.10.3 Risk Analysis

A major barrier in implementing explicit performance-based procedures for design and procurement stages is the request to bear responsibility for outcomes. When such procedures are employed, the design verification is a crucial link in the demand-supply chain. The lack of accuracy of the assessment

tools and their deterministic nature make it very difficult to address random effects in a manner that can increase credibility of the results. This is overcome today by means of partial safety factors, which are used to transform the performance threshold values to more conservative design values, and the characteristic agents to more conservative design (generalised) Loads. Designers, who are troubled by the increased responsibility, would tend to add extra precautions and increase the margins of safety even further. Consequently, the overall safety factor may be excessively increased, leading to increased costs that are not substantiated by corresponding explicitly increased benefits. In some areas of building performance (e.g., Fire safety, Earthquake resistant design, and Durability assessment) this has been recognised as a major economic burden, and more accurate scientifically based methods are sought for deriving the optimal solutions.

A limited amount of research has been performed hereto trying to utilise the tools developed in the general area of Risk Analysis for establishing optimal design procedures in the above mentioned areas of building performance [Thurston, 1987, Reid 1989, Marshall 1989, Moses-Fred 1998, Meacham 1999, CIB 2004]. In the area of fire safety design there is evidence to the utilisation of this tool in many actual projects, using the technique of risk delineated decision trees in order to compare alternative solutions [Fitzgerald 1986, Bjorkman 1996, Aiello 2002, Charters 2003]. The tool seems to be adequate for prediction of potential performance-in-use and design optimisation in other areas of building performance as well, and mainly for those related to user safety and health, which are the main topics for exaggeration in design when increased designers' responsibility is requested by the entrepreneur or the state.

Much more research is needed before risk analysis can become an everyday tool of PBB, and this is probably one of the areas where basic scientific research is still needed in the various domains of building performance.

4.11 Quality Management

The main target of quality management is to ensure that the organisation takes the correct routes to supply the outcomes it promises and that the entire organisation may benefit from the level of investment in quality attentive activities. In the building industry, this pertains to actually supplying the promised performance of products, or in-situ works. For the design profession it implies ensuring that the envisaged design outcomes are actually supplied, and in a PBB design process, that the designed building meets the design brief requirements. Managing quality includes several phases (Quality Control, Quality Assurance, Certification) and involves the entire organisation's devotion, collaboration and responsibility, as suggested by the term Total Quality Management.

Quality control is a prescriptive-based technical task intended to ensure conformance between executed works and/or final products and the prescribed properties, thus enabling their designation with a standard marking (e.g., the CE Marking). The properties can be given as an exact description of form and works, or as a set of test results. Although prescriptive in nature, this activity is an essential part of a PBB environment, as it is intended to ensure the customer that the produced product actually carries the promised properties. Quality Assurance is an administrative activity intended to ensure that the quality control procedures are well structured, that testing is performed properly and with the adequate equipment and tools. Total Quality Management is a managerial activity intended to ensure that every member of the organisation is aware of his specific responsibilities and does his best to fulfil them, is attentive to difficulties in achieving them, identifies handicaps that need remediation, and tries to be creative in finding solutions for the identified maladies.

In the last decade plenty of research and implementation of TQM took place in the building industry, but the PeBBu Network did not include a Task to address this topic. Consequently, no State of the Art Report or summary of it was enabled. However, in 2003 Toakley has prepared a review of research needs in this area [Toakley 2003], which also includes some review of existing knowledge (23 references). As the PeBBu Network did not address the topic of quality management at all, while TQM is so much in line

with the PBB conceptual framework, Tokaley's review can be regarded as complementary to the PeBBu outcomes.

4.12 Research Needs

The first activity of the various Tasks was mapping of existing relevant knowledge. Each of the Tasks has gathered, by means of its members and the first series of Workshops, extensive information on PBB-related research activity and implementation efforts ongoing in their countries. The Task Leaders have reviewed the international literature relevant to their task, and combined it with the national information to produce State of the Art Reports, which are posted on the Tasks' websites. In addition, CIB Secretariat undertook a general mapping activity for PBB-related literature, and created a dynamic database, which contains relevant information on ongoing Research Projects, Publications, (recently published scientific) Papers, Organisations and Contacts (with their expertise). All this information is posted on the PeBBu Network website http://www.pebbu.nl/maincomponents/mapping/ (see section 3.3.4 above for details).

The next steps of the Tasks' activities and Workshops were devoted to identification of knowledge gaps and lack of tools for proper implementation of PBB. Each Task has chosen a different way for gathering and analysing this information, and rendering it into a list of Research Needs, which was then arranged in a framework denoted as a proposed Research Agenda in the Task's knowledge area.

The Final Report of most Tasks (as listed in section 8.2) includes a detailed proposed Research Agenda, and the summary reports in the Annexes to this Report include summarised versions, produced by the Task Leaders.

The research needs found by the nine Domains, three Generic Tasks and two Aligned Tasks cover the scientific, architectural, engineering and managerial areas where additional knowledge and tools are needed. Most of the items on their research agendas are needed internationally, and collaboration in producing the necessary knowledge should cross boundaries all over Europe in order to enrich the entire research community and be relevant to PBB implementation in all member States. It is envisaged that this part of the PeBBu Research Agenda would lead in the future to preparation of research proposals with a global orientation, submitted by international teams, which will not necessarily be of a purely European composition.

The research needs identified by the four Regional Platforms include mostly complementary items that stem from the particular features of the region (e.g., weather, natural hazards, living habits, socioeconomic conditions, culture, etc.). Advancing research in these areas is of direct relevance to the specific European regions, but is less general in nature and cannot replace the knowledge still needed by the entire building community.

The research needs that would be identified by the three User Platforms will include complementary items that are relevant to the specific sectors of stakeholders. Proper implementation of PBB requires first and foremost collaboration between the various stakeholders included in the first two platforms (the users and owners platform, and the building industry platform). The tools and infrastructure that these sectors need in order to cope with the non-traditional framework is significant from the practical and applicative viewpoint of PBB. Despite the rareness of such endeavours, attracting industry, owners and entrepreneurs to collaborate with academic research teams in order to produce the most adequate tools should be a challenge for those engaged in promoting and supporting research.

PBB-related research needs may be sorted within the following distinct groups:

Basic Research – better understanding of human response (including health and safety implications) in the vicinity of threshold levels of user satisfaction and beyond; refinement of basic tools for transforming user needs into performance requirements; development of reliable design and verification tools; application of risk analysis tools to the above and to performance-based design procedures; development

of tools and procedures for various performance-based procurement methods; development of performance-based Post Occupancy Evaluation procedures.

Applied Research – monitoring and analysis of demonstration projects; preparation of quantitative statistically valid databases for user needs, performance requirements, and generalised Loads; preparation of model documents for performance-based procurement; benchmarking of Key Performance Indicators with due attention to physical factors of the case studies; preparation of computerised design platforms using n-D modelling to assist design collaboration and team work; preparation of reliable statistical data for implementation of risk analysis; supporting quality management research needs.

In the last years several international organisations have prepared research agendas and road maps in some specific areas of PBB, including Sustainable Development [CIB 1998], Energy-Related Indoor Environmental Quality [LBNL 2002], Total Quality management [Tokaley 2003], Energy Performance of Buildings [ENPER 2004], Acoustics [ISO 2004], Fire safety [NIST 2004]

The entire set of individual Research Agendas prepared by the various PeBBu Tasks has been analysed by a dedicated CIB team that has produced the final PeBBu Research and Develoment Roadmap for PBB, and reported it in a separate Report [Foliente 2005c]. A summary of the Research and Development Roadmap, prepared by Dr. G. Foliente, is presented in Chapter 6 below.

Incentives, Barriers and PBB Implementation

CHAPTER 5

5 INCENTIVES, BARRIERS, AND PBB IMPLEMENTATION

PBB is more than anything else a way of thinking and communicating in terms of intensions for long-term performance in use of buildings rather than in terms of means and technologies. Striving to introduce PBB as an underlining philosophy and theoretical conceptual framework for the various professions involved in the building industry stems from the belief that intension-based design and construction would yield more adequate buildings. However, we have already shown in the Introduction that philosophically performance-based thinking is not new, and that despite the fact that intension-based design has been one of the main features of the architectural profession since its inception, the implementation tools in architectural design areas were rather implicit, without promising or undertaking responsibility for actual envisaged outcomes. In sub-chapter 4.7 we have pointed out that during the last 50 to 60 years progress in scientific and engineering knowledge led to the development of performance models and assessment tools, which make it possible to explicitly address performance requirements during the design stage, and ensure a sufficient level of confidence that the building constructed according to the designed details would perform as predicted under the expected and foreseeable circumstances. Linking the lifelong intension-based approach with the new design tools occurs sporadically in various projects, mainly when the entrepreneur is performance-conscientious and requests the best value for his money. The question "under which circumstances is explicit implementation of PBB desired and favourable to the project, and when is it inadequate?" has been pursued by Domains 6 and 8 (see Annexes VI and VIII, and section 5.4.1).

There are several driving forces in the building market, which push forward the more rapid overall incorporation of PBB principles into various links in the building chain. The stakeholders interested in explicit implementation of various performance-based steps include:

- Building product manufacturers who draw a parallel line between the building industry and the other classical manufacturing industries, and are interested to ensure the wide spread acceptability of their products;
- Inventors of new building components and systems who are eager to introduce their innovations into the market without excessive restrictions;
- Builders who wish to use innovative technologies and alternative materials;
- Public entrepreneurs who are obliged to employ various sorts of design-build-operate procurement methods in order to accomplish the building project without investing excessive financial resources;
- Entrepreneurs who are interested in optimising the design at the whole building level and are disturbed by restrictive unjustified specifications at lower levels;
- Entrepreneurs who remain the building owners and are interested in ensuring the long-term suitability of the built facility for its intended uses;
- The owners, renters and direct end users who are interested in the satisfaction of their needs within the building they occupy;
- The facility managers who are interested in the easy maintainability of the building they operate.

The first three groups wish to enable a flexible border-less building market and to ease the barriers encountered by innovative building technologies. This target is common to most Western countries, which are interested in advancing industrialisation and enhancing the quality of buildings. It has been recognised world wide that utilising an explicit performance-based approach in product specification and assessment is one of the most instrumental means for achieving these purposes. This must be supported by a regulatory framework that does not dictate the usage of specified solutions and enables a free choice of the most suitable product, fortified by performance-based classification Standards, and a formal

mechanism for assessment of fitness for use of innovative products, which cannot yet be standardised. An additional instrument for achieving these groups' targets is performance-based construction tendering [Lugez 1987], which states explicitly the required properties of components without dictating the preferred solution. Although the USA public sector is obliged by law to pursue this route only, forbidding other modes of tendering in the private sector is not reasonable.

The wish of entrepreneurs to derive the optimal solution for a given project requires a regulatory framework that enables optimisation at the whole building level, without imposing unjustified restrictions at the lower levels. This target can be accomplished by ensuring that the regulatory framework avoids, as much as possible, stipulating mandatory descriptive or prescriptive specifications for building elements and sub-systems, and instead provides the tools for stating performance requirements in a top-down hierarchy, starting with the building as whole, via spaces, to sub-systems, and only then to elements and components. The mechanism for a hierarchical generation of requirements enables the introduction of innovative concepts and high performance systems, which compensate for reduced performance of more traditional elements, into actual projects.

The wish of the last three groups for adequate long-term performance-in-use of the building facility does not necessarily imply that an explicit performance-based process (either at the design stage or for contracting) is preferable. Although the performance approach is a valid theoretical way of thinking and underlining philosophy for these groups, PBB as a process has not yet been sufficiently tried out, and there is not sufficient evidence that it can provide these groups' target in a more reliable manner than the traditional linear prescriptive routines.

In order to obtain a multi facetted view of the incentives and barriers for PBB actual implementation, all the Task Leaders were asked to include these as distinct items in their summary reports. The following two sub-chapters integrate these inputs, and submit the overall incentives and barriers as identified by the PeBBu Network.

5.1 Incentives for PBB Implementation

Numerous incentives for more extensive implementation of PBB are outlined in literature and many others have been sketched by the various Tasks. Some similar incentives appeared in various textual versions in most documents, while others have been mentioned more sporadically in one or few reports only. The following integrated list of incentives has been compiled. Unfortunately, there are hardly any follow-up studies of projects handled within an explicit PBB environment, which include a comprehensive exposure of the procedures used along the various phases of the building process [PBSRG Newsletter], and systematic monitoring and evaluation of successes, failures and implications on the listed incentives. Consequently, there is not sufficient evidence to support the listed incentives.

Reducing barriers on trade – PBB is based on true user-related requirements, which enhances international harmonisation of product classification and standardisation. This reduces unjustified technical barriers on free trade at national as well as international levels.

Enhancing innovation - In a modern dynamic society there is an aspiration for and admiration of vitality, innovation and renewal. Given the low prestige of the building industry at large, every positive new experience, brought about via an innovative well performing industrialised technology, is a potential vanguard carrying the flag of improved image. PBB identifies needs and exposes gaps where new solutions are needed. It may thus be a stimulus for product and process innovation. In addition, it also provides the most adequate infrastructure and tools for assessing the innovation's likelihood to meet the relevant performance requirements, and thus enables its fast and safe introduction into the market. By providing these tools and creating the easy track for introducing innovations, it is not only a supportive environment for innovators but may also become a trigger and promoter of such initiatives as opposed to the discouraging situation when a prescriptive-based approach prevails.

Catering for the users - From a societal viewpoint, PBB caters much more explicitly for the needs of users, customers and renters who are the silent and less influential stakeholders, as they are usually not explicitly represented along the design and construction chain. It brings forward, and enforces the consideration of user needs for serviceability, comfort, healthy indoor air quality, and longer lasting and durable building fabric and systems even when the prescriptive provisions fail to provide adequate solutions for these attributes.

Providing transparent regulations - PBB ensures a transparent and intension-based legislative and regulatory framework, which prevents arbitrary unjustified stipulations.

Explicit information flow - PBB provides a better flow of explicit information and intension-based reasoning along all the demand-supply stages of the building process, as well as between manufacturers and customers.

Predictability of outcomes - Employment of Performance Indicators and scientifically-based assessment methods is very useful when a reliable estimate of the outputs and life cycle costs of a complicated system is needed.

Public sector procurement restrictions - In some countries, governmental and public sector entrepreneurs are obliged by law to use performance-based contracting. This requires a more comprehensive performance-based regulatory infrastructure, which may affect the private sector as well.

Organisation's benefits - Improved facility performance affects user satisfaction and improves worker productivity. This may motivate performance-based design contracting.

Enables tradeoffs and multi disciplinary optimisation – when whole building performance in more than one area is sought, explicit criteria and assessment tools must be employed. An example is the incentive to use a performance-based approach for the indoor environment once the Directive on energy performance of buildings will be actively implemented in Europe.

Achieving optimal solutions - From the entrepreneur's viewpoint, PBB provides means for achieving an optimal level of performance when desired, and/or for overall cost optimisation without reducing overall required performance.

Improved prestige - PBB enables using performance advantages and lingo as part of a commercial strategy for establishing reputation and status, and for improving market competitiveness and sales.

Clarifies responsibilities - In a PBB framework, the responsibility hierarchy must be clearly defined. With the advent in standards of living, owners are less tolerant when faults occur and litigations against entrepreneurs became more frequent. The entrepreneur's need for liability as to the design and construction outcomes may be a dominant factor in enhancing PBB.

Essential to TQM – Total quality management is a vague notion if not accompanied by clear performance targets and established methods of assessment.

May reduce costs - Some claim that PBB is expected to reduce total construction costs. On the surface of it, from the entrepreneur's viewpoint PBB involves increased costs during design and assessment phases, while it may reduce construction costs (by choosing cheaper but equally durable and well-performing technological solutions for the same purpose). However, one should be cautious with citing such statements, as there is not yet sufficient literature proving that this has actually occurred in a sufficient number of projects [PBSRG Newsletter].

May improve performance-in-use – Most PBB advocates claim that the main features of the explicit implementation of a performance-based approach (i.e., explicit addressing of user needs and design objective, utilising quantitative tools for the verification, clear responsibility for the fulfilment of the specific targets, streamlined flow of information on intentions and solutions, addressing during the design stage long-term maintenance and operation needs as well as requirements for flexible change of occupancy during the building's life cycle, the potential for transparency of user oriented life cycle

cost/benefit analysis) decrease the probability for occurrence of building faults, and by this increase the overall likelihood of achieving desired levels of performance-in-use and destined user satisfaction levels. This has a potential for improving inter-relations all along the demand-supply chain, and improve the image and prestige of the building industry at large. In countries with a generally lower level of building quality, researchers believe that various elements of PBB (e.g., regulations and standards that are intension-based, performance-based design briefs) are instrumental in raising consciousness and motivation to improve building performance.

PBB as an innovation – PBB is regarded as an innovative framework for various phases of the building process. Changing the basic paradigm for the building industry's modus operandi into one much more akin to modern technological industries may be a significant contributor to improving its degraded image.

5.2 Barriers for PBB Implementation

Numerous barriers for implementation of an explicit PBB environment have been outlined by the various Tasks. Some similar barriers appeared in various textual versions in most documents, while others have been mentioned more sporadically in one or few reports only. The following integrated list of barriers has been compiled:

Incompleteness of regulations during transition phase – During the transition period, many regulations may remain prescriptive while others have already been re-written in the performance-based approach. The regulators' scheduling priorities may not match those of practitioners' needs. This mismatch may lead to aggravation with the process and to lack of confidence in the new approach.

Lack of quantitative user-related data – The information on human response to given conditions in the vicinity of normal conditions is mostly qualitative, and only a limited amount of statistically valid data is available. For derivation of quantitative criteria based on known probabilities of dissatisfaction one needs information on human response versus dose much below the levels of hazard and failure. Having the shape of the relevant curves in the vicinity of acceptable percentages of dissatisfaction is essential in order to account for sensitivity of decisions to the stipulated criteria. Present gaps in databases and lack of accepted criteria for the most common situations encountered in design prevent a comprehensive implementation in some areas of building performance.

Requires more profound professional expertise – Implementation of PBB requires more profound professional expertise at most stages of the building process. In the preparation of the regulations, codes and Standards there is a need for professionals familiar with updated knowledge in the relevant fields; for preparing the design brief the entrepreneur would need a professional consultant to assist with the derivation of criteria and identification of assessment tools; design teams may need fortification by adding professionals familiar with more sophisticated design and evaluation tools; officials of the authority having jurisdiction must be professionally competent to follow the more sophisticated assessment tools; contractors who respond to performance-based tenders need professionals familiar with the performance statements and the variety of possible solutions.

Lack of experience – Despite the rational and philosophically accepted intension-based approach to architectural design, explicit accountability for design outcomes is not the common practice. Most professionals lack the necessary quantitative knowledge and experienced, and may feel uncomfortable with the change in design routine PBD requires.

Time consuming and costly processes – The intension-based activity inherent in a PBB framework requires much longer periods and more intensive professional resources. The main stages that are affected include: preparation of regulations, codes and Standards; preparation of the design brief; evaluation of design outcomes; assessment of design outcomes during the approval phase. The lengthening

and increased cost of the design period, and the increased time needed for design approval are the major barriers.

Requires a holistic approach – An intrinsic feature of PBB is addressing all identified and prioritised requirements simultaneously without, as much as possible, sacrificing any of them. The fragmented nature of the building profession, including of the design team structure, does not support such an approach. PBB requires more balanced team work and a holistic approach, which are sometimes difficult to achieve at present.

Delegation of power to entrepreneurs, owners and users – Some designers do not like the extent of control and influence other stakeholders gain for specifying the building's performance.

Conflicting requirements – When form precedes function in the design phase, artistic and cultural aspects of the facility's design may be in conflict with solutions needed to satisfy the more prosaic performance requirements.

Reluctance to accept direct responsibility - Designers and builders are usually reluctant to accept responsibility for explicitly defined consequences. They prefer the easier way, of being obliged to prove compliance of detailed drawings and construction brief to prescribed standard provisions, and of the executed details to the prescriptions in the design documents.

Uncertainty about risk and liability – The incompleteness of design and assessment tools may increase the risk for poorer performance than expected. This increases the risk taken by entrepreneurs as well as by design team members, and they all may feel more comfortable with well-experienced prescriptive provisions. In addition, lack of experience with the new framework leaves many ambiguities with regard to how the direct responsibility for outcomes would affect the various professionals.

Difficulties in separating responsibilities – Fulfilment of some performance requirements involves combined design efforts and there is no simple method for separating the responsibility for the technical design from that for the functional and architectural design.

Undermining of the designers' status – Due to direct responsibility for outcomes, design team members may become the scapegoat for any malfunction or fault that occur. This may increase lawsuits against designers, and even if found blameless by court, the trend to sue them may undermine their status.

Lack of evidence that PBB may succeed – PBB as an explicit intension-based framework in the demand-supply chain is an innovation in itself. It suffers from the syndrome of newness and lack of recorded long-term evidence that it can be successful.

PBB as an innovation – The building market is historically the most traditional one, hesitant and unwelcoming to change and innovations. PBB implies a change in paradigm as well as practical changes along many phases in the building process.

Conservatism, Scepticism, prejudice, and resistant to change - "The most important quality aspects of buildings cannot possibly be translated into performance specifications", "What do they really want?", "What is all the fuss?", "But this is obviously what we supply anyhow!", "You don't use a shooting machine to kill a fly".

5.3 Unique Features of the Building Industry

Performance-based production and marketing is the common way in most manufacturing industries. However, although building is a manufacturing industry as well, there are several inherent differences between the building market and other industries, which explain the numerous barriers for PBB. These unique features of the building market would not, and probably cannot and even should not, be altered, implying that PBB, if implemented, should cope with them and be integrated into them in a harmonious manner.

Each building is unique - In conventional construction technologies, the technical flexibility enables architectural diversity, which led to the development of an individualist culture and appreciation of the different. Each building is expected to be unique in its appearance, with almost no building facility being an exact replica of others. Consequently, each new building has a different architectural design and consists of a different combination of similar but not identical components and materials. Even when the same building system is used for producing industrialised buildings, the number of identical layouts and plans is very small, and the number of prototypes is extremely large in comparison to other industries such as aeroplanes, trains, buses, cars, home appliances or computers.

This diversity prevents prototype testing of the end product before marketing, and there is actually no possibility for first producing an experimental prototype, subjecting it to controlled testing, and only then proceeding to serial production. Consequently, practitioners' knowledge and experience are built in a real-life cumulative cyclic process, which consists of identifying faulty decisions in one building project, followed by remedial trials in actual new building projects, discovery of new faults, subsequent remedies in other projects, etc.

The buildings with faulty decisions cannot be discarded, and there are no recalls. Consequently, the building culture consists of an inherent acceptance of some level of faults in every building, and there is very little incentive or trigger for a zero faults culture.

Different supply-demand cultures – Aeroplanes, trains, buses, cars, appliances and computers are produced by manufacturers and sold to those who wish to own and operate them. The producer is aware of the competition and regards customers' needs as the most significant motive for design decisions. Before starting full-scale production, the producer verifies the product's prototype performance, and only after that puts the product on the market. Information on products' performance characteristics is given explicitly in the documents used to promote sales, and liability towards performance is explicitly stated, including the exemptions. Instructions for use, operation and maintenance are supplied in the documents accompanying the product. The customer will anyhow have to transfer the bought product to the place where it will be used, so that he addresses no other items except product-related life cycle cost benefit considerations in order to choose the most adequate product.

Multifamily residential buildings that are built and sold to individual families by large companies seem to constitute a similar market. However, the decision to buy a specific dwelling stems not only from the product's properties, but first and foremost from its location (neighbourhood quality) and the facilities available in its vicinity (schools, commercial centres, public amenities). Next, come size and layout which should meet the specific family's needs. These preferences narrow the supply inventory to such an extent that final choice is almost never based on the entire set of performance attributes of the alternative dwellings on the supply side. The readiness to compromise with performance has become an inherent feature of the demand side. The companies' incentive for improving performance is thus much lower than in the other industries. Despite this situation, the general increase in household incomes and education, which are followed by expectations for an elevated standard of living, promote the wish for generally better performing and more durable dwellings. The supply side of the chain responds to this evolving change in expectations, but, as long as customers are ready to compromise, full proof performance-in-use will not become the suppliers' most dominant target. In some countries, a strong driver for improvements in residential buildings' performance is the development of a litigation culture, with building companies being sued when post occupancy faults occur during the liability period.

Most non-residential buildings, including offices, commercial, public, and monumental buildings, as well as low-rise housing, are not produced by manufacturers who continue to produce and sell buildings, but rather commissioned by an entrepreneur who will either own the building for his own use, or for renting it to others, and will in most cases remain attached to the building and its operation and maintenance throughout its entire life cycle. The same entrepreneur will usually commission only a limited number of building projects during his life time, none of them identical to the others, and does not have any interest or ability to investigate prototypes before putting his merchandise on the market. The demand-supply

chain is altered in this case. The main manufacturer (entrepreneur) is also identified with the customer (owner/user), and becomes a client (instead of employer) of the professional practitioners (designers and contractors) who perform the works necessary to realise the desired building. Upon project initiation, entrepreneurs choose first the architect who then becomes the dominant person in the project. Despite being initiated, sponsored, financed, used and maintained by others, the finished building is regarded as the architect's artefact. This sort of relations is unique to the building sector.

Separation of architecture from engineering – although the building-related demand-supply chains characteristics have the potential for emphasising the entire set of user needs and performance requirements, a bias has developed during the years towards the aspects of visual appearance, space flow and spatial characteristics, degrading the significance of most other performance requirements. This order of priorities, which has no parallel in other industries, stems from society's separation of building architecture from building engineering, and perception of architecture as part of the plastic arts and not as a technological profession, and of its products as a work of art and not as a technological product.

In other industries, the constellation is usually different. Engineers establish the performance requirements and quantitative characteristics of the product based on the market needs or on the innovative yet virtual need the inventor has foreseen. They analyse and design the product, using simulation tools and interim testing to verify its performance. When attractive appearance and user friendliness are part of the requirements, industrial designers are called upon at a not-too-late point along the development chain, and collaborate with the engineers, never becoming the team leaders or dominant professional.

In Vitruvius' days, the term engineering did not exist, and architecture included both, the artistic as well as the technological aspects of building and civil engineering works. However, today, the professions are separated, probably interminably, with the architect leading the project upon its initiation, and engineers entering the design and decision-making stages much later in time and at far-off points along the building process. Moreover, in many projects, the engineers are hired by the architect, and are considered as his consultants, not gaining even the status of designers.

5.4 The Way Ahead

The main premise in the entire Report hereto, as well as in this sub-chapter is that a distinction should be made between PBB as a general conceptual framework that caters for ensuring buildings' performance-in-use, and the specific manifestations it may get during various phases of the building process, such as, but not excluding others: delineating explicit performance requirements in regulations, codes and standards; contracting design by means of a detailed performance-based brief; contracting construction, operation and/or maintenance by means of a performance-based specification of materials, components, and long-term actual performance of the facility; commissioning the entire project by means of a performance-based procurement method. The notion that preparation of prescriptive documents should be delayed as much as possible along the demand-supply chain is not an essential part of PBB, although under some circumstances and a given project it may be implemented by such a process.

It is recognised that some of the above mentioned features are more essential than others in implementing a PBB environment. Above all, some innovation and alterations in existing formal documents and procedures (Regulations, Standards, and Approvals) are the most instrumental. On the other hand, it does not necessarily require altering the flow of activities during the building process, neither the contracting or procurement methods. It is also recognised that final working documents for in-situ works must be prescriptive, while final specifications for the purchase of materials, industrialised components, and service systems may be performance-based, but that even in this case, the manufacturer will provide his workers with exact prescriptions. The decision with regard to who along the process and when prepares the prescriptive documents or specifications, and until which stage performance-based language is used in the documents passing between professionals, is project dependent, and not an essential feature

of PBB. Consequently, although an interesting topic for further research, the Report does not try to address it at all.

Most of the PeBBu Network Tasks assumed a-priori that given the many incentives for its implementation, PBB is certainly something to aspire for. Consequently, they engaged mostly in responding to the question "given the many incentives, what are the best strategies for overcoming the barriers in order to promote PBB implementation?". However, two PeBBu Domains (6 and 8) have been more fundamental and posed the question "is PBB really needed and justifies implementation?". Only Domain 8 reached a positive conclusion. Section 5.4.1 summarises this debate before proceeding in section 5.4.2 to the suggested strategies for promoting PBB implementation.

5.4.1 Is PBB Needed and Justified?

Domain 6 identified the notion PBB with the changes it may imply in the building process in general, and in the procurement stage and methods in particular. In this context it could not reach a conclusion and supply a reply to the question "is PBB really needed and justifies implementation?". Moreover, it pointed out that it "*has been frustrated by the dearth (total lack) of empirical data*", and then stated: "*PBB needs greater clarity and rigour. It is clear that PBB poses many challenges for legal and procurement practices in building and construction but because of the unstructured nature of the field (discipline) it is not clear how these can be approached (overcome)*" (see Annex VI for details).

Domain 8 regarded PBB as an innovative paradigm, which is an innovation enabler. It declares first "*Innovation is not always appropriate. Innovation has to enhance the overall performance of the building in use*". The same is stated for PBB. However, it then proceeds and clarifies that as currently supply (existing performance level of buildings) does not meet demand (expected performances), innovation is needed to bridge the gap. Figure 2 in the Domain 8 Summary (Annex VIII) indicates that only a balance between supply-push innovation and demand-pull innovation has the chance to improve performance-in-use. Consequently, as the need for innovation is proven, PBB seems to be an excellent solution since it is "*an enabler of innovation*", and in a cyclic process (outlined in Figure 3 of the Annex), when implementation of the contextual innovations (technological development and process change) are successful, confidence in PBB (as an innovative paradigm) grows and enhances the driving forces for further innovation and improved performance.

5.4.2 Strategies and Activities for Promoting PBB Implementation

Implementation of a PBB environment that explicitly caters for the performance in use of buildings, while enabling innovation, change and free trade of building goods, is not a straight forward task. The means include first and foremost majors changes in the regulatory framework and the accompanying formal documents (Laws, Regulations, Codes, Standards, Specifications, Approval and building permit administrative rules), in order to enable the other changes that may be needed at any point along the demand-supply chain of the building process. Preparation of the entire set of documents in a coherent manner, and providing all the necessary changes in the formal associated bodies (authorities having jurisdictions, product and building system approval bodies, innovation assessment bodies) require long time periods, and raise the problem of an interim incomplete infrastructure. However, as a research community whose aims and vision are always at a somewhat distant horizon, the PeBBu Network has the ability and duty to deliberately ignore the time obstacle, and address the strategies and means that may be instrumental in achieving the final target.

Based on the PeBBu Tasks' inputs, the following strategies and activities have been compiled.

Strategies

The following strategies are to be adopted internationally and accompanied by national commitments to support the ensuing activities.

Public relations – Increasing general awareness to the principles of PBB, and its basic paradigm of intension-based activities along the entire building process, with performance-in-use of the built facility as main target.

Increasing awareness to the benefits of a PBB environment – Increasing awareness to benefits of improved building performance and the role of a PBB environment in attaining it. Target groups include all the various stakeholders including the non-professionals on the demand side (i.e., entrepreneurs, owners, and end users) to create the pull force, and professionals on the supply side to create the push force.

Enhancing Government leadership – Governments interested in the outcomes envisaged by creating a PBB environment, should assume leadership via the regulatory framework, as well as in projects for government buildings and public housing.

Enhancing professional knowledge – Incorporating the basic concepts and tools of PBB in education and training of the young newly emerging professionals, as well as in continued education of practitioners. Performance-based design has already been used in the past, but not necessarily under that name. It can be instrumental to raise awareness of design professionals to the links between PBB and PBD approaches they already know and use.

Making knowledge and information easily available – Information at various levels, intended for the different stakeholders should be made readily available. The internet is an excellent medium, and most of the PBB-related knowledge can be found there even now when one knows what to look for. The knowledge needs of the practicing community are clear to researchers in the area, but less so to the practitioners who may be puzzled by not knowing even what to look for. Making relevant knowledge easily accessible is a basic strategic target for PBB implementation.

Standardising objective tools – Design verification and assessment by means of proper analytical tools are an integral part of using a performance-based design brief. As these tools are usually international there is no need to re-invent them in every project which has chosen to use this mode of design contracting.

Assessment of the envisaged performances upon delivery, or post occupancy, may be needed when a performance-based design and/or construction contract have been employed. Standardisation of the methods is needed in order to avoid redundancy of efforts and disputes.

Simplifying! – The scientifically-based design evaluation methods yield a multitude of outputs, which is a suitable information source for the design team members, but too cumbersome for managers and approval bodies, who need simpler tools for enabling fast decisions. Linkage between the sophisticated tools and the needs of decision makers is essential.

Bringing research to practice – Extensive research at prototype level is carried out at universities. Some of it may be sufficiently ripe for turning into practical tools. Collaboration between academia, applied research institutes and practitioners is essential for most activities intended to bring research results into practice. Emphasis should be made on friendly user interfaces and simplicity.

Learning from practice – Feedback on successful implementation of a PBB environment, as well as on the actual methods employed, difficulties encountered during the process, and how they were solved is a means for increasing confidence in the innovative parts of PBB. Feedback on failure in implementation and its causes is significant as well.

Enhancing team work – An inherent feature of the building market is the fragmentation into many small companies, plenty design offices, and individual consultants. On the other hand, an inherent feature of PBB is the need to address and satisfy a multitude of needs in various areas of building performance, which requires coordinated team work. Actions geared to increase team work at the design stage should be sought.

Activities

The above strategies can be implemented by means of the following activities. Some strategies were delineated by more than one activity, as well as some activities serve more than one strategy. In addition the last strategy (enhancing team work) was not delineated into specific activities and remains as a general strategic aim for the building market, to be implemented individually per project.

Knowledge dissemination – Establishing national platforms, including a national website in the native language. Organising workshops/seminars in conjunction with other events, or as stand alone events, for the various stakeholders' target groups.

Establishing a PBB enabling infrastructure – A regulatory framework that enables performance-based design and contracting is essential for PBB implementation. Governments should advance the changes needed in the regulations and other formal documents.

Preparing model performance-based tendering documents – Government should prefer performance-based tendering in its projects, and prepare performance-based tendering documents for building construction works. Such documents may then serve as model documents for the private sector.

Incorporating PBB knowledge in professional curricula – Development of model syllabi for professional education at various levels from vocational schools to university and continued education courses. These can be accompanied by PowerPoint presentations for specific modules.

Preparing a structured information source – An international body, probably CIB, should create a structured information source, which is built so that each of the various stakeholders and professions can find easily the knowledge relevant to him at every phase of the building process, without being confused with too much additional non-relevant knowledge. The current outcomes of the PeBBu network are a good start for the general part of that site, but the entire structure and professional parts need careful elaboration. The site branches should include links to existing knowledge, with new items from many of the following activities dispersed accordingly.

Preparing an inventory of quantitative performance-based requirements – The research community should develop tools that can assist regulators, entrepreneurs and design team members in the transformation of User Needs into quantitative criteria amenable to design. In addition to the general tools, it should prepare a handy international inventory of accepted performance requirements and associated criteria for various occupancies, building types and geographic and cultural regions. The Compendium of Performance Requirements prepared by Aligned Task 2 is a good start.

Standardising accepted design assessment methods – Efforts for international standardisation of assessment and performance verification tools should be enhanced in all areas of building performance. These tools should be scientifically based and broad enough so that they can be adopted with only minor adaptations by all countries. The structural Eurocodes can serve as a good example.

Standardising assessment methods for the built facility – Methods for performance monitoring in existing buildings should be developed for most of the performance attributes. The in-situ acoustic tests that are formalised in the ISO Standards are a good example.

Developing decision-making and assessment tools – Development of integrated computer platforms that enable performance evaluation of given designs for entire buildings within all the relevant disciplines. The user interface and input module of such programs must be linked to design drawings in order to become part of the design-office routine, as well as to enable linkage between the various design team members. The tool should use a common database that follows the dynamically developing design solution to be used by all the disciplines. The outputs must include a design oriented module presenting design outcomes in terms of the relevant performance indicators. The n-D modelling concepts are a good starting point. The scientific scrutiny of such programs can vary, according to the specific target. Tools for

conceptual and preliminary design can be based on qualitative rules, inventories of best practice examples and simple grading tools, whereas tools for evaluation of detailed design at the stage of final decisions and choice of detailed items must be based on building physics and mechanics. Various modules for such tools exist and are used by the research community. These may be integrated into such a platform. The research community, in collaboration with the commercial computer programming community are the partnerships for developing such tools.

Developing an inventory of Key Performance Indicators – Key performance indicators, KPIs, may provide simple yet coherent aggregated information on achieved performance levels. An inventory of accepted KPIs should be prepared at international level, and then followed by national Benchmarks. Benchmarks can be derived theoretically, but should be verified by means of POEs.

Developing tools for the managerial phases – Adequate tools for the various managerial phases of a performance-based project should be developed/modified, tested, and validated by means of pilot case studies. Those found suitable should be further developed to suit implementation in actual projects. Focus should be on design management, procurement methods, and liability.

Conducting Post-Occupancy Evaluations – A powerful, though expensive, tool for feedback on the implementation of a new performance-based strategy or method in a particular project is a Post Occupancy Evaluation study, carried out several years after occupancy. POEs should be accompanied, as much as possible, by monitoring, and not rely solely on questionnaires and visual inspection. Lessons learned should be used to modify the initial methods. Continued follow-up is needed for modified methods.

Preparing an inventory of case studies – Preparing an inventory of case studies and examples of best practice, indicating the benefits of performance-based design. It should also address difficulties encountered in practice and methods that have been successful in overcoming them. An integral part of such an inventory may be examples of failure in implementation with careful delineation of causes and detailed monitoring of outcomes.

PBB Research & Development Roadmap Summary

CHAPTER 8

6 PBB Research & Development Roadmap Summary

Author of this chapter: Dr. Greg Foliente

6.1 Introduction

This chapter presents a summary of a global research & development (R&D) roadmap for the next two to three decades. The purpose of the roadmap is to establish a comprehensive application of the performance approach in practice and make it one of the key enabling principles to transition the building, construction and property industry into a client-focused, knowledge-based and services-based industry, characterized by sustained innovation and excellence. It could be argued that this transition will be difficult to achieve without embracing the performance concept.

An R&D roadmap is needed to assist: (1) researchers and research planning agencies in identifying topics of investigation that will make significant contributions to advance knowledge and facilitate practice; (2) practitioners and building professionals in better understanding the state of development and application of the concept and in supporting priority R&D areas; and (3) R&D funding agencies in directing or allocating their resources wisely.

The full report [Foliente 2005c], of which this is a brief version, was the outcome of a collaborative effort by Wim Bakens, George Ang and Dik Spekkink (from the Netherlands), Pekka Huovila (Finland) and Greg Foliente (Australia), considering multiple sources of data and information – including the other chapters of this report by R. Becker – as explained later.

6.2 Process Overview

Our starting point was to identify a critical role for performance based building (PBB) in a long-term vision for the building, construction and property industry. The year 2030 was chosen to coincide with European Construction Technology Platform (ECTP)'s 2030 vision for the industry in Europe (ECTP 2005).

Then, on the basis of current knowledge and practice, we mapped strategies that will link 'what is' (the state of the art and state of practice) to 'what could be' (the vision). The R&D needs identified in the discussions and activities of the PeBBu Domains, Tasks and Platforms were collated and synthesized with key PeBBu publications (Becker 2005, Szigeti 2005), and other literature and sources of information (e.g., Foliente et al. 1998; Huovila 2005; Bakens et al. 2005; Preiser and Vischer 2005; Szigeti and Davis 2005).

Following a group brainstorming session on the drivers and general strategies that can contribute to fulfilling the 2030 vision, an R&D Roadmap supporting this vision was developed considering three time horizons (after Baghai et al. 2000):

- Horizon 2010 (short-term, incremental)
- Horizon 2020 (medium-term)
- Horizon 2030 (long-term, transformational)

Projected impacts in the horizon planning periods were also identified.

6.3 2030 Vision and Strategic Pathways

Based on ECTP's 2030 Vision document and the collective knowledge of those named earlier, we propose the following PBB vision statement:

Performance concept underpins (i.e., is used routinely and applied comprehensively within) a construction and property industry that: (1) delivers value to present and future stakeholders; (2) delivers sustainable outcomes; and (3) is transformed into a knowledge- and services-based industry, characterised by innovation & excellence.

The above maps with the ECTP Vision as follows:

ECTP 2030 Vision	*PBB 2030 Vision* Performance concept underpins industry that:
▪ Meeting clients' requirements	▪ Delivers value to present and future stakeholders
▪ Sustainable construction	▪ Delivers sustainable outcomes (environmental, social, cultural & economic)
▪ Transformed industry sector	▪ Is transformed into a knowledge- and services-based industry, characterised by innovation & excellence

Although there may be other factors and pathways that could help bring these outcomes (right-most arrow in Figure 1), through the performance approach, there are reactive and proactive strategies (Figure 1, central arrows). Examples of reactive strategies include those related to setting minimum performance requirements via regulations. Examples of proactive strategies include performance concept applications in building procurement, production and management (Gross 1996; Ang et al. 2005; Bakens et al. 2005). Whether one follows a reactive or proactive strategy, both product and process innovations are possible. When the concept is applied in a sustained manner, over a number of projects and over time, the attitude and practice of innovation and excellence can become systemic, not limited only to one-off projects but embedded in organizational culture, and becoming a major influence throughout the industry.

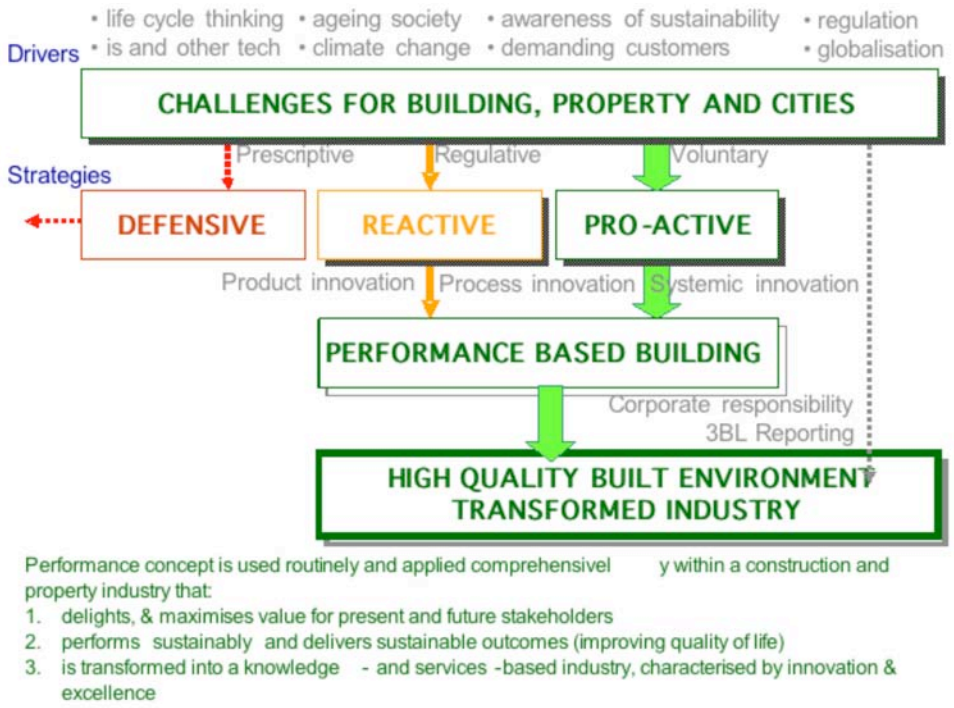


Figure 1. Strategies to achieve the PBB vision

6.4 R&D Roadmap

6.4.1 General

A summary diagram of the PBB R&D roadmap is shown in Figure 2. The current state of the art and state of practice (e.g., this report) is the starting block, and achieving the PBB vision is the ultimate objective. Three planning horizons link these two. The first horizon is what we aim to achieve in 2010 (i.e., Horizon 2010). Some of the key elements (or R&D needs) at Horizon 2010 are related to each other, and they feed into the elements of Horizon 2020. Likewise, some of the elements at Horizon 2020 are related to each other, and they feed into Horizon 2030, which in turn directly contribute to achieving the PBB vision. The basic idea is that PBB is ubiquitous in the industry by 2030, no longer seen as a special concept or method but part of normal industry activities – a natural basis for how things are done in the industry.

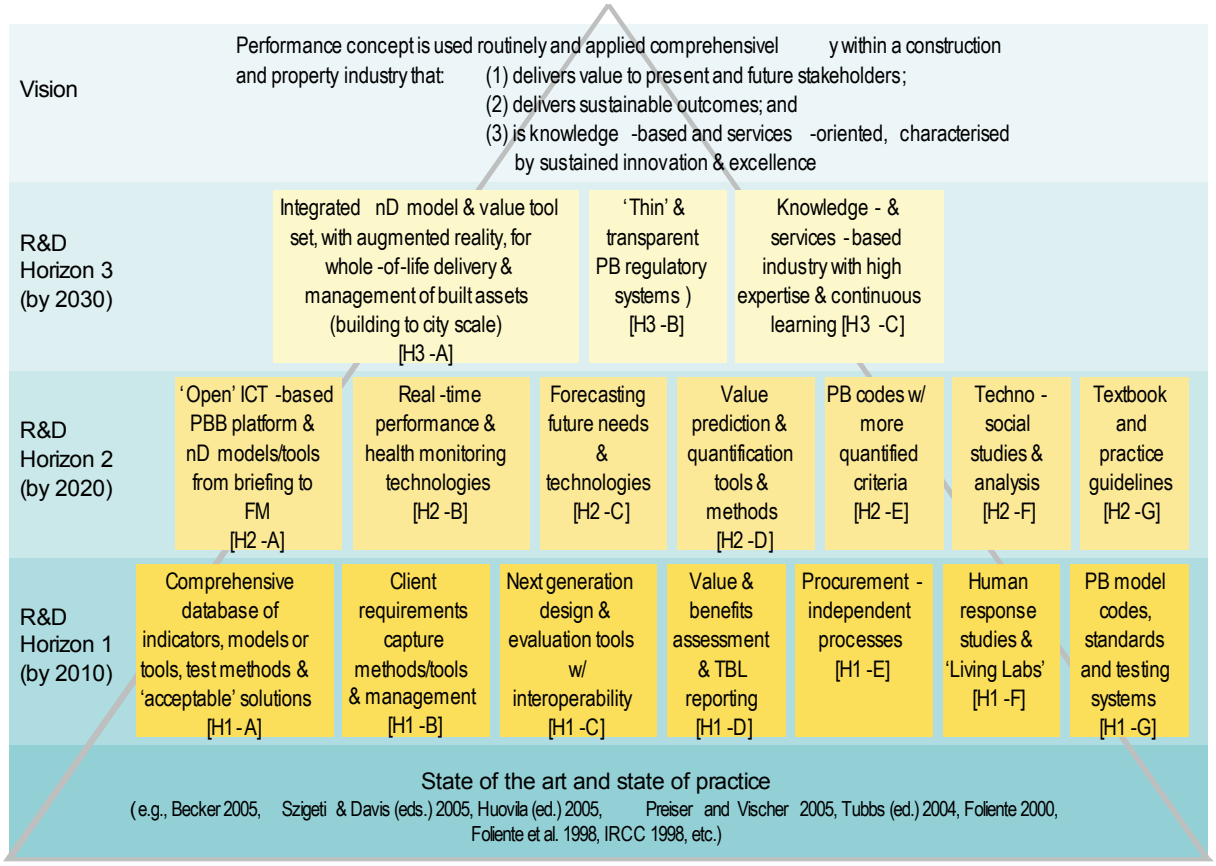


Figure 2. Summary diagram of R&D roadmap in three planning horizons to achieve the PBB vision

The basic meaning of R&D is generally understood, but it should be noted that Figure 2 includes some aspects of demonstration/delivery (right side) and, thus, could be more appropriately called an 'RD&D' (research, development & demonstration/delivery) roadmap. Having said this, however, not all demonstration/delivery needs are identified and included; other demonstration/delivery needs have been

discussed in this report by Becker and in [Foliente 1998] and [Bakens 2005]. The expansion or extension of the roadmap to RD&D as presented in Figure 2 is needed to achieve the stated PBB vision.

Each element of the roadmap is briefly explained in the following sections. Further details are given in [Foliente 2005c].

6.4.2 Horizon 2010

Comprehensive database of indicators, evaluation tools & solutions

Performance indicators, requirements and targets/criteria are at the heart of the performance concept. PBB currently lacks a universal classification of the performance properties of building – where 'building' could mean one or all of the following: (a) finished product (physical asset), (b) process, and (c) service (financial asset or key component of business delivery).

A building code (or building regulatory document) specifies the minimum set of legal requirements, in terms of both specific attributes to be considered and level of performance to be targeted. There are many other performance attributes and requirements/measures – qualitative and quantitative – which are not covered by building regulations and need to be considered from planning/briefing to facility management during occupancy stage [Szigeti 2005b]. The appropriate set of additional requirements could change from one project to another. Thus, a comprehensive and readily accessible national and/or international database of performance indicators and measures that allows multiple views of contents and simple ways of extracting sets of indicators by project type, life cycle phase, stakeholder view, etc., will provide tremendous assistance in getting the PBB concept and framework considered and adopted at the very outset.

The indicators database should be as comprehensive as current knowledge allows. Indicator entries should be clearly defined, with literature references where applicable, include reference values (minimum, 'target' and/or maximum) and methods of calculations and/or measurements where known/available, and be wrapped/tagged with other useful information that supports the concept of semantic web. The context and applicability of reference values should be clearly spelled out (i.e., they serve as 'reference' not as universal targets) since they are normally set to meet local objectives and conditions.

In the basic PBB application process illustrated in Figure 3 over a facility life cycle, setting of performance requirements could be greatly facilitated by a comprehensive performance indicators database. This process is typically iterative (sometimes involving a number of design cycles), although changes usually decrease dramatically in successive cycles. The figure also shows the Generic AEC Reference Model (GARM), also popularly known as the 'Hamburger Model', which shows the relationship between functional concept (shown in the figure as 'setting performance requirements') and the solution concept (shown in the figure as 'defining technical solution') in the shape of a hamburger sandwich, after [Gielingh 1988]. Any design and/or technical solution can be checked against target requirements (either in prediction mode, before construction, or as-built or in-service evaluation mode, after construction); this is shown in the figure as 'validating the conformity'.

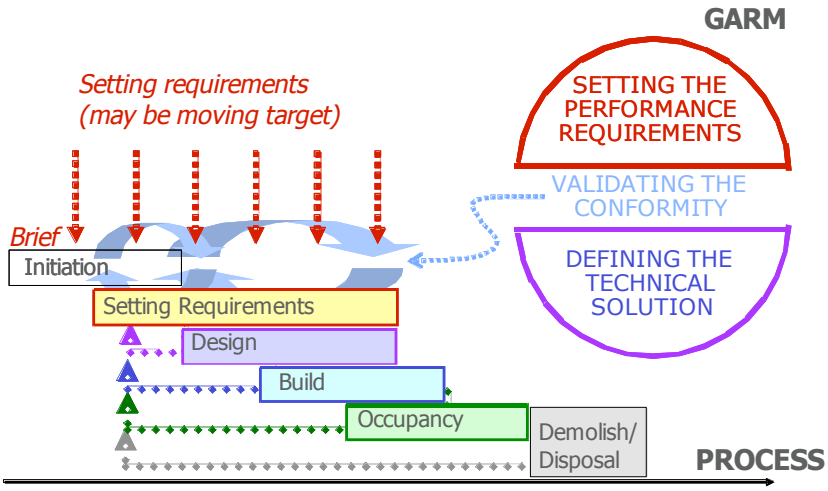


Figure 3. PBB application from setting requirements to assessing designs or technical solutions on the basis of target requirements

As demonstrated in Figure 3, two related databases are needed to complement the indicators database:

1. performance models and assessment methods (or conformity validation tools) database – used for design (seeking solutions to meet target) and/or evaluation (assessing whether supplied design or actual built system meet the target performance); see also Annex XX, Compendium of PBB Models.
2. proven or accepted solutions (or technical solutions) database – a registry of products/technologies, designs and solutions that have been shown to meet specified requirements ('fit for purpose') in a specific project/application or trade zone (e.g., CPD in Europe). It should be noted that this kind of database needs specific information that describes the context of 'acceptability' (i.e., context-specific), even for those considered to be 'standardised products' or 'standardised solutions' (i.e., what does 'standard' mean in this particular context?). This is needed to provide transparency, improve understanding and avoid mis-application of information.

All the databases should be universally available, as a reference and guide, and should be easily updated and populated by anyone from anywhere in the world (along the lines of 'open source' software model – everyone can use freely and anyone can contribute). Ideally, anyone can also comment on relevant entries (along the lines of independent public reviews of products and books in www.amazon.com, where the individual reviews are, in turn, also publicly rated (e.g., with a question like 'Was this (review) helpful to you?').

Client requirements capture methods & management

In the proactive application mode of PBB – e.g., applied to promote best practice in building production, on a project by project (or project group) basis – there is a glaring need for systematic and user-friendly methods of capturing or setting user needs and client requirements. This includes guidance on process methodology and technique (e.g., charrette or value management method), but also special-purpose tools such as EcoProp [Huovila 2004], that facilitate the process of capturing requirements. Development of methods for the capture and assessment should also include capture of 'subjective building performance' such as image expected, perception, cultural value, etc. Then assuming the requirements were captured properly, these should then be managed (maintained, referenced, updated, etc) throughout the life of the facility.

In order to deliver 'good performance' it is crucial for 'delivery' partners in the building process to have a common understanding of the needs and requirements of the client(s) – both sides need to have a shared understanding of the desired outcomes. In other words, industry professionals need to capture, understand and define user and stakeholder needs before they start thinking about the solutions. The main problem is that one side knows only 'user language' related to the users'/clients' own perceptions and vocabulary. The supply side building partners tend to think in terms of 'solution concepts', using 'technical language'.

The performance concept can bring about considerable improvement, as this concept offers an 'intermediate language' that makes it possible to match demand and supply – the use of 'performance language' (Figure 4). But, there should still be explicit efforts to develop and explain methods of bridging this language gap, and to improve existing briefing tools and/or develop new tools to better match demand and supply. As user and stakeholder needs may vary in time, tools for the management of user and stakeholder requirements are needed in all stages of a facility's life cycle.

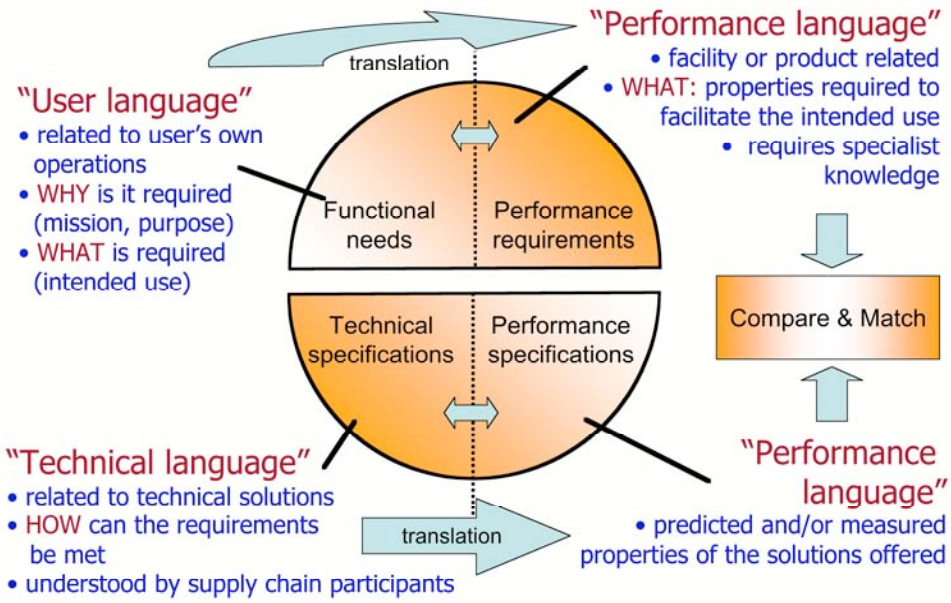


Figure 4. Performance language as an intermediate between User language and Technical language

Next generation interoperable design & evaluation tools

The availability of appropriate building performance models, as mentioned earlier, is critical in the implementation of performance based building. They refer to computational procedures or computer programs that can be used in:

- *developing quantified performance criteria* for building codes and standards;
- *designing* a building or part of a building to a target performance; or
- *evaluating* the whole building or any of its part as built, at commissioning, or at any time during building occupancy, e.g., as part of a performance review or audit.

Figure 3 illustrated the use of these models in validating the conformity of designs and technical solutions to target requirements.

Nearly all PBB models currently available, some of which can be found in the Compendium described in Annex XX, were developed and are typically used in practice as stand-alone tools, and analyses performed in series (i.e., one tool at a time). A few have some level of integration and/or inter-operability with other tools (especially CAD software). But there are increasing numbers of new tools with greater integration

and inter-operability such as LiCHEE (Life Cycle Housing Energy Estimator; www.cmit.csiro.au/brochures/tech/lichee/), LCADesign [Tucker 2005], (www.cmit.csiro.au/brochures/tech/lcadesign/), and the prototype nD models from Salford University [Lee 2005, Aouad 2005].

The next generation of tools should allow inter-operability with larger number of tools that deal with different aspects of performance, and better integration of functions, even when they have been independently developed. This means greater use of inter-operability standards and protocols. After all, the actual in-service 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, etc. The end user experiences the performance of a built facility as a whole. Thus, the design and delivery disciplines (including contractors and sub-contractors, in some cases) will have to co-operate closely to create an integrated facility design. Designers have to deal with systematic interrelations between different performance specifications, which often relate to different fields of expertise. Thus, application and benefits of the performance-based approach will be maximised with integrated design, with parallel, interrelated contributions from all design disciplines involved (Figure 5). The next generation of performance tools should make this possible and easier to do.

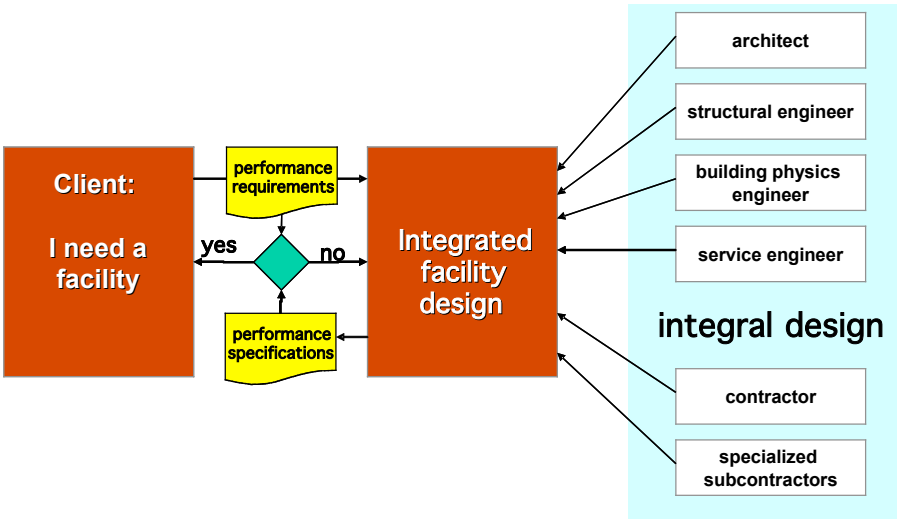


Figure 5. 'Performance' is the result of different solutions for different subsystems and a combination of effort from different disciplines

Values & benefits assessment & TBL reporting

The need for accounting for the benefits of the performance approach in real or practical projects has consistently been identified as a critical RD&D need [Becker 1996c, Foliente 1998, Bakens 2005, Foliente 2005c, Becker 2005], Unless the economic value/performance and benefits can be articulated and supported by reliable data, key decision-makers (e.g., investors, owners and developers) will not explicitly adopt or promote the concept.

A detailed statement of the value and benefits of performance-based building for different stakeholder groups has not been produced. This requires some serious effort and should become a priority. The CIB report on a framework to document and capture the economic benefits from the performance approach [Tempelmans 2001] needs to be re-visited From a practical viewpoint, a collection or compendium of case studies of projects where the performance approach has been used, and analysis of cost and value are needed (e.g. [Chapman 1996]).

The process of defining and delivering stakeholder values (as in CIB's Proactive Program on Revaluing Construction [Barrett 2005a]) is a natural area of application of the performance concept. Whether the value is direct or indirect, tangible or intangible, they have to be accounted for, systematically collected and assessed. Case studies may be used to validate them. The value networking and value creation process needs to be studied from different stakeholders' points of view.

The increasing interest on, and in some cases demand in projects for, triple-bottom-line (TBL) reporting (covering economic, environmental and social sustainability) are also positive drivers for incorporating the performance concept in planning, processing and evaluation/assessment. Publicly traded companies are starting to be rated in the area of corporate social responsibility (CSR) and using other 'ethical investment' indicators. If the share value of companies depends, not only on the economic results, but also on environmental and social consequences, this will have an impact on the strategies of, not only the owners, but also the users of buildings. If the supply chain can reliably deliver buildings that perform to meet the needs of their customers and the TBL criteria over their life span, that should have positive implications in their value.

At present, valuing of buildings primarily depends on several variables, such as location (and local services), market conditions (the level of supply and demand, the interest level of credits), and not much on the performance of buildings. In the short term, it would be ideal to have a model that could be used for estimating how the TBL performance of buildings correlates with market value. Beyond the direct influence on users and owners of built facilities, buildings also have social and cultural impacts at the community and city level. The performance approach should underpin TBL reporting guidelines and requirements for built facilities.

Procurement-independent processes

Project delivery and procurement systems determine the rules of engagement and the work relationship environment between client and supply team, and among members of the supply/delivery team (including their sub-consultants and sub-contractors) – not just in a formal legal sense but this also flows into informal aspects of the work relationship. Procurement is, in essence, about the acquisition of project resources for the realisation of a constructed facility, in whole or in part, at a discrete life cycle stage or over a defined period of time.

Many factors affect the choice of procurement method, and this is determined or driven by the client – decided sometimes across its portfolio and sometimes on a project by project basis. Recent action research in Australia, investigating actual public and private projects, has shown that *relationship management*, regardless of the type of contract that was adopted (e.g., traditional, partnering or alliancing), holds the key to positive outcomes. The underlying principles of relationship management approaches are open, frank communication and a joint approach to problem solving and these principles can be applied to any procurement system and contract types [Cheung 2004; Rowlinson 2006].

New procurement independent processes, such as that cited above, need to be developed to facilitate and promote innovation and excellence in a sustained way. The application of the performance concept in ensuring that relationship management principles are incorporated in any procurement model or system, for example, needs to be investigated and developed. Other enabling principles need to be considered, with the ultimate objective being value creation for client and project stakeholders.

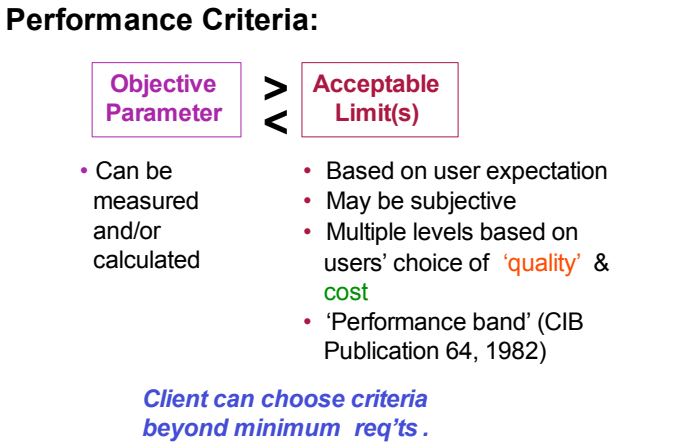
Human response studies and 'Living Labs'

Although the performance concept can be applied whether the performance criterion is either quantitative or qualitative [Beller 2002], its validity depends on the rigour of the solution evaluation process. This means that the more quantitative the performance criterion the better.

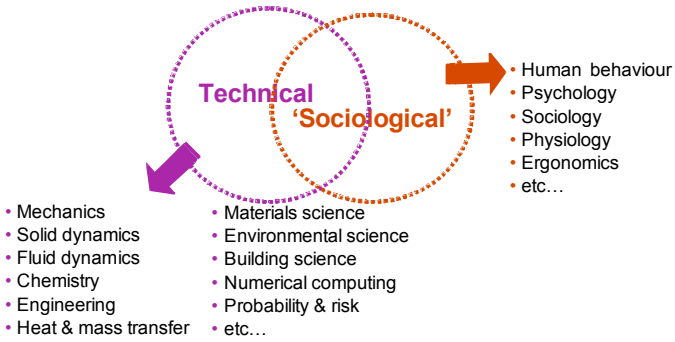
Figure 6a shows the two sides to a quantified performance criterion: an objective parameter (left) and the acceptable limit (right). As indicated in the figure, the proper establishment of performance criteria (or setting of acceptable limit) requires extensive human response studies. Unfortunately, this remains the

biggest gap in building science research [Foliente 1998]. Figure 6b shows the areas in social science that need to be considered, in conjunction with the traditional technical studies. This needs to be done for most performance attributes, even for those that currently have suggested or required limits based on ad hoc decisions of technical committees.

Human behaviour studies may be laboratory-based, field-based (specifically set-up for it or 'experimentally controlled') and/or based on surveys, interviews and observations of 'uncontrolled' environments. They need careful use of statistical techniques in both experimental design and data analysis. Different methods and techniques can be employed to obtain human response data, including the use of stress-sensing set-up (contact and/or non-contact), and mobile ICT-based methods. In both research planning and data/results analyses, the driving objective should be the establishment of acceptable criteria that meets societal expectations.



(a) Basic elements of performance criteria



(b) Topics of consideration in establishing acceptable limits

Figure 6. Set-up and considerations in establishing quantified performance criteria

PB model codes, standards & testing systems

For practical and economic reasons, building codes will always have a mixture of performance and prescriptive provisions (in varying proportion). But model building codes that have full performance based provisions from the highest level ('goal' or 'objective') down to performance requirements are needed because they demonstrate in a technical sense what can be done and how (e.g., [UN 1996]). This does not only help countries that would like to wholly adopt the performance approach in building regulations but

any country or regulatory body that would like to adopt performance requirements in parts, or by individual performance attributes (e.g., to add to, or replace existing parts of, its current code).

Performance based building codes need to be supported by a set of standards covering definitions of the objective parameter(s) in performance criteria (or of the performance indicator), and how they are to be measured and/or calculated, among others. To demonstrate that a given product or design satisfies the performance criteria, objective methods of evaluation are needed. Proposed technical solutions (Figure 3) can be evaluated by:

- Testing;
- Calculation; or
- Combined testing and calculation.

It is obvious that without agreed performance evaluation tools and methods, the performance concept cannot be implemented properly because performance cannot be verified.

Other specific issues and needs are further identified and discussed in literature [IRCC 1998, Tubbs 2004, Meacham 2005].

6.4.3 Horizon 2020

'Open' ICT-based PBB platform & whole-of-life nD modelling

The lack of an ICT-based PBB platform to facilitate integrated analysis of building performance hinders the widespread application of the performance concept [Becker 1996c; Porkka 2005]. Beyond mere data inter-operability between tools, that was aimed for in Horizon 2010, and integrated 'nD models' for building performance analysis (or, monolithic tools that can do multiple performance analyses [Lee 2005, Aouad 2005]), herein we envisage a whole platform that allows extensive and seamless linkages and inter-operability across independently developed tools and databases throughout the facility life cycle [Foliente 2005b].

This will require a standardised information exchange format that is widely accepted and supported in both the ICT and the AEC industries. Since performance assessment is relevant in all phases of the building process, it is important to build a seamless chain of services from the identification of needs and initiation of a project through briefing, design, product development, manufacturing and construction to commissioning and operation, maintenance demolition, recycling and disposal (Figure 7). The information once created should not be lost and reproduced, but enriched and completed in the process. It should be possible to validate the conformity of the required, designed, constructed and maintained performance at any stage of the process. Different tools (including powerful visualization tools) are extremely useful in customer interaction and feedback. The performance models beyond 4D, now referred to as nD models (with modules and databases that can be plugged in and out, i.e., not monolithic) can be developed from such an open ICT-based PBB platform [Foliente 2005b]. Ideally, every cell in the n-dimensional matrix in Figure 8 would be populated with performance criteria and method(s) of evaluation.

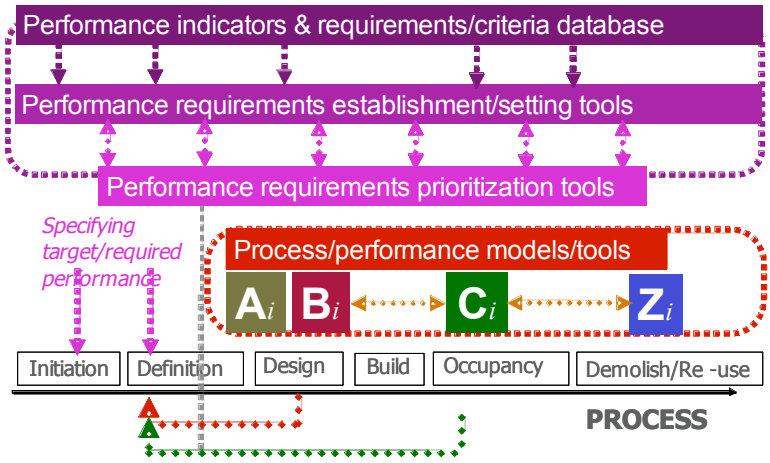


Figure 7. Interactions of databases and tools to be captured in an open ICT-based platform for performance based design and evaluation through the life of the facility

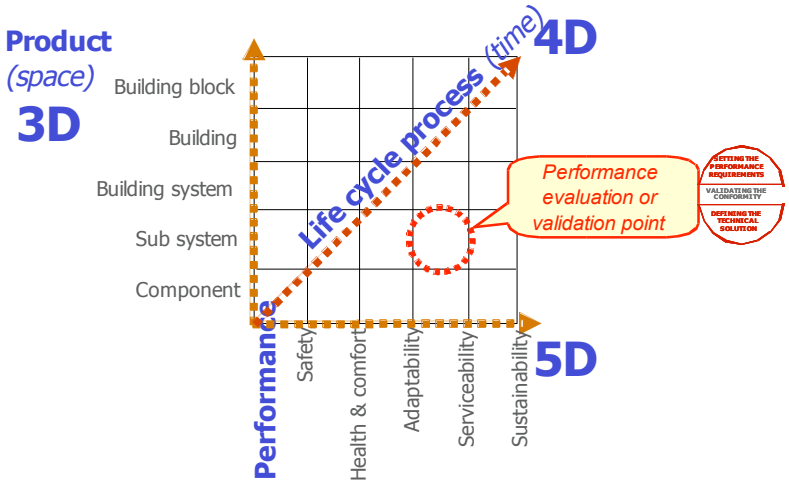


Figure 8. Dimensions in nD models for building and construction; every cell in the matrix is a point to match requirements and technical solutions

Real-time building performance/health monitoring technologies

Performance assessment by direct measurements is the most reliable way of knowing actual in-service performance. If the value of the facility is based or linked to actual in-service performance, then there should be strong motivation to know the actual performance, state or 'health' of built facilities, regardless of what calculations and model simulations said they would be. Many factors get in between design intent and in-service performance of facilities.

Building performance/health information is useful not only for diagnosis (i.e., to find out what to do when something unexpected has happened) but also for prognosis (i.e., to plan what to do before something adverse happens or to do something now to prevent it from happening). Periodic assessment will be sufficient in many cases but, where available, real time monitoring could provide better opportunity to adjust and make corrective measures sooner to improve performance, minimizing business disruptions and other 'failure' costs. New sensors and visual, wireless and mobile technologies are expected to offer opportunities for a new generation of services and innovative sustainable business models, especially in the

operation, maintenance and refurbishment of buildings. Of special interest to property investors, owners, businesses and building tenants is the quality of indoor environments (spatial, functional, thermal, visual, acoustic, indoor air quality) that affect human comfort, health and productivity. There has also been increasing interest in security and safety, and environmental impacts due to resource use and overall building use (e.g., electricity and water).

Forecasting future needs & technologies

The products, technologies and processes in construction have developed over hundreds and thousands of years and only slight changes seem possible in the future. But looking at Horizon 2020 from a sustainable knowledge society perspective, and in an 'info-tronics age', a number of systemic innovations, even disruptive innovations, can be expected to see daylight by that time. Technology, innovation and business trends in the last 5 years alone point to this strong possibility. At the same time, the future citizens of the information society may have different life and work styles than we know now, and thus different needs and requirements from their built environment.

A number of mega-trends can be identified concerning emerging technologies, the maturity of intelligent products and systems, and potential new processes and services. At the same time, some 'weak signals' can also be identified. They may either pass or transform into new mega-trends that affect both the demand for, and the supply of, built facilities within the next decades. Thus, it is proposed that a systematic forecasting procedure on future society changes, people's needs and technologies be established in order to help both the R&D community and the industry to adapt and develop efficient and productive ways of meeting the building performance needs of future clients. This would also, naturally, include to an increasing degree the need for knowledge and technologies to transform the current building stock to meet the building performance requirements of the future.

Value prediction & quantification tools/methods

Key to stakeholder engagement and industry-wide adoption of PBB is industry knowing and enjoying the benefits and value gained from PBB [Bakens 2005]. In the same way as the performance concept is applied in setting technical performance requirements and assessing technical solutions, it can also be used in setting 'expected value' (using appropriate indicators) and then assessing whether this value has been realized, based on the delivered product or service. Thus, the first need is establishing a basic set of indicators of value (considering both economic and non-economic indicators). Since 'value' has a number of dimensions, differing in significance according to the perspective of the stakeholder in the project, methods of eliciting additional value indicators from clients and project partners also need to be established. One of these methods can be employed on a project by project basis.

Then, as in technical performance evaluation, value quantification models and evaluation methods need to be developed and included in the database of 'performance' tools, and linked into the open ICT-based PBB platform described earlier.

PB codes with more quantified criteria

The need for quantification of as many performance criteria as possible has been made earlier and fairly strongly in this report. As a result of Horizon 2010 outputs of human response studies, methods and techniques of establishing quantified, risk-based performance criteria from human response studies would have also been developed and some standardised. The desired 2020 outcomes are that: (1) quantified criteria in Performance Based building codes have been established using these methods (not only replacing qualitative criteria but also quantitative criteria that have been set in an ad hoc manner by technical committees), and (2) multiple levels of performance have been established allowing consumers choice of risk or performance level vs. cost balance they are willing to take (all above minimum code requirements).

Techno-social studies and analysis

Decision-making becomes more complex when the context moves from product/material level to whole building to whole site development or portfolio of buildings scale, and when the key variables increase. The availability of technology-based decision-making tools alone is no longer sufficient to predict outcomes at higher levels of complexity; the influence of human decisions, behaviour and actions, and the dynamic relationships between and among 'actors' and physical systems need to be explicitly taken into account. This means that performance models based on complex systems science need to be employed for both scenario planning and evaluation. This would allow practical applications of the performance concept beyond buildings and into the wider context of development.

Textbook & practice guidelines

Although basic PBB-related education and training materials should be available sooner, by 2020 there should be widespread availability of textbooks, handbooks, compendia of demonstration projects, case studies and best practice, and guidelines on criteria, processes, performance models, evaluation and assessment, etc, through various media (e.g., print, electronic, audio, video) and from multiple and easily accessible sources (including on-demand).

6.4.4 Horizon 2030

Integrated nD model & value tool set for whole-of-life delivery & management of built assets

Elements of Horizons 2010 and 2020 relevant to an open ICT-based PBB platform, databases, inter-operable tools and nD models – including value models and criteria – should have converged by this time, changing AEC practice and enhancing industry knowledge in the process. The briefing experience will be enhanced by n^{th} generation visualization and augmented reality technologies, wherein it would be possible to be fully immersed into spaces that have not been built yet, augmented by physical simulation of environment over specified periods of time or through seasonal cycles that can be set by the user.

Technical solution options can also be virtually built, again augmented by physical reality, and, if needed, evaluated in a similar manner by owners and potential users before they are actually built. There will be very little or no surprise in the final finished physical product because the briefing simulation and the solution-trial evaluations of the building are fairly realistic.

Further challenges in this area lie in developing models of the interfaces of individual buildings and neighbourhoods at a city scale and including uncertainty assessment in performance prediction for maintenance and facility management purposes.

'Thin' & transparent PB regulatory systems

PB building codes are 'thin' in that their normative content only includes the objectives and quantified performance requirements with multiple levels of criteria, not the approved solutions or 'deemed-to-comply' requirements. They are also thin because the explanations/commentary and links to related standards and databases (one of which keeps the approved solutions) are accessed through hyperlinks.

In addition, code requirements are linked into the ICT-based PBB platform. For example, tools for establishing performance requirements would have seamless access to the latest code provisions, automatically called up, based on key parameters of the project identified at the start.

Knowledge- & services-based industry with high expertise & continuous learning

Since tailored or cost-optimised solutions are better achieved using holistic first principles models and tools, industry professionals are expected to keep up with the latest developments of more sophisticated and realistic models of performance. The regulatory system expects technical proficiency. They would also

be expected to be more aware of, and sensitive to, user and client needs; they would be focused on value adding through the whole life of the facility. Because of their high level of knowledge and professionalism, their opinions and services are sought after. Thus, industry professionals invest in continuing technical and professional education, quality assurance and continuous improvement.

6.5 Concluding Comments

A performance based building R&D roadmap should have a definite destination, and not exist for its own sake. This destination should be the realization of industry's long-term vision for itself; and for the purpose of this roadmap was chosen to be ECTP's Vision 2030.

On the basis of current knowledge and practice, the R&D needs identified in the discussions and activities of the PeBBu Domains, Tasks and Platforms and related sources of information, an R&D roadmap supporting this vision was developed considering three planning horizons. With the adoption and acceptance of the performance concept over these time horizons, industry's vision would be realised.

Conclusions

CHAPTER 7

7 CONCLUSIONS

Performance Based Building, PBB, is an environment in which performance-in-use of buildings is an explicit target along the various phases of the building process. It facilitates the development and introduction of innovative technologies and building systems into the market, reduces the technical barriers on free trade, and may enhance the overall quality of buildings. Its implementation can be achieved by using innovative explicitly performance-based procedures and documents in design, construction tendering and procurement, but may also include the more conventional tools and procedures that are based on well documented and approved prescriptive provisions, which are known to supply given levels of performance.

The PeBBu Network has supplied the opportunity to carefully review the state of the art of PBB in research and in practice, and to systematically produce a proposed international Research and Development Roadmap.

In addition to the present Report, 24 individual State of the Art professional Reports [Matolcsy 2005a, Barret 2005b, Cardillo 2005, Chevalier 2005, Davidson 2005, Fenn 2005, Foliente 2005c, Gray 2005, Huovila 2005b, Huovila 2005c, Huovila 2005d, Jasuja 2005, Loomans 2005, Matolcsy 2005b, Pilzer 2005, Sjostrom 2005, Spekkink 2005a, Spekkink 2005b, Szigeti 2005b, Szigeti 2005c, Vandaele 2005a, Vandaele 2005b, Winnepennickx 2005, Yates 2005] have been produced by the network's Tasks; a dedicated informative CIB website has been established; a research mapping module, which accommodates the literature submitted by the PeBBu members, has been created and included in it; a pilot of an interactive website for educational purposes has been started and included in the main PeBBu site; in addition, two Compendia and two initial versions for design support tools were produced. Links with existing specific CIB Commissions and Task-Groups engaged in scientific and particular disciplinary areas of PBB have also been established.

The deliberations and activities did not remain part of the European Member Sates only, and during the operation of the Network most of the New Associated States have joined as well. Activities and deliberations took place in disciplinary scientific domains, which are of global nature, as well as in four European Regional Platforms that addressed the topic from their specific perspective, and in three dedicated User Platforms that addressed specific stakeholders.

With this organisational structure and deliverables, a comprehensive coverage of the PBB subject has been enabled, and it may be assumed that the state of the art situation is well exposed.

The following summary remarks conclude this state of the art report:

Plenty of conference and workshop papers have been published hereto by the research community on various conceptual aspects of Performance Based Building, PBB, and the means for its implementation. Many more popular articles are spread in various web sites. In addition to this overwhelming amount of explanatory literature, scientific refereed international journals include a vast amount of knowledge on health hazards; performance aspects and properties of building materials and components under various conditions; performance and behaviour of whole buildings or their major parts in various areas of the recognised performance attributes as a function of various design variables; performance-based design and evaluation tools in specific areas of the various performance attributes (e.g., serviceability needs and spatial design, performance-based design for structural safety and serviceability, user needs and risk analysis in performance-based fire safety design, indoor air quality and healthy buildings, analysis of hygro-thermal performance and moisture effects, thermal comfort and energy in buildings, room and building acoustics, illumination and visual aspects of spatial design, analytical and testing tools for building materials' durability); and on the economic aspects of decision making (e.g., cost-benefit analysis, risk analysis, and multi disciplinary optimisation). In contrast, the amount of quantitative knowledge on human needs at the

vicinity of user satisfaction levels is too small, and is regarded as a main handicap in the transformation of User Needs into Performance Requirements and Criteria.

Some basic parts of the PBB conceptual aspects have been formulated into ISO and ASTM consensus Standards, focusing on the vocabulary, delineation of performance attributes and user needs, methodological aspects of performance requirements derivation, and preparation of performance-based design briefs.

Parts of the scientific disciplinary knowledge have been implemented in consensus ISO and CEN Standards that provide performance-based design evaluation tools for specific areas, including structural safety and serviceability, structural fire safety, thermal comfort, energy analysis, day lighting, and service life.

Applied research in the disciplinary areas has been implemented in consensus ISO and ASTM Standards, as well as in EOTA guides, which provide comprehensive testing methods for measuring performance properties of building materials, components, and entire building elements in the laboratory and in situ. Most of these documents provide also classification procedures and ranking scales.

PBB concepts have been adopted in the Nordic countries regulatory framework, in the Dutch Building Decree, in the European New Approach and the accompanying CPD Directive, in the Building Code of Australia and New-Zealand, in the USA new ICC Performance Model Code, and are in the process of adoption in the Canadian Building code and in the Israeli Regulations. None of these documents is purely performance-based. In some cases the quantification of performance requirements is incomplete and adversely affects implementation, in others some prescriptive solutions are still used instead of performance requirements.

Performance-based assessment has been an intrinsic methodology in the evaluation process and procedures for approving innovative building systems and components since the 1950s. There is world wide consensus that it happens to be the most suitable conceptual framework for handling and enabling the safe and economically valid introduction of innovations into the building market. However, although believed that it may, there is no evidence that this in itself promoted innovation and creativity in the building sector.

Conceptual aspects as well as detailed scientific disciplinary knowledge in most areas of the main performance attributes have been included in the curricula of professional education of many Building and Civil Engineering departments in European universities. A similar situation exists in Australia, New-Zealand and Israel. In Canada only a few university departments cover PBB-relevant topics in their curricula. In USA universities the situation is much worse, with very few Civil Engineering departments carrying some relevant syllabi. The hard core scientific topics are taught at Civil Engineering departments in the NAS countries as well. Architectural departments world wide include some PBB-relevant topics in their syllabi, but these are usually taught at a qualitative level without elaborating the quantitative assessment tools. In the USA PBB-related topics are given in a quantitative manner in some Architectural Engineering departments. As a consequence of the university education situation outlined above, most of the research in the various disciplinary areas of PBB is performed in Europe at universities as well as in Research Institutes, whereas in the USA it is mostly carried out at National Research Institutes and in industry.

Numerous incentives have been pointed out for the implementation of PBB, with a main emphasis on the facilitation of innovations. However, they are hampered by a multitude of barriers, with the innovative concepts and major procedural changes required in an explicit implementation being a significant deterrent. Given the specific features of the building market, PBB is a desired environment, but its implementation should not necessarily be associated with an overall revolution in the entire building process and introduction of explicit new procedures. Piece-wise implementation of such procedures in design, tendering or procurement, according to specific needs of a given project should be enabled by the regulatory framework, and remain the free choice of entrepreneurs.

Most of the PeBBu Network Tasks have noticed that the basics of the Performance Concept in Building are sufficiently covered in the popular professional literature, bringing them to the attention of other researchers. In contrast, practitioners and other relevant stakeholders in the building market seem to be much less aware of its fundamental principles, and mainly of the associated scientific knowledge. This may explain the low level of implementation. Professional public relations are thus necessary, and the PeBBu Website is a good starting point, with the ensuing National platforms and National Thematic Networks assisting in spreading the knowledge.

Many of the Tasks complained that there is not sufficient documentation of case studies in which a PBB environment has been implemented throughout the entire building process and its consequences have been monitored with the required scrutiny. The documentation of those claiming to proceed along this route is mostly explanatory and of a journalistic nature, rather than professionally detailed. Consequently, it is difficult to analyse the steps, documents, requirements, and assessment methods that have been employed during preparation of design briefs and tendering documents, or during approval and other building performance-relevant decisions. Lack of such information is frustrating in particular with regard to performance-based procurement methods.

Various Tasks stressed the significance of implementing a flexible performance-based regulatory framework, which enables free choice of the performance route when found suitable for to the specific needs of a given project or one of its stages. Since it was envisaged that PBB will not be the main trend for many years to come, the need to leave the prescriptive provisions as approved, deemed to satisfy solutions, has been recognised. Still, once performance requirements are delineated, it may be necessary to verify some of the standardised solutions by preliminary research before endorsing them as deemed to satisfy solutions.

Carefully delineated performance requirements and accepted verification and assessment methods are of major significance in a PBB environment in order to ensure, before starting actual construction, that demands are clear and that there is a sufficiently high level of probability that the supplied solutions would meet them. The main difficulty in addressing long-term performance is associated with the dynamic nature of owners' needs, and the implications of unknown occupancy or usage changes on future fitness for use of the built facility. Literature has very little information on how to handle this topic economically in general, and in a PBB framework in particular.

To be properly implemented during the design process, PBB requires team work and explicit devotion to the integrated performance of the facility. This has to be accomplished without sacrificing performance requirements due to lack of charisma, dominance or leadership of some team members.

Given the traditional character of the building market, resistance to change will probably continue to persist. However, with Governments becoming more and more concerned with enabling free trade, as well as being forced to base their own construction contracts on performance-based tenders, they may become the main drivers of PBB implementation in the technological part of the building market. Due to the tendency to cut Government expenditure on public works and involve the private sector in building, operating and maintaining the public facilities, Governments are also forced to procure their own projects by means of various new procurement methods in which performance-based design briefs are an inherent feature. This may be a significant driver to implementation of more explicit PBB procedures along the entire building process.

Linkage between performance assessment tools and life cycle economic evaluation tools can be instrumental in optimisation of cost while fulfilling performance requirements at the most effective level. The knowledge and tools for such efforts are available. They are implemented extensively in other industries. However, their implementation in actual building projects is still scarce, but it is envisaged that if PBB will gain momentum, thorough cost-benefit analysis and/or overall optimisation will also become part of the new environment.

PeBBu members of the East European Regional Platform, as well as NAS countries delegates, believe that a PBB environment can be instrumental to enhancing the quality of buildings in their countries and to the

competitiveness of their building industries in the European market. This of course has not been substantiated by evidence from similar markets, and thus remains to be verified.

In conclusion we dare stating that in order to meet the 2010, 2020, and 2030 horizons for PBB the strategies and activities outlined in Chapter 5 should be implemented, and the Research Roadmap summarized in Chapter 6 and elaborated in [Foliente 2005c] should be activated internationally.

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CHAPTER 8

8 REFERENCES

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Davidson, C.H., 2005, "Final Report on Information and Documentation (Domain 9)". PeBBu Network, CIBdf - International Council for Research and Innovation in Building and Construction, Rotterdam, The Netherlands.

Fenn, P., Haugbølle, K., Morse, T., 2005, "Final Report on Legal and Procurement Practices (Domain 6)". PeBBu Network, CIBdf - International Council for Research and Innovation in Building and Construction, Rotterdam, The Netherlands.

Foliente, G., Bakens, W., Ang, G., Huovila, P., Spekkink, D., 2005c, "Performance Based Building R&D Roadmap". PeBBu Network, CIBdf - International Council for Research and Innovation in Building and Construction, Rotterdam, The Netherlands.

Gray, C., 2005, "Final Report on Built Environment (Domain 4)". PeBBu Network, CIBdf - International Council for Research and Innovation in Building and Construction, Rotterdam, The Netherlands.

Huovila, P., 2005b, "Final Report on Organisation and Management (Domain 5)". PeBBu Network, CIBdf - International Council for Research and Innovation in Building and Construction, Rotterdam, The Netherlands.

Huovila, P., 2005c, "Final Report on Decision Support Tools (Generic Task 3)". PeBBu Network, CIBdf - International Council for Research and Innovation in Building and Construction, Rotterdam, The Netherlands.

Huovila, P., 2005d, "Final Report on CRISP Sustainability Indicators (Generic Task 2)". PeBBu Network, CIBdf - International Council for Research and Innovation in Building and Construction, Rotterdam, The Netherlands.

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Sjostrom, C., Trinius, W., 2005, "Final Report on Regional Platform North Europe (Task 13)". PeBBu Network, CIBdf - International Council for Research and Innovation in Building and Construction, Rotterdam, The Netherlands.

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Annexes

ANNEX I: STATE OF ART SUMMARY REPORT FOR DOMAIN 1: LIFE PERFORMANCE OF CONSTRUCTION MATERIALS AND COMPONENTS

Domain Leader:

Chevalier, J-L., France; Sjöström, C., Trinius, W., Sweden

Domain Members:

Australia – Foliente, G., Tucker, S.; Belgium – Parthoens, J., Winnepenninckx, E.; Bulgaria - Nazarski, D., Tzvetkov, G.; Czech Rep. - Teply, B., Netopilová, M.; Denmark - Brandt, E., Hansen, M. H.; Finland - Huovila, P., Porkka, J.; France - Cope, R., Lair, J., Hans, J.; Greece - Papaioannou, K.; Hungary - Matolcsy, K., Tiderenczl, G., Toth, P.; Iceland - Olafsson, H., Marteinsson, B.; Israel - Baum, H.; Italy - Galimberti, V.; Netherlands - Vrouwenvelder, T.; Norway - Haagenrud, S. E.; Poland - Goreczna, M., Lizak, R., Syrda, E., Babut, R., Koc, D., Wojtowicz, A., Weglarz, A., Panek, A.; Saudi Arabia - Jannadi, O. A.; Slovakia - Krivacek, J., Sladek, J., Hermanská, B., Parobek, J., Sedlak, P., Stefko, J., Durica, P., Merjavá, V., Sternova, Z.; Slovenia - Bosiljkov, V., Lutman, M., Srpcic, J.; Sweden - Rolén, C.; UK - Matthews, S., Prior, J.; USA - Augenbroe, G.

Domain Website:

http://www.pebbu.nl/maincomponents/scientificdomains/domain1/

Scope and Objectives:

Additional to the common PeBBu objectives, domain 1 on life performance of construction materials and components is to foster the further development of the performance concept in the domain, for a better concern and assessment of the performance over time, and to anchor this development with sector stakeholders, which are more and more demanding information, tools and data for service life prediction. This will focus in particular on:

- The further development of the Factorial approach as regards (i) theoretical and engineering approaches, (ii) basic knowledge base of different factors, (iii) development of pedagogic application examples and (iv) test-training of practitioners.
- The exploration and description of the conditions and prerequisites for reference life (performance) data for classes of building materials and components with account of sub-sectorial industry structure

Conceptual Framework:

Performance Based Building in relation to life performance of construction materials and components is interpreted as the methodological intersection between concepts of performance requirements, service life and durability and sustainability aspects related to buildings as well as to their functional components and as transferred to materials and components. Due to the character of design processes, both related to product design and to building design, the application of the performance concept involves many actors. Consequently, information related to life performance must be communicated widely throughout the

sector. Further, it must be enabled that rather generic product information can be adapted to current and highly specific building design conditions.

PeBBu Domain 1 specifically relates to the ISO 15686 standards. Domain 1 intends to exemplify these standards with the goal to enable wider provision of information needed for the process of service life planning, as well as enabling a wider application of service life information in project planning and building design. While focussing building materials and components, the context of functional application of materials and components deserves consideration. Consequently, D1 also addresses systems. The topic of sustainable construction provides the contextual frame and the philosophical reason for acting on the topic of service life. This involves the development of methodologies to identify reference service lives and estimated service lives, also in terms of service life declarations. As to the latter the D1 work closely adheres to the standardisation performed by CEN TG on Durability and ISO TC59/SC14/WG9 "Guide on the inclusion of requirements of service life assessment and service life declarations in product standards". The methodologies developed provide important input especially to environmental product declarations of building materials and components and equally evident, to the assessment of environmental performance of buildings. Both items are addressed in ISO/TC59/SC17 and in CEN/TC 350.

The communication of service life information within the construction sector sets high requirements concerning transparency of the information. A declaration of service life can only reflect one or a few scenarios for product application. Therefore, designers for instance, may need to perform or initiate a process of modification of declared information, all in order to obtain information that is relevant to the situation in a specific building context. The primary source of information will still be the manufacturers, while recognizing that information provided by them only can be based on reference scenarios. Such scenarios must be available for scrutiny by those applying the provided information.

Methodology and Process:

Core means and the process applied to reach the objectives are:

- Interaction with CIB and RILEM technical committees, coordinated R&D activities in the Domain work area
  - The upcoming work programme of CIB W80 / RILEM TC 175 – TSL is focussing the dominating issue of D1
- Interaction with ISO TC59/SC14 "Design Life" in the development and implementation of the standard series ISO 15686. Especially so the standards 15686-1 (describing the Factor Method), 15686-2 (Service Life Prediction Procedures), 15686-8 (Reference Service Lives), 15686-9 (Guide on the inclusion of requirements of service life assessment and service life declarations in product standards) and CEN TG on Durability.
- Interaction with ISO TC59/SC14/WG9 and the CEN Task Group on Durability in establishing principle methods for Durability Assessment and Declarations in Product Standards. ISO TC59/SC14 are to produce a standard on the issue, and CEN two Guiding Documents (short and long term, respectively) for standard committees working on European harmonised product standards.
- Survey selected building materials and components producers within PeBBu member countries on their present ways of testing and declaring life performance of products and their apprehension of the emerging standard concepts
- Conduction of Domain workshops
- Contribution to non-PeBBu conferences, workshops and symposia with the intention to involve a larger audience in the discussion, to present and to receive external points of view
- Academic publications and doctoral dissertations.
- Preparation of user guidance on the application of PBB related international standards

- Involvement in the discussion between academia / standardisation bodies and industry on the topics related to performance and service life declaration in the context of environmental declarations and compliance to the European Construction Products Directive (CPD)

State of the Art:

Since 1993, international standardisation in the field of service life planning is undertaken. The main purpose of standardisation efforts in ISO/TC59/SC14 "Design Life" is to identify routines that support the design of buildings that meet identified performance requirements, throughout their design life. By directing the work to this thematic field, also demands originating e.g. from the European Construction Products Directive (CPD) are addressed. The methodology obviously is equally worthy for other regions. For Europe meanwhile, the CPD can be identified as a very significant driver for Standardisation and harmonization, as products fulfilling the six essential requirements of the CPD are eligible for CE marking. One of the routes to CE marking is based on an assessment of the product, including an evaluation of its durability in order to obtain a reasonable working life, as required in the CPD and elaborated in Guidance Paper F. Especially for the evaluation of new and innovative products, where no experience-based information is available, the European Organisation of Technical Approvals (EOTA) has developed general guidance based on the service life prediction concepts, as expressed in ISO 15686-2.

The current development of internationally harmonised standards follows to large extent a modular approach that allows the inclusion of use phase (and thereby service life) scenarios that can be adapted to better reflect the situation in which a material, component or system is to be applied. The ISO 15686 standards on service life planning can be applied in order to generate information for such adaptable modules and scenarios. With the relative ease to adapt scenarios and modules as a positive aspect, also the negative potential to include information based on scenarios that are not in line with each other, or service life information that is based on performance requirements that do not sufficiently well reflect the situation at hand, is rising.

For the process of identification and adaptation of service life information to the planning situation at hand, ISO 15686 identifies two core concepts, one being the establishment of a reference service life and the other being the identification of an estimated service life. Where the earlier must be based on testing, exposure or experience, the latter is a modification of a given reference service life that shall allow the planner to establish a reasonable estimate for a material, component or system as part of a specific building design. As both, the reference service life and the process of adaptation in order to establish an estimated service life are forming the basis for the generation of information, PeBBu Domain 1 sets its focus onto these aspects of service life planning methodology. With this in specific focus, PeBBu D1 addresses demands in co-normative research and development, where the target is to provide information that is needed in everyday application of the standards.

PeBBu strives to identify current practice in the building sector, both to identify the potential for improvement and to provide feedback of experience and practical information into the process of formulating standards. Based on the requirements posed by the standards and the experience and practice in the building sector, thematic fields for future attention and research can be identified. The derivation and communication of performance requirements and performance information are to be named expressly. Developing standards in the field of EPD (environmental product declaration) and sustainable construction show modular structures, where scenarios for service life and life performance have significant influence on the declared information.

Proposed Research Agenda:

No	Topic	Priority
General R&D Items for PeBBu		

1	Handbooks, Demo projects, Case studies, Application & Experience, Evaluation tools for entire building LC	Precondition for topic no 3
2	Adaptation of information to user demands (simplification)	
3	Dissemination (coordination of Dissemination), market creation	1
4	Verification tools	1
5	Communication between actors / Stakeholders / users Services in the construction sector	1
6	Transfer performance requirements, knowledge, verification between different users of information	1
Additional R&D Items specific for D1		
7	Modelling of Performance Demand & Supply (building, functional subsystems, materials)	1
8	Reference Service Life – generic information and guidance for modification	1
9	Standards and Standard Application in Innovation	2

Incentives for PBB Implementation:

- Performance is the key linking aspects of sustainability, environmental declarations, user requirements etc, by this performance based building can take a central role in the agenda towards a more sustainable built environment
- Performance a key argument in product marketing (at the same time a barrier when provided information is perceived as biased)
- Directives and standards establish demand for service life (and hence life performance) information
- Consideration of "life cycle" is not possible without information on service life

Barriers to PBB Implementation:

- Difficulty to relate building performance requirements to material and component requirements
- Difficult to match required performance and provided performance
- Development of performance over time depends on numerous factors, not necessarily within the control or knowledge of parties providing or applying service life information
- Potential for misunderstanding of service life and performance information as if being warranties.
- Problem of being held reliable also for conditions outside the influential sphere of providers of information
- Sum of component performances gives no sufficient indication of system performance

Dissemination and Implementation:

The work of D1 has been disseminated through workshops within and outside the PeBBu network, through contribution to other international conferences, research networks and standardisation projects and through academic publications. On the other hand, information seminars have been conducted with participation of industry stakeholders and building sector actors, students have been taught and guidance for the application of relevant ISO standards has been provided. Further, the experience from PeBBu D1 is directly available to relevant standardisation activities.

Conclusions:

PeBBu D1 investigated to what extent actors in building construction already today are informed about the ISO standards, to what extend they make use of service life information and apply the performance based building concept. A general conclusion is that the concepts appear to be well known, but there still is a significant lack of experience and feedback from examples, where the concepts have been applied systematically and successfully. The question whether performance based building in practice leads to innovative solutions, and concerning which performance aspects these innovative solutions are beneficial and in that case to whom they are beneficial, remains to be investigated and documented. Such documentation, as part of the developed training material and presented as successful examples, is supposed to take the role as a key driver to motivate for the application of the performance concept. Motivation of actors to enable and apply performance information is regarded as the main obstacle to more frequent application of the performance concept in building construction.

However, the availability of information and the number of examples of application is rising, all while the development of tools for the application of service life planning has taken up momentum. From this, in combination with the general awareness of the usefulness of the concepts of performance based building and service life planning, it can be assumed that the development of tools, and the integration into standards relating to building sustainability, will spur the application of the concepts.

The liaisons to other international activities within the thematic field of D1 have increased international cooperation in the field, as well as together these groups have succeeded to shape basic agreement on how to address life performance issues in the context of international standardisation.

Publications:

The following list of publications is intended to state a few core documents to which PeBBu D1 and its members have made significant contributions, or key publications generated by network members.

Chevalier, J. L. et al: "10dbmc", Documentation of the 10th International Conference on Durability of Building Materials and Components, Lyon 2005

Huovila, P. (Ed): "Performance Based Building", VTT and RIL, Helsinki 2005

Jernberg, P.: "Service Life Planning of Constructed Works - Users Guide to ISO 15686-1", in print; to be published 2005, English translation of: Jernberg, P., "Livslängdsplanering av byggnader och byggnadsverk - Användarhandledning för SS-ISO15686-1: Livslängsplanering av byggnader och byggnadsverk - Del 1: Allmänna principer", (in Swedish), SIS Förlag, ISBN 91-7162-636-0

Lair, J., Chevalier J.L. (2002). "Service life assessment of building products with data fusion", Revue Française de Génie Civil « Fiabilité des ouvrages de Génie Civil – Conception et maintenance ». Volume 6, n°3/2002. pp 421-431. Paris : Hermès Science Publications, 2002.

Marteinsson, B.: "Service Life Estimation in the Design of Buildings - A Development of the Factor Method", Doctoral thesis, ISBN 91-7178-026-2, KTH Research School, Centre for Built Environment, University of Gävle, Sweden, 2005

Szigeti, F. and Davis, G. (Eds.): "Performance-based Building", Special Issue of the International Journal on Building Research & Information (March - April 2005) 33(2)

Talon, A., Chevalier, J.L., Hans, J.: "State of the Art Report on Failure Modes Effects and Criticality Analysis Research for and Application to the Building Domain", Draft CSTB Report to CIB W80 and RILEM 175 on Service Life Methodologies, Grenoble 2005

Trinius, W.: "Performance-based Building and Sustainable Construction", CEN Construction Sector Network Conference, Prague, 25 - 26 April 2005, http://www.cenorm.be

References:

ISO 15686-1	Buildings and Constructed Assets – Service Life Planning – General Principles
ISO 15686-2	Buildings and Constructed Assets – Service Life Planning – Service Life Prediction Procedures
ISO 15686-6	Buildings and Constructed Assets – Service Life Planning – Procedure for Considering Environmental Impacts
ISO 15686-8	Buildings and Constructed Assets – Service Life Planning – Reference Service Life
ISO 15686-9	Buildings and Constructed Assets – Service Life Planning – Guidelines for Product Standards
Guidance Paper F	Durability and the Construction Products Directive
ISO / TC59 / SC14	Building Construction – Design Life
ISO / TC59 / SC17	Building Construction – Sustainability in Building Construction
CEN / TC 350	Integrated Environmental Performance of Buildings
CEN / TG Durability	CEN task group on Durability
EOTA	European Organisation for Technical Approvals

ANNEX II: STATE OF ART SUMMARY REPORT FOR DOMAIN 2: INDOOR ENVIRONMENT

Domain Leader:

Philo Bluyssen and Marcel Loomans (support), TNO – Netherlands Organisation for Applied Scientific Research

Domain Members:

Foliente G., CSIRO–DBCE, Australia; Brown S., CSIRO–DBCE, Australia; Paevere Ph., CSIRO–DBCE, Australia; Wouters P., WTCB-CSTC-BBRI, Belgium; Vandaele L., WTCB-CSTC-BBRI, Belgium; Nazarski D., SEC, Bulgaria; Szigeti F., ICF, Canada; Stylianou M., NRCan,Canada Mallory-Hill S., Un. ofManitoba Canada Kumaran M., NRCC-IRC, Canada; Kalousek M., Brno Univ. Techn., Czech Republic; Sedlak J., Brno Univ. Techn., Czech Republic; Hansen MH., SBi, Denmark; Marsh R., SBi, Denmark; Kurnitski J., HUT-HVAC, Finland; Huovila P., VTT, Finland; Porkka J., VTT, Finland; Allard F., Un. de la Rochelle, France; Laret L., CSTB, France; Inard Chr., Un. de la Rochelle, France; Mayer E., Fh-IBP, Germany; Wetzel Chr., Fh-IBP, Germany;Holm A., Fh-IBP, Germany; Papaioannou K., Aristotle Un., Greece; Matolcsy K., ÉMI, Hungary; Prashad D., VIA Arch. Cons., India; Becker R., TECHNION, Israel; Paciuk M., TECHNION, Israel; Meroni I., CNR-ITC, Italy; Lollini R., CNR-ITC, Italy; Collaro C., Arch.S.F., Italy; Azuma K., Nat. Inst. of Publ. Health Japan Teodorescu R., VROM-RGD, Netherlands; Jasuja M., CIBdf, Netherlands; Bluyssen Ph., TNO, Netherlands; Loomans M., TNO, Netherlands; Cox C., TNO, Netherlands; Adan O., TNO, Netherlands; Koc D., KAPE, Poland; Sowa J., Warsaw Un., Poland; Canha da Piedade A., IST–DECivil, Portugal; Oliveira Fernandes E., Un. Porto, Portugal; Katunsky D., Techn. Univ., Slovakia; Bahyl Vl., TUZ, Slovakia; Darula S., USTARCH SAV, Slovakia; Hraska J., Slovak Un., Slovakia; Sternova Z., VVUPS-NOVA, Slovakia;Jurcak B., TUZ, Slovakia; Bendzalova J., VVUPS-NOVA, Slovakia; Matiasovsky P., USTARCH SAV, Slovakia; Knez F., ZAG Ljubljana, Slovenia; Sandelin J., FORMAS, Sweden; Johannesson G., KTH, Sweden; Hagerhed L., FORMAS, Sweden; Andersson J., IFS, Sweden; Dawidowicz N., FORMAS, Sweden; Mattsson B., KTH, Sweden; Ekstrand-tobin A., FORMAS, Sweden; Bourke K., BRE, UK; Prior J., BRE, UK; Wright A., MACE, UK; Liyanage Ch., Glasgow C. Un., UK; Malkawi A., Un. of Pennsylvania USA

Domain Website:

http://www.pebbu.nl/maincomponents/scientificdomains/domain2/

Scope and Objectives:

The intention of Domain 2 Indoor Environment is based on the believe that the achievement of healthy buildings can be pursued by designers, constructors, building owners and building occupants, through the application of qualitative and quantitative health-based criteria. From the occupant point-of-view, the ideal situation is an indoor environment that satisfies all occupants (i.e. they have no complaints) and does not unnecessarily increase the risk or severity of illness or injury. This environment is directly related to attributes as: *air quality, ventilation, thermal comfort, noise, visual comfort.*

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

Special emphasis was put on performance criteria for healthy building and on methods, guidelines, protocols and tools to evaluate / measure the health status of buildings or designs for buildings. Furthermore, attention was put on required international standardisation as concerns the measurement of performance criteria for healthy buildings.

Conceptual Framework:

Within Domain 2 the concept of PBB and its methodology as described in CIB-Report 64 in 1982 [1] have been used and discussed to come to a clear definition of PBB in relation to the indoor environment. Figure II.1 presents the visualization of the PBB definition as applied. It has been compared to the non-performance approach. The total figure was developed and agreed on during the 1st PeBBu Domain 2 Workshop and the NAS Workshop [2] and is well in line with the general understanding of the performance concept.

Within Domain 2 also a conceptual framework was developed to position the building performance information that is available. This also accounts for all the translation rules, i.e. the intermediate steps that are required to translate performance information from qualitative to objective and reverse. It provides a system that allows a logical structuring of all the information related to performance based building, but also may improve the applicability of the PBB-approach.

The parameters that determine the framework are the *stakeholders* (i.e. they set the performance requirements), the *building phase* (i.e. the point of time in the building process determines the type of requirements that are set) and the *building objects* (i.e. they determine the actual building performance). Inter-relations between these parameters are obvious and when combined they result in the performance-based matrix (see Figure 2). The matrix approach presents a database that allows filtering to come up with the specific performance requirements that relate to a specific building phase or stakeholder. It may also relate to a specific environmental attribute that is addressed differently (i.e. different target values and evaluation methods) at different points in the building process.

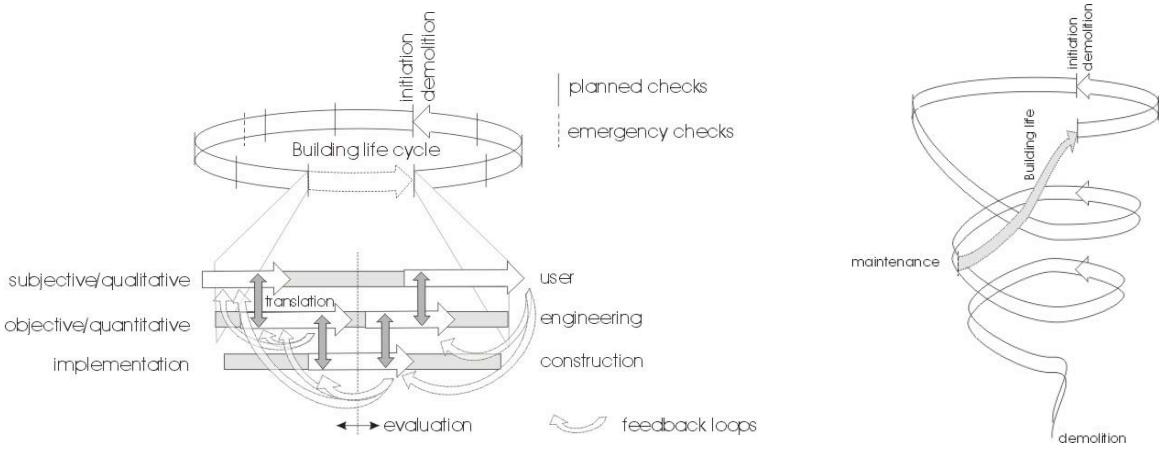

Figure II.1: Performance based [left] versus a non-performance [right] approach.

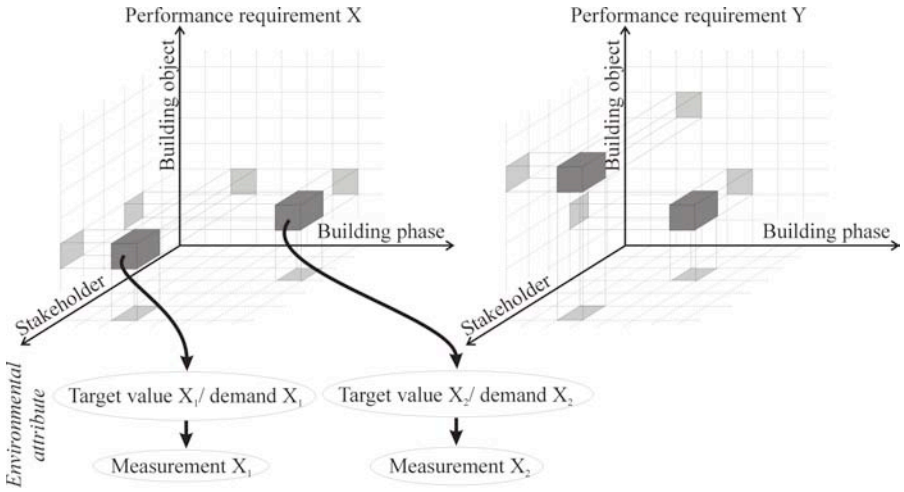

Figure II.2: The Performance-based Matrix.

Methodology and Process:

The work in the Domain has been organised around the four workshops that have been held during the run-time of the project. With an average participation of 25 persons, these workshops were very well and actively attended.

The first workshop centered around the introduction of the problem and the description of the definition and framework as presented above. The NAS workshop was more or less a repetition of this workshop and presented an introduction to the concept. The second workshop presented State of the Art information from guest speakers in the respective areas. The third workshop looked forward and discussed research issues.

Input from the participants was asked for in each workshop, either through active participation in smaller workgroup sessions discussing, e.g., propositions, or through plenary presentations presenting the status in their homeland. Besides, a well responded written questionnaire provided valuable information on the current status of PBB in the participating countries, generally and specifically with respect to the indoor environment.

Input for domain reports, workshop preparation reports and minutes etc. was provided for by the Domain leader. Draft versions were send for commenting on to the Domain members, guests and observers (contact list in total: 62 persons). All information that has become available has been made accessible directly through the Domain 2 website (http://www.pebbu.nl/maincomponents/scientificdomains/domain2/).

State of the Art:

The above presented definition of PBB and the developed framework were required to come up with a State of the Art on PBB, and PBB and the Indoor Environment in particular. This State of the Art has been derived through a literature study and a study of ongoing research in combination with input from the participants in the network. This was a continuous process given the enormous amount of work that

already has been devoted to PBB. A large part of the information has been organised in a database that has the same structure as the developed framework.

Summarizing the information that has been gathered from the literature research one can conclude that a lot of information on PBB is already available. However, most of this information deals with isolated topics and lacks the connection to the larger point-of-view. For example, with respect to materials (e.g., material emission) and some individual performance requirements (e.g., energy) the performance thinking is well established. Though differences between EU-countries are obvious, with at a first stage focus on the energy performance and in a second phase on, e.g., material emission. Furthermore, focus has mainly been put on the separate (building) phases and not on the translation between higher level performance requirements and lower level implications (see Figure 1 [left]). A general translation, beyond the traditional solutions, from qualitative criteria to objective design parameters, and reverse when dealing with the evaluation, to a large part is still lacking. This hampers innovative developments, which forms one of the important drivers for the application of the performance based approach. Individual initiatives on several aspects however can be found. The coupling of these initiatives and the generalization appear to be important research areas for PBB. The Indoor Environment domain is one of the domains within PeBBu for which the translation from qualitative to objective information is a key-item.

Some interesting examples of PBB and the Indoor Environment already can be found. They are described in the Domain report [2]. With respect to health and comfort we can also find some initiatives on defining performance criteria and translating them into design solutions. In the EU 5th FW Project HOPE (Health Optimisation Protocol for Energy-Efficient Buildings) a procedure has been develop to determine the health and energy performance of existing office and apartment buildings [3]. Recently also the ISIAQ-CIB TG42 Guideline on Performance Criteria of Buildings for Health and Comfort has been published [4]. This guideline contains performance criteria and practical information to design and commission healthy buildings.

These references present the State of the Art with respect to performance and healthy buildings. Recently, developments at national level, e.g. in The Netherlands, and in connection with developments at EU-level, e.g. Energy Performance of Building Directive (EPBD) [5], show more attention on the general health performance and characterizing buildings towards that performance.

The ISIAQ-CIB TG42 Guideline has been used to test the within Domain 2 developed framework principle (database). This example has been made accessible through the PeBBu Domain 2 homepage. From the work in HOPE a listing of target values for the most important performance indicators referring to healthy buildings has been provided for.

Inter-relations with other Domians/Tasks:

Within the Domains structure, inter-relations were most obvious with Domain 3 Design of Buildings. Especially the topic encompassing the assessment tools has a large overlap. However, the Indoor Environment Domain did not deal with the design phase only. Instead, the whole building life performance (from initiation to demolition) is the point-of-departure. In the PeBBu network the Domain leaders have visited each others workshops and had personal contact.

With respect to the tasks, an important contribution was given to Generic Task 2 (Decision Support Toolkit). Besides input to the reports presented by this task, a Workshop was organised in the Netherlands, with invited guests, to allow a presentation and discussion of the work performed within the Generic Task 2. Input was provided for, on request, to the other Generic Tasks and the Regional Platforms.

Proposed Research agenda:

Following the State of the Art, a research agenda has been prepared for Domain 2 [6] that lists developments that are regarded required to enhance the performance-based approach with respect to the indoor environment and in particular healthy building. The developed methodology and framework have been applied to set up this research agenda. Figure 3 summarises the important topics. The explanation of this Figure and topics for further research can be found in the Research Agenda.

The results from the work in PeBBu and the PB concept have been included more elaborately in several proposals that have been developed over the run-time of the project. More specifically, the PeBBu work had an important contribution to the Ecospace IP proposal.

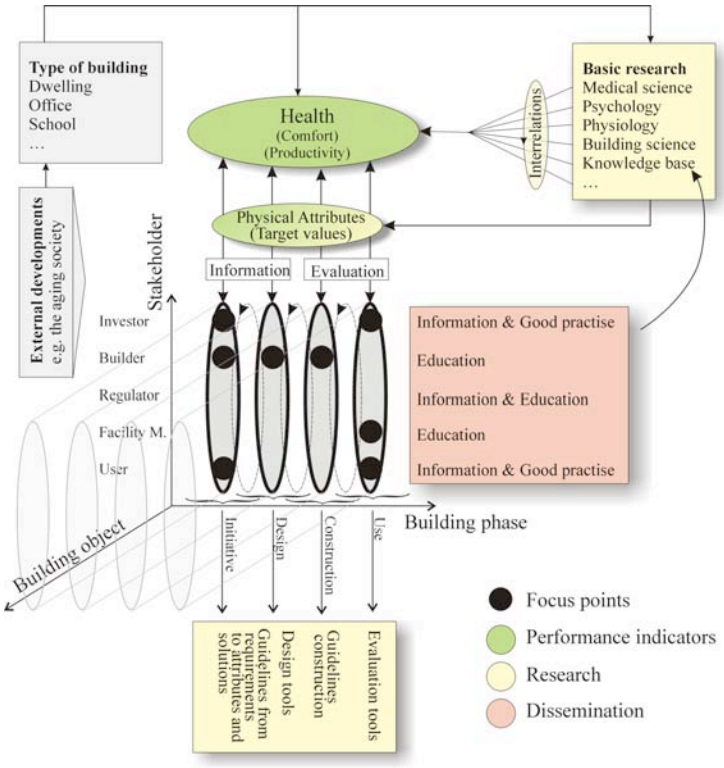

Figure II.3: Research agenda for the PB approach in relation to the indoor environment.

Incentives for PBB implementation:

The obvious incentive for the application of the PB approach for the indoor environment and healthy building will be the EPBD [5] that will come into action in 2006. Developments are ongoing that try to qualify the quality of the indoor environment as part of the overall building performance in relation to energy use. Furthermore, the request for performance assessment in terms of health and comfort, besides performance parameters as energy use, is increasing. Importance will be gained if this performance can be quantified in terms of investment costs and rate-of-return.

Barriers to PBB implementation:

Specifically with respect to healthy building the problem remains that only a limited amount of information is available on dose-response relations that influence the health of persons at the levels encountered in buildings. There is however a lot of information on building aspects in relation to health hazards. This makes, on the one side, that we lack information to fully adhere to the performance approach based on

target values. However, we can, with a reasonable reliability, indicate health performance based on building design and applied building components.

Dissemination and Implementation:

Dissemination is directed towards the stakeholders in the building process. Three major dissemination items have been mentioned in the workshops: Information, Education and Good Practise. Where information is a subject that concerns all, education and good practise have a focus on individual stakeholders.

These three dissemination methods should result in a positive attitude towards PBB in all countries worldwide. It should start from the understanding that PBB is a good 'thing' for the client and that this presents the driving force (pull instead of push) to adopt the PBB approach. The positive attitude is regarded critical for the success and further development of the PBB approach.

At this point dissemination and implementation is provided for, supported by the information on the website, by actively promoting the concept through the work of the PeBBu members. PeBBu in this case can serve as an important reference. Furthermore, for Domain 2 a prototype website will be prepared with an educational intention. Nevertheless, the research agenda indicates that more work is required in order to allow a successful dissemination.

Conclusions:

The State of the Art has indicated that PBB, in the Indoor Environment domain and healthy building, already is being applied to some degree in the different phases of the building process. Furthermore, attention on this topic has increased significantly in recent years. However, mostly application is restricted to a single building phase or building object and little information is yet available on the translation of qualitative performance requirements to quantitative implications for the building. This hampers the further introduction of PBB in the building process and the innovation.

For performance requirements on health and comfort interesting initiatives are ongoing or have recently been completed. The work in HOPE and ISIAQ-CIB TG42 are good and practical examples of that. However, the topic remains complex and very extensive and a lot of work still is required before PBB can completely replace the current prescriptive building methods, if possible at all. PeBBu presented the opportunity to determine this current status and required future directions.

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ANNEX III: STATE OF ART SUMMARY REPORT FOR DOMAIN 3: DESIGN OF BUILDINGS

Domain Leader:

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Domain Website:

http://www.pebbu.nl/maincomponents/scientificdomains/domain3/

Scope and Objectives:

The end users of buildings and other stakeholders become more and more important. It is an economic necessity for the building industry to pay more attention to meeting with stakeholder requirements. It is to be expected that this will be an important incentive for performance based design (PDB). A major part of the research in the domain is focused on the 'translation' 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, a framework for further development and education and training modules for design professionals.

Conceptual framework:

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 inter-relations 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.

Methodology and Process:

The 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 the Domain Workshops.

In the first Domain Workshop (Rotterdam, July 2002) the Domain Members 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.

State of the Art:

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 organise 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, an early and continuous verification has to take place in the design process (Ang et. al, 2001).

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).

Inter-relations with other Domains/Tasks:

There has been interaction with Domain 2 'Indoor Environment' in so far that the Domain Leaders participated in each other's workshops and read each other's reports. There has been no active interaction with the other domains, but the (more or less informal) communications in the context of the series of Domain Workshops in Manchester and Porto turned out to be very fruitful.

There has been close co-operation with Françoise Szigeti in developing the conceptual framework for PBB as a whole and – in relation to that – the conceptual framework for Domain 3.

There has also been a good co-operation with Generic Task 3: Decision Support Toolkit (DST). The Domain Leader participated in a DST workshop in Delft and Domain 3 provided for a test case for the

DST. This test case was presented in the third Domain 3 Workshop by the Task Leaders of the DST project.

Proposed Research Agenda:

As one of the main problems in PBD is how to 'predict' the performance of a building in use on the basis of a design, it is only logical that 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 matrix, showing which performance aspects can be assessed in which design stage and which assessment tools are available for that. The principle of this matrix is shown in diagram 1. '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.

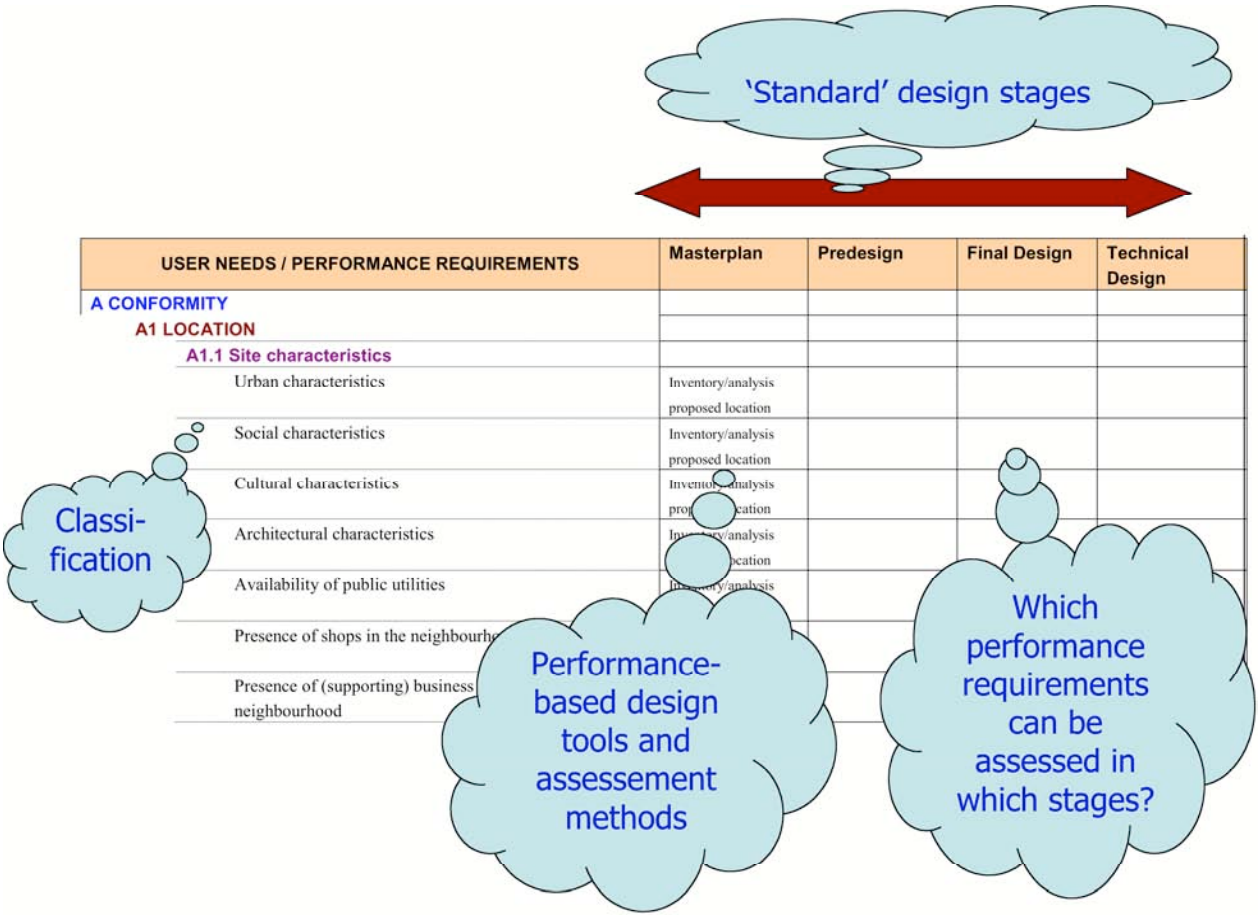

Diagram 1: Principle for the development of a RTD Agenda for Domain 3 Design of Buildings

Incentives for PBB implementation:

The main incentives for Performance-based Design are the fastly growing need for a more user orientated building industry and performance-based legislation and standardisation.

Barriers to PBB 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 and lack of experience.

Dissemination and Implementation:

In is commonly agreed by the Domain Members 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:

- contribution of Domain Members through Organising workshops/seminars in conjunction with other events for the target groups;
- the development of education modules and training of professionals;
- provide clients, local governments and design professionals with case studies and best practices indicating the benefits of performance-based design;
- providing clients/designers with decision-making and assessment tools
- in the past performance-based design has already been put tpo practice, but not necessarily under that name. It is therefore necessary to be make design professionals more aware of PBD approaches they already know and use;
- enhance government leadership in the implementation of the performance-based approach and performance based regulations;
- enhance "total building performance" in a life cycle environment;
- mutual recognition of the performance assessment methods through standardization.

Conclusions:

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. 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. Performance based building regulations have proven to be a key success factor in the implementation of PBD and governmental clients should take the lead in further implementation.

ANNEX IV: STATE OF ART SUMMARY REPORT FOR DOMAIN 4: PERFORMANCE OF THE BUILT ENVIRONMENT

Domain Leader:

Professor Colin Gray

Domain Members:

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Domain Website:

http://www.rdg.ac.uk/PeBBu/
http://www.pebbu.nl/maincomponents/scientificdomains/terminateddomains/domain4/

Scope and Objectives:

The object of the Domain 4 is to define those issues that a building project must embrace to enhance the many aspects of the built environment in which it is located in order to add benefits, value, space and life to achieve urban sustainability. The importance of this task is that it sets the project into its context and ensures that it reflects the growing need to contribute to the sustainability of the urban built environment.

Conceptual Framework:

When attempting to set a performance specification for the built environment as defined above it is soon apparent that there are a very large number of issues that have to be considered. Also to be knowledgeable in every area will be very difficult. Checklists could be used but the link to the knowledge base in each area is either missing or not dynamic. Each topic such as sustainability is potentially huge. Many topics do not have associated measures nor an action oriented outcome in order to set a specification objective. Initially the task was to develop a state of the art report however performance based approaches have not been applied in this area so there is little or no state of the art and yet it is a real problem for future projects. There is a lot of information but in an unstructured form. The Domain therefore has had to address several problems:

- The definition of the built environment
- The definition of the sub areas within the domain
- The lack of performance criteria or existing performance specifications
- The underlying knowledge base is huge and difficult to access quickly and in sufficient depth
- The user needs to be informed of the possible choices as well as being able to develop new aspects
- The specification for every project and local environment will have to be tailored to the specific case

- Alternative options need to be considered and evaluated quickly and economically

Accomplished Workplan:

In order to establish the state of the Art as required in the overall PeBBu project a questionnaire was developed after an extensive literature search to determine the scope of the subjects within the domain. The questionnaire required that for each area the definition was confirmed or that suggestions were made as to amendments so that an agreed definition of the topic could be achieved. The respondents were also asked to give information on their local activity in each of the topic areas so that the draft state of the art could be obtained. To date six completed questionnaires have been returned with sufficient information to contribute to the project. These have been incorporated into the developing data base for each topic area.

A major workshop was held in Budapest attended by the members and the new participants from the new EU member states. This was held after the issue of the questionnaire to enable the full importance of the questionnaire to be appreciated and to encourage further contributions to the questions and definition setting phase. Approval was sought for the approach and the development of the briefing mechanism that was being proposed that would enable potential users to access the information and to set the performance objectives. Even so the response to the questionnaire was weak and the main development was a survey of the literature and international websites in the sub topic areas. This led to the development of a rich web site for the Domain together with a powerful search engine based on briefing software used in manufacturing industry. At this point the Domain was terminated.

State of the Art:

Domain 4 started by asking one significant and initial question; 'in what type of urban situation is the performance based built environment going to be designed to perform? This question was addressed because it sets the framework for the whole of the subsequent specification. So far three concepts have been identified: the compact city (Jenks et al, 2000), the creative city (Landry, 2000) and the high-density city (DETR, 1999). The compact city debate questions the cost of urban sprawl versus the social and psychological issues of high-density living. The argument is one of conservation, reduced transportation and a general increase in well being through a reduction in the dependency on cars. The creative city case is one of releasing the potential within the citizen by providing the right leadership and facilities within the various 'rings' (hub, inner urban ring and suburbs) or areas of a city. These concepts have been used to provide an initial sort of the desirable features that a specifier may need to consider.

The three city concepts have been used to structure the review of the literature and surveys of the World Wide Web. A dedicated PeBBu website has been developed and is maintained at http://www.rdg.ac.uk/PeBBu/. This contains the current state of the collection and analysis of the relevant published literature and website surveys. The difficulty with the available information is that the desirable urban features and regeneration actions are implicit within the description of the urban problem. The continuing task is to review the literature and to determine action-oriented statements that can be construed as performance requirements.

In order to establish the state of the art as required in the overall PeBBu project a questionnaire was developed based on the findings of the extensive literature search described above. The development of the questionnaire was done on schedule. The questionnaire required that for each area the definition was confirmed or that suggestions were made as to amendments so that an agreed definition of the topic could be achieved. The respondents were also asked to give information on their local activity in each of the topic areas so that the draft state of the art could be obtained. By necessity the questionnaire was complex and few returns were made because the built environment had not been described in performance terms before so respondents had great difficulty in replying to the specific questions that were asked.

The primary goal of the questionnaire was to establish the scope of the domain and to obtain an agreed definition of each sub-topic. Whilst input to the PeBBu website was a goal of the project this has been developed in this Domain to be the primary method to access the knowledge that is available about the built environment. An extensive website has been created that is in excess of the original intended scope. Because little in the built environment has been configured in performance terms the response to the questionnaire has been limited. Much of the content of the website so far has been developed by the domain leader and research team.

Switching to a format based on the World Wide Web enables a potential user to access not only current practice, but also future practice if the respective web sites are maintained. The request to the contributors therefore switched to include relevant web sites.

The website describes the project, the domain objectives and for each sub-topic the definition that has been used and a brief description of the scope of the topic. Twenty-one sub areas have been developed so far. Some are further developed with long lists of actions and areas that have to be considered. Few are developed as performance specifications, although all have an implicit expectation that by adopting new practices in each area then the overall performance objective will be achieved. Work has commenced to review the information in each area and to produce a performance oriented text that links the many websites and information sources. To review every site and every piece of information and to evaluate it as state of the art or not is an impossible task. This realization has led to the development of the domain as a support system to users who themselves would have to develop an intimate knowledge of those topics and areas that are relevant to their particular project. Therefore a user or client needs assistance to identify the relevant topics and also a means of accessing and stating the basis of the performance requirement once they have understood the issues. That understanding can be supported by the international research that is now accessible via the domain website.

Inter-relations with other Domains/Tasks:

The briefing tool developed within the Domain 4 activity was offered to all of the other domains at the conference in Manchester.

Incentives for PBB Implementation:

The output of the Domain is unique and probably ahead of its time. Briefing in this area of a project is very poor and the tool that was developed provides a mechanism for involving not only project teams but also the wider population in debating quite fundamental issues that surround new projects. Even the limited work that has been produced has attracted interest from a wide range of people when presented at conferences.

Barriers to PBB Implementation:

The most significant barrier is that the subject is so large and ill defined. It is well beyond the scope of anyone individual to be able to specify a performance criteria for the built environment. The tool that was developed enable those involved in setting performance specifications in this area to at least be able to access the relevant topics and how to explore their relevance.

Proposed Research Agenda:

The following recommendations are not meant to be specific research projects but to be areas where fruitful research but more importantly development could take place. The Domain produced a pilot data

base driven briefing support tool linked to a web site which itself was linked to many other web sites dealing with specific topics and sub topics.

1 Definitions

More precise definitions need to be developed for each topic area. Attempts were made based on the approach used in the UK in the Common Arrangement of Work. This approach not only states what is included in the definition but also states what is excluded.

2 The built environment affected by the project

The project will have an impact on its surroundings. These are commonly the subjects of planning disputes. These impacts need to be clarified so that a more articulate debate can be undertaken.

The project will also have an impact on the wider world in terms of its contribution to: global warming, carbon emissions, sustainability as well as the local infrastructure. These need to be described in a way that the buildings affect on the 'performance' of its wider environmental impact can be measured and assessed.

3 The effect of the environment on the project

A building cannot be isolated from its surroundings. The debate over context, planning and style preferences must be had for every project. Because there is no formal basis for the decisions that are made in this area the debate over every project is often heated because of miss-information, predjudice or wilfulness. The discussion is very arbitrary and needs to be better informed. Enhancing the WWW sites with examples, photographs and video images is becoming a possibility and needs to be considered.

4 Development of the briefing tool

The setting of standards, and priorities within the tool is done in an informed but somewhat arbitrary manner. Much of the discussion is better conducted with visual examples which themselves have been benchmarked. The development of benchmarking of current practice so that the performance expectations can be assessed is required.

Dissemination and Implementation:

The tools that have been developed in prototype form need to be developed and made more widely available. They are already part of the University of Reading's courses in Design Management and are introduced to other audiences where appropriate.

Conclusions:

The work in this Domain has shown that even when the information that is available is not set out in a readily accessible performance based form a specification can be produced. Techniques for developing specifications used in other industries can be used in the field of construction.

The development of decision making techniques appropriate to the construction industry are essential as the context within which projects are built increase in complexity. The number of issues that have to be considered, weighted and then traded off against each other are considerable. The range of issues within each subject is growing. Building projects have to consider them all. Clients have to be aware of the issues and their decision making transparent.

The work in this Domain has shown that by using the WWW the state of the art, as it is emerging and changing, can be made available to clients in any situation. Connecting this to decision making tools enable

them to respond effectively to the changing environment. The decision making can become transparent and there is an audit trail of the process.

The work in the Domain has developed a pilot demonstrator of this approach. The lack of readily available performance based specification material in this subject area hindered the development of a complete and fully functioning specification system. Consequently the work was terminated at an earlier point than originally scheduled. However the tool that was developed demonstrates the potential and it is recommended that it is further enhanced and developed.

ANNEX V: STATE OF ART SUMMARY REPORT FOR DOMAIN 5: ORGANISATION AND MANAGEMENT

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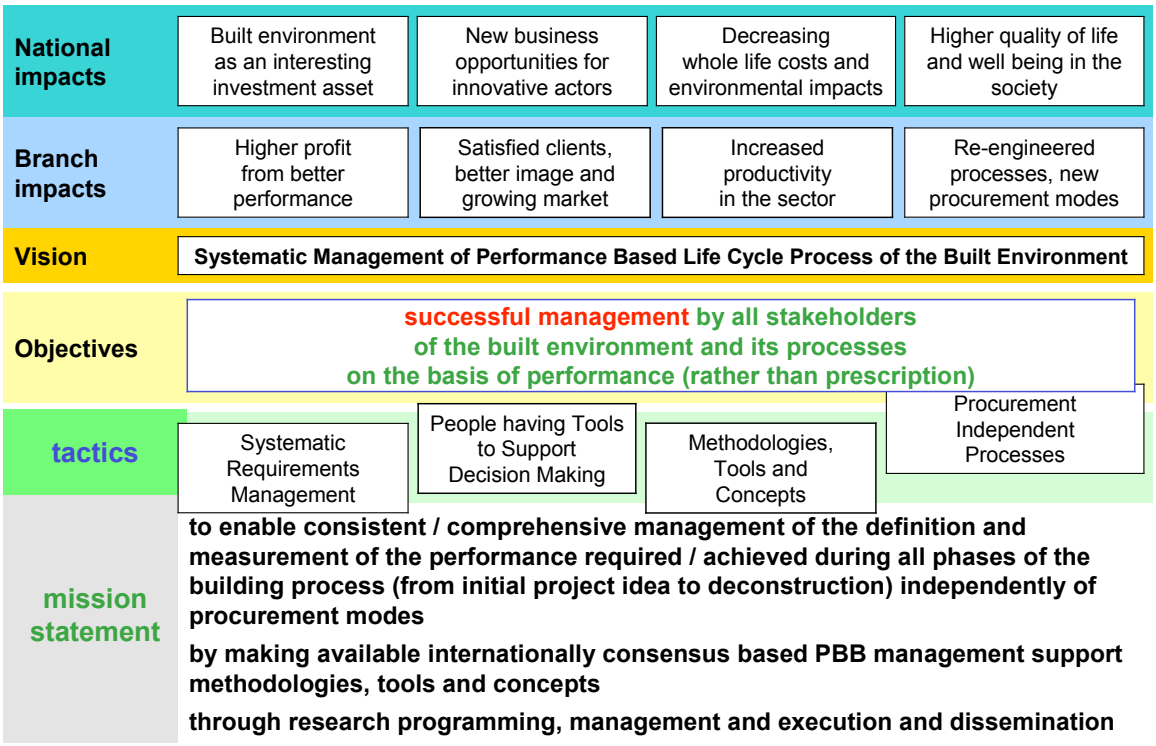
Domain Website:

http://www.pebbu.nl/maincomponents/scientificdomains/terminateddomains/domain5/

Scope and Objectives:

To support transforming user need into performance requirements and managing design, construction, operation and maintenance processes achieving the desired building performance of life time.

Conceptual Framework:



Accomplished Workplan:

The framework was developed and the project plan followed until the Domain was terminated by mid term.

State of the Art:

Performance based building in general seems to be a promising concept, but it is still not widely applied. The organisation and management specific issues deal with decision support, where some promising generic tools exist, even though they are currently not much used.

Inter-relations with other Domains/Tasks:

The organisation and management issues are overlapping with many other PeBBu Domains.

Incentives for PBB Implementation:

No specific incentives or barriers for organisation and management, general PBB statements apply.

Barriers to PBB Implementation:

No specific incentives or barriers for organisation and management, general PBB statements apply.

Proposed Research Agenda:

Decision Support Toolkit, Performance Indicators, Procurement independent processes, and methodologies and concepts.

Dissemination and Implementation:

The tools will be implemented in practice and results disseminated through experiences.

Conclusions:

No specific agenda for organisation and management drawn in this project.

ANNEX VI: STATE OF ART SUMMARY REPORT FOR DOMAIN 6: LEGAL AND PROCUREMENT PRACTICES

Domain Leader:

Peter Fenn, Timothy Morse & Kim Haugbølle

Domain Members:

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Domain Website:

http://www.pebbu.nl/maincomponents/scientificdomains/domain6/
http://www2.umist.ac.uk/construction/research/management/pebbu/

Scope and Objectives:

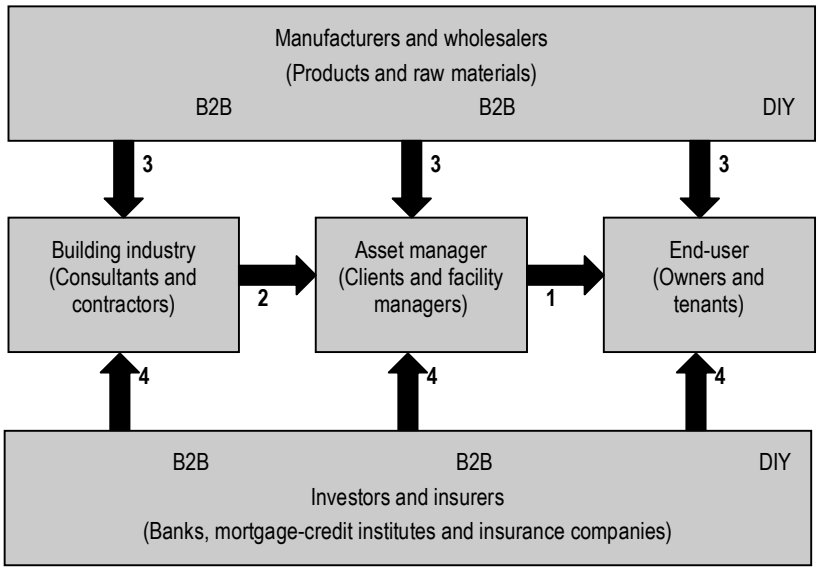
The overall aim of Domain 6 is to review the practice and procedure of PBB in the member countries as this relates to the domain Legal and Procurement Practices in those countries. Within the overall aim the following measurable objectives are set:

1. To consider the drivers to PBB.
2. To document the limitations placed on innovation by: Professional indemnity insurers: The particular insurance problem of a 'funding gap'. Tendering rules e.g. requirements to circulate Contractor's Change Proposals to all tenderers: Consideration of the scope allowed to contractors to affect construction. Professional Practice (Quantity Surveyors in the UK): Consideration of the problems of measuring compliance with the basic parameters of time and quality.
3. To investigate how initiatives towards value, and tendering restrictions affect PBB: EU rules and requirements; Value for Money (UK Government procurement); Best Value (England and Wales Local Government Act 1999); Most Economically Advantageous Tender (MEAT) and other approaches; their national practices and procedures.
4. The crucial issue of where and why PBB turns into prescriptive procurement.
5. To investigate how national and legal jurisdictions affect PBB (NB: Common and civil codes).
6. To produce a review of national practices and procedures.
7. To investigate training and education requirements across the domain.

Conceptual Framework:

Figure 1 synthesizes the analytical framework deployed in Domain 6 illustrating the actors and markets of the building/housing cluster.

The framework provides us with an overview of the *context* in which the actors of the building process have to operate. Framed by governmental regulation and the knowledge system, the building/housing cluster can be divided into five subcategories of actors linked through four separate markets. The five groups of actors are the end-users, the asset managers, the building industry, the manufacturers, and the investors and insurers. The four markets are the property market (1), the building market (2), the product market (3), and the capital and insurance market (4). Focus in Domain 6 has been on the relationships between the building industry and the asset managers on the building market.



Note: B2B = Business-to-Business (professional). DIY = Do-It-Yourself (non-professional).

Figure 1. Overview of the context.

Methodology and Process:

The methodology and process of Domain 6 has included 4 main activities:

- Four Domain workshops in Manchester (UK) July 2002, Sofia (Bulgaria) Manchester (UK) January 2004 and Porto (Portugal) November 2004.
- A systematic and rigorous literature review was one of the first tasks of this domain and the results were published in the first domain report.
- Five national case studies carried out by the members from UK, Israel, Belgium, Denmark and Ireland.
- A Delphi survey.

State of the Art:

The initial PeBBu outline for this Domain stated that there is no current state of the art which could be applied across the EU; rather a collection of national practices. The work of the domain is to review these practices and procedures with a view to collecting best practice and producing guidelines. This position is restated here.

The definition of quality in terms of performance criteria raises problems for construction procurement and legal issues. The establishment of pragmatic performance criteria is fraught with problems; and the legal framework may lay down liabilities in differing ways depending on whether the building is prescribed by result or by performance.

The term State of the Art produces special problems in this domain, since it is also used as a legal term in some jurisdictions. In the UK for example the duty on a designer may vary between a duty of care (design only) and a duty to provide a building fit for the purpose intended (design and construct). Simply put under a duty of care a defence may be available that the designer used the knowledge that was available at the time i.e. the state of the art. Under a duty of result no such state of the art defence is available. Professional Indemnity insurance cover (at least in the UK) is often restricted to claims arising from negligence on the part of the insured i.e. non-negligent errors are excluded. This point is often used by designers in seeking to restrict their liability for design errors to those involving negligence. They seek the ability to use a "state of the art" defence if they have one.

Factors may be driving shifts in procurement towards PBB might be considered under three headings: International competition, government policies and European policies. Influence from international competition has arisen from experiences of multi-national companies around the world and a desire to replicate best practice in other countries. Significantly better results were experienced in design and build procurement leading to an increase in the use of this procurement, see e.g. Royal Institute for Chartered Surveyors (2001) for a UK analysis. Similar results are reported elsewhere e.g. the USA (Haviland, 1998).

Since the early 1980's government influences have been founded on two things. That governments are responsible for the large part of construction output described above; and that governments need to maintain or increase output, particularly on infra-structure whilst at the same time reducing public sector expenditure. In order to reconcile these two opposing forces governments have increasingly turned to methods that involve private finance in projects. These methods include Design and Build (D&B); Design Build Fund Operate (DBFO); Build Operate Transfer (BOT); Build Operate Own Transfer (BOOT); Private Finance Initiatives (PFIs); and Public Private Partnership (PPP). Currently it is reported that in excess of 100 countries are procuring construction and engineering works under the generic heading of PFI (Merna & Smith, 1999). Private activity in infrastructure grew dramatically between 1990 and 1997, from about US$16 billion to US$120 billion (Roger, 1999).

In future years the Commission of the European Communities, as part of its role as promoter of legislative and operational initiatives, may consider defining the general lines of policy across the EU. The collection of best practice and producing guidelines will allow the views expressed to contribute to that definition of general lines of policy. Analogies could be made with other EU initiatives; specifically with the current Green Paper on Alternative Dispute Resolution in Civil and Commercial Law (European Commission, 2002).

Both international competition and government policies have resulted in moves towards PBB since performance specification lies at the heart of both D&B and PFI philosophy.

Proposed Research Agenda:

Domain 6 proposes three research objectives to be addressed in future work on performance-based procurement:

- A detailed and case-based analysis of the processes of interpretation, negotiation and translation of requirements (whether performance-based or prescriptive) between the various actors and through the various phases of a building project.

- Although some tentative conclusions has been suggested and discussed in the domain meetings, a more substantial analysis on the reasons of clients for procuring in different ways is clearly needed. These analyses should use both interest-based and resource-based approaches in order to address both the issue of willingness and the issue of ability of clients to procure in new ways.
- A better understanding and characteristics of the negotiation space (see figure 2) available for the actors in the building process is needed in order to analyze and evaluate under which circumstances various procurement methods, requirements etc. are most appropriate.

Relationship to Other Domains:

Australia has provided a useful paper on the inter-relationships within the scientific domain of performance-based building and links between other related domains (namely Domain 7 Regulation and Domain 8 Innovation). The relationship with Domain 7 and 8 has also been strengthened through the participation of individual domain members in these domains.

Incentives for PBB Implementation:

The issue of incentives and barriers to PBB implementation implies that PBB is per se a more appropriate approach than the prescriptive approach. The work of Domain 6 has not primarily been driven by a concern of implementation but rather of a concern to understand the characteristics of performance base procurement.

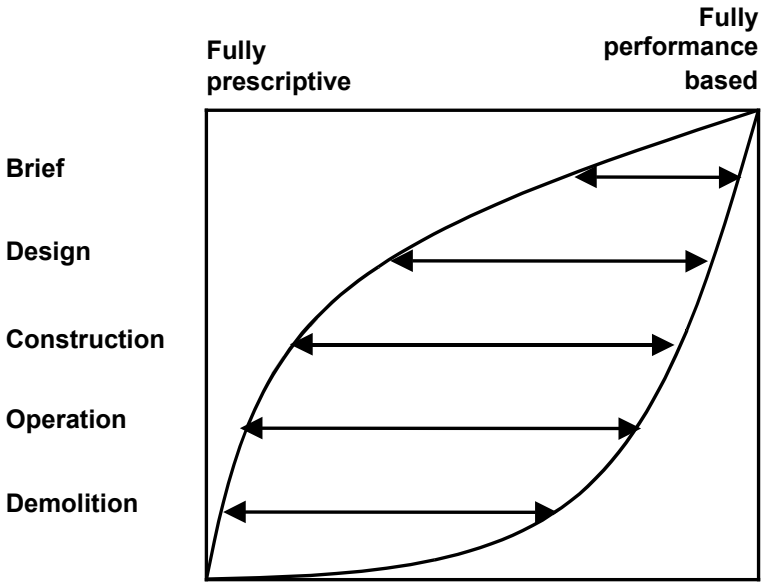


Figure 2. The negotiation space available to the actors.

The incentives and triggers for PBB are well documented but need greater clarity and dissemination. For example the claim in PebbU Newsletter Nr 1 ./ 02 that PBB is a strong stimulus for product and process innovation and enhances consumer-orientation, cost optimisation and trade possibilities in construction requires detailed back-up and analysis. The claims that PBB is therefore expected to reduce total construction costs by as much as 25% must similarly be defended and justified.

It is apparent that clients and in particular government clients who are such an important part of construction demand are receptive to change

Barriers to PBB Implementation:

Besides the well-known barriers to any kind of innovation and change in the building and construction industry like the low level of R&D investments and the segregation and fragmentation of design, engineering and construction, the delphi study and the national case studies have hinted at some of the more specific barriers related to procurement. These barriers include:

- The uncertainty about risk and liability, not least the issue of duty of care versus a duty of result;
- The suspicion of designers and other advisors that the application of PBB will further undermine professional status;
- The wish of clients to exercise extensive control of the end product;
- The dominant position of consultants in the building process in some countries like UK and Denmark;
- The administrative practices of municipalities requiring very detailed project description before granting various approvals in some countries;
- The elaborate involvement of the end-users requiring specific solutions.

Dissemination and Implementation:

The issue of dissemination and implementation inherently requires a normative stance of favouring PBB as the solution. However, Domain 6 has not been fully convinced of the superiority of the performance approach in all cases and under all conditions. Rather, it has exactly been the attempt of the domain to explore the conditions under which the performance approach may be appropriate. Thus, the issue of dissemination and implementation should instead be viewed as a matter of how the domain has contributed to a continuous debate on the performance approach. Viewed in this light, the dissemination and implementation activities of Domain 6 has included:

- Setting up a website at UMIST and contributing to the website of PeBBu;
- Participation in the regional platforms;
- Production of various publications including the domain reports and conference papers e.g. for the conference Combining Forces;
- Participation in national and international events such as conferences, workshops etc. like Combining Forces.

Conclusions:

Domain 6 has been frustrated by the dearth [total lack] of empirical data. The benefits, incentives and triggers for PBB are well documented but in a journalistic manner. Thus, PBB need greater clarity and rigour. It is clear that PBB poses many challenges for legal and procurement practices in building and construction but because of the unstructured nature of the field [discipline] it is not clear how these can be approached [overcome]. The CIB PeBBu Thematic Network has been an invaluable first step in approaching the challenges.

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ANNEX VII: STATE OF ART SUMMARY REPORT FOR DOMAIN 7: REGULATIONS

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Domain Members:

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Domain Website:

http://www.pebbu.nl/maincomponents/scientificdomains/domain7/
http://groups.yahoo.com/group/pebbu_task7

Scope and Objectives:

Domain 7 of the Performance Based Building Network has collected relevant information about progress in implementing performance regulations in the participating countries. While discussion in the various domains tends to provide a favorable picture regarding performance based building, it may be a case of preaching to the convinced. The status reports in Domain 7 reflect an uneven picture of successes and frustrations in attempts to change the regulatory framework in the participating countries. While almost all of the countries are moving in the direction of performance regulations, most do not yet have a complete or fully integrated performance based regulatory system. In the absence of such a system, it is difficult, if not impossible, to implement fully the various aspects of performance based building.

Conceptual Framework:

The Performance Based Building Regulations Domain is part of a thematic network funded under the European Commission's 5 th Framework – Competitive and Sustainable Growth. The program

commenced in October 2001 and runs until September 2005. It involves networking among various European and international stake holders to promote performance- based building, research and implementation.

Performance based building regulations need to be viewed within the larger general discussion of performance- based building. The concept put forth by the thematic network is that thinking about building and construction should be oriented to ends rather than means. "The basis of all building activity should be the performance of the building in use rather than the prescription of how the building is to be constructed".

Accomplished Workplan:

In addition to the task members listed above, guests or observers from Australia, Canada, New Zealand and the United States participated in one or more of the Domain meetings. The participation and contribution of Australia was particularly significant as Australia operates a parallel network to the European Performance Based Building Network and several members were present at the various domain meetings.

Furthermore representatives from Australia discussed the findings of a productivity commission authorized by the Australian government to examine the contribution that reform of building regulation has made to the construction industry and to economic efficiency in that country. The Australian experience was particularly important as they have been pioneers in performance- based regulation.

Meetings, task members and guest represented a variety of organizations, academia, industry and government. They brought with them a range of professional backgrounds: architecture, code enforcement, engineering, legal, research and public administration.

As noted, all of the participating countries have some level of involvement with performance based building regulations. Obviously, there is a level of self selection as participation in the building regulatory domain was voluntary.

Members decided to undertake two surveys of the participating countries, both in order to understand the subtleties and differences between the regulatory systems, and to gauge and compare progress in implementing performance based regulations. The first survey was undertaken early in the network and domain activities, the second approximately four years later towards the conclusion of the project. The first survey had a limited response and the second is now being completed.

Discussion was undertaken as to the possibility of a common shared international or pan- European performance based building code. The idea was resoundingly rejected for the foreseeable future.

Discussants noted the widely variable social, political, economic, administrative and legal contexts among different countries that make a common code impractical. Certainly there are also differences related to climatic conditions, building materials and building traditions. However, the intensity of the negative response may indicate additional underlying, less transparent, factors such as national, regional or even local pride and concerns about a loss of autonomy. All of this is not to say that the domain members did not see a broad basis for international cooperation. In fact there was full consensus on the benefits of cooperation and the opportunity to learn from the experience of other countries.

The Domain developed three prototypes for performance- based building code development that are described in the flow chart and survey form that follow. They constitute the second survey. Essentially for purposes of simplification and comparison, the pathways for performance based building code development were channeled into three prototypes that were designated cases A,B and C.

A represents those countries with the political will, the economic resources and the technical capacity to develop their own national model code.

B represents those countries at the opposite end of the spectrum in terms of very limited resources, internal technical capabilities, and perhaps lesser commitment to performance based regulations. These countries are generally prepared to phase in various performance based building requirements into an existing regulatory system at a gradual and graduated pace.

C represents those countries that are prepared to revamp their building regulatory system to one that is performance based but from existing work carried out in other countries that can be adopted with minor adaptations or alterations.

All of the cases A, B and C involve some simplification and generalization and make various assumptions that obviously vary in the extent of their accuracy in the different countries. Probably the most important assumption is that in all the cases key stakeholders in the building regulatory process have been engaged performance based regulations and are supportive. The point is that changing a building regulatory system requires a broad base of support. It cannot be imposed top down as it will encounter resistance in the field. Neither will it evolve bottom up, as the field levels are unlikely to invest the time and resources or enlist the political clout to effectuate the change .

State of the Art:

The Australian model will be discussed separately based on their extensive experience and a productivity commission study recently completed.

Belgium has a building regulatory system that is partially performance based. Local authorities continue to use prescriptive requirements. Performance based regulations are viewed as a means and not an end. Representatives see a combined system of prescriptive and performance based regulations evolving over time.

Hungary`s building regulatory system is primarily prescriptive. There is an energy survey requirement in place. that is performance based but not widely used. Representatives see a trend toward withdrawal from mandatory requirements.

Israel currently has primarily prescriptive requirements. However a government commission appointed after a social hall collapse recommended a substantial overhaul of the regulatory system including a comprehensive performance based code, and a process for evaluating new building technologies. Preparation of the performance based code is well underway. Fire safety requirements will remain mostly prescriptive.

The Netherlands also has a mixed building regulatory system that has been evolving over the past decade.

Poland has mandatory norms and standards, some prescriptive and others performance based that now constitute a building code of approximately 70 pages. Ordinances increase from year to year and the code grows.

Slovakia has a performance based code for the energy performance of building and is focusing regulatory efforts on CPD implementation.

The United Kingdom has a regulatory system based on 15 "approved documents" that are essentially performance based. "Deemed to satisfy" provisions are prescriptive but allow for equivalents. Experience shows private enforcers have resisted and complicated the use of performance based documents.

In 1994, the Australian government established the Australian Building Code Board that vigorously pursued a performance based code. While the Board had no regulatory powers in and of itself, the code was adopted and used by the states and territories. This past year, 2004, the government of Australia undertook an extensive examination of the contribution of building regulation reform to economic efficiency and the construction industry.

The report found that the reform was successful in encouraging skill acquisition, reducing costs and encouraging and enabling innovation. It constitutes a strong endorsement of performance based building requirements.

However, the report found that regulatory reform is far from complete. The report recommended:

1. Further reducing, jurisdictional variations and reducing the, erosion of the codes uniform application by local planning decisions.
2. Better articulation of the performance based requirements.
3. Seeking ways to enhance local administration and enforcements.
4. Re-examining the approach to property protection from fire.
5. Better incorporating environmental requirements in the code.

As described in a PeBBu news article from February 2005 the report further found that:

The majority of the performance: requirements contained in the Code do not provide readily measurable outcomes nor specify verification methods. The standards are more accurately described as "principle" based, specifying broad, but not measurable, targets or objectives for building. For instance, for structural provisions, the Code does not specify precisely the loads that must be withstood by any building (such as wide-speed loads or dead loads)–rather it requires that the building must withstand "actions to which it may reasonably be subjected". This means it is not possible to judge whether objectives have been met and gives little guidance to building practitioners.

The report advocated resolving this issue and several other weaknesses in performance aspects of the code as part of the future work program. Overall the examination endorsed the performance based approach as "having the capacity to deliver significant benefits to the building industry and consumers".

Inter-relations with other Domains/Tasks:

Several domain members were also members or participants in other domains. The Decision Support Toolkit was presented and discussed by the domain. Other activities, inputs and outputs were not directly coordinated with other domains.

Incentives for PBB Implementation:

The issue of performance based versus prescriptive regulations pertains primarily to architects and engineers and to a lesser extent to building contractors. It also pertains more to large, unusual and sophisticated buildings than to residential, low rise, standardized
building and construction. Manufacturers of building materials and products are also relevant clients of the performance based code.

The satisfaction level of these practitioners with performance based regulations tends to vary. All desire fast building review approvals. The extent to which they themselves and the local regulatory officials are familiar and comfortable with the performance aspects of the codes is a function of time and willingness to learn and innovate.

In general there will be a segment of the building community that is resistant to change and will constantly pose the question:

"What do they really want?" Accordingly it is helpful that a new, performance based requirement be accompanied by deemed to satisfy provisions that are also prescriptive.

Barriers to PBB Implementation:

Given that the introduction of performance based regulations is often a gradual process, the new regulations may not address what some building professionals regard as the most important issues or those that most interest them. Similarly when they are partial or fragmented they cannot comprehensively address all code requirement issues. There may be a need to merge performance requirements with prescriptive ones for various building systems or materials. Performance requirements by their nature often require greater effort by the practitioner to demonstrate compliance. In addition because they are new the performance requirements are less familiar and have not yet stood the tests of time and use by the various building professionals. Most of all it is difficult to verify compliance with performance based regulations. This last issue will be discussed more extensively in another section.

Proposed Research Agenda:

Each of the performance based building network domains was requested to recommend research priorities in their field. For the building regulations domain this proved not to be a difficult task. The experience of the various countries at various stages and with different degrees of success in implementing performance based regulations provided a convenient
platform for the discussion of research priorities.

There was wide agreement on the importance and benefits of network and the potential for sharing the results of research in a number of areas. The subjects that emerged as research priorities were agreed upon based on the needs and wants of at least several of the participating countries:

These were as follows:

1. Verification methods to demonstrate that the required performance was achieved.
2. Risk-informed regulations.
3. Methods for addressing acceptable or desirable levels of performance in existing buildings.
4. Creating a systems approach to performance requirements with quantifiable levels of performance.
5. Methods for evaluating the economic impact or feasibility.
6. Development of certification models and other means of approving designs and products.

Dissemination and Implementation:

Quantitative requirement can be matched to qualitative objectives of performance based building regulation but it is difficult if the advantages of the performance approach are not to be lost in the process. Key performance indicators are a promising approach that may be able to bridge the gap. They need to provide simple yet coherent criteria that set the acceptable level or range of performance in ways that can be verified by tools at the disposal of the regulatory community. Generally key performance indicators involve benchmarking a given situation so that targeted performance can be assessed and compliance determined.

While technical performance criteria and verification methods have been proposed in a number performance based regulatory areas, particularly energy conservation, domain members demonstrated their keen interest in the expansion of verification methods as research priorities, the results of which can be shared internationally.

This is a significant challenge that will impact the future success of the approach.

Conclusions:

Performance Based building regulations have broad support in the international arena. Different countries are proceeding according to separate prototypes and at varying paces in incorporating performance based

regulations into their building codes. Most are not doctrinaire in their approach and are prepared to mix performance based regulations with prescriptive ones according to their understanding and experience as to which will best serve them.

While the idea of an international performance based building code was resoundingly rejected, there was full agreement regarding the advantages of international cooperation and shared research. The strongest future research priorities revolved around verification methods that provide quantitative indicators for qualitative objectives. International cooperation should continue and these and other research priorities should be aggressively pursued.

ANNEX VIII: STATE OF ART SUMMARY REPORT FOR DOMAIN 8: INNOVATION

Domain Leader:

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Domain Members:

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Domain Website:

http://www.pebbu.nl/maincomponents/scientificdomains/domain8/,
http://www.scpm.salford.ac.uk/cibpebbudomain8

Scope and Objectives:

Domain 8 is focussed on the dynamic of innovation that is required for, and is triggered by, successful performance-based building (PBB). The domain's scope and objectives are more specifically divided into two phases: phase 1 focuses on performance objectives and measures for PBB-driven innovation; phase 2 builds upon these results by investigating the impact of PBB-driven innovation on construction (see Figure 1), both in terms of PBB as the innovation and PBB as a driver for innovation. The focus relays on the interaction between performance-based building and innovation and clusters around the following issues:

- Identification of innovation objectives and measures and their impact on building and construction practice as related to PBB, taking into account the various changing roles of the respective stakeholders.
- Establishment of how connections can be created and sustained between performance objectives and innovative activities throughout the various phases of the building process and the lifetime of the building.

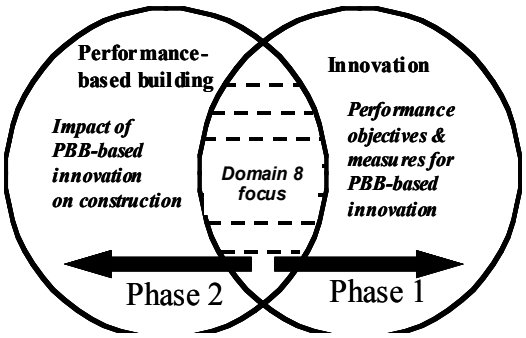

Figure 1: Focuses of Domain 8, Phases 1 and 2

Conceptual Framework:

The conceptual framework and assumptions underpinning the work of Domain 8 are:

- The principal focus of PeBBu is the performance of buildings in use. Domain 8 will contribute to, and be in alignment with, this principal focus. The expression 'performance of buildings in use' will be understood within the broader context of the PeBBu project documentation, and is taken to convey the multifaceted value creating, capture and delivery role of buildings. This includes the building appropriately meeting the needs of the client system and of whole life cycle performance.
- The focus will principally be on building, but will capture key lessons from construction and civil engineering where appropriate.
- The focus will be on new and existing building stock. The rationale for this is that the refurbishment/ renovation/ reuse of building stock is (compared to new build) a substantial part the construction and property industry, and is a key change agent in the built environment.
- Innovation is not always appropriate. Innovation has to enhance the overall performance of the building in use.
- It cannot be assumed that performance-based building is always appropriate. Performance-based building has to enhance the overall performance of the building in use.
- Appropriate innovation is required to close the gap between existing construction and property industry performance and the performance needed to understand and satisfy client systems' increasingly demanding needs. The implication is that the enhanced performance of buildings in use requires an appropriate balance and leverage of 'industry-push' innovation and 'client-pull' innovation (see Figure 2) – neither client systems nor industry can bring about successful performance-based building in isolation from each other. A stakeholder perspective is therefore an important aspect of the Domain's work.

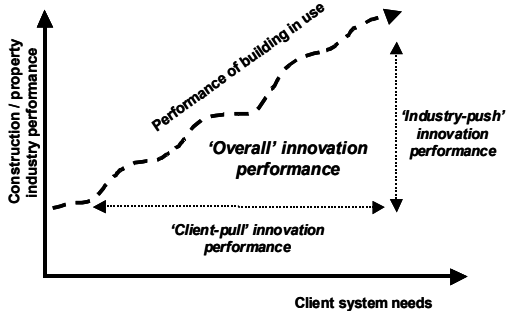

Figure 2: 'Client-pull' / 'industry-push' innovation interaction

Methodology and Process:

The Programme of Work for Domain 8 is given in full at http://www.scpm.salford.ac.uk/cibpebbudomain8/programme%20of%20work.htm There are links to milestones/ deliverables from this web-site, a summary is given below.

Task	Delivered
Start of Project	October 2001
Develop Stimulus Paper 1	October 2001
International State of the Art Report	April 2002
Team to respond to the Stimulus Paper 1	June 2002
Workshop 1 Preparation Report	June 2002
1st Workshop	24-25 July 2002
1st Domain Report to CIBdf	August 2002
International State of the Art Report update to CIBdf	August 2002
Develop Topic Papers	August 2002
Feedback on Topic Papers (Revised Stimulus Paper)	December 2002
2nd Workshop (part of the PeBBu NAS Week)	27-28 March 2003
Phase 1 Industry Report to CIBdf (Synthesis Report)	August 2003
Delphi Study amongst International Experts	April 2003
Mid-Term Report to CIBdf	30 August 2003
Develop Stimulus Paper 2	October 2003
3rd Workshop (Manchester, UK)	12-14 January 2004
Domain 8 News Article to CIBdf	February 2004
Delphi Study News Article to CIBdf	February 2004
Progress Report to CIBdf	August 2004
Develop Stimulus Paper 3	November 2004
4th Workshop (Lisbon, Portugal)	November 2004
Phase 2 Industry Reports	March 2005
UK dissemination workshop	April 2005
RTD Agenda	May 2005
2nd Domain Report	July 2005

State of the Art:

Innovation performance objectives and measures need to focus on what is important (hard and soft factors) to all of the various stakeholders, and within a global framework they need to be particularised to the construction industry and within that to more specific sectors, clients, companies, or even projects to reflect the actions needed in these local circumstances and demands. The findings from both Phase 1 and Phase 2 have produced two schools of thought regarding the relationship between performance-based building and innovation: content and context. The 'content' school of thought has advocated that PBB is the innovation in itself, and that PBB approaches replace traditional prescriptive approaches with a new paradigm. In contrast, the 'context' school of thought has argued that performance-based building provides the enabling environment to stimulate a raft of innovation activity which may include prescriptive, as well as performance-based, elements. The two schools are not in conflict; indeed, there is significant

value in recognising and integrating them to form an evolutionary approach which promotes continuous development and use.

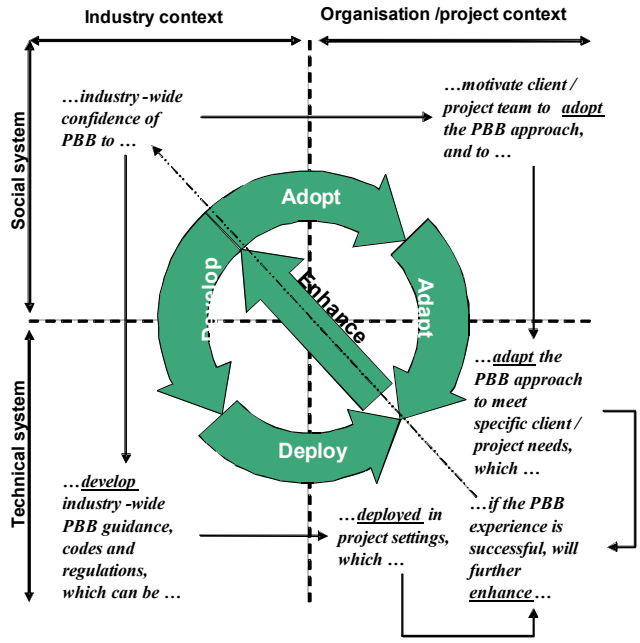

Figure 3: An evolutionary model of performance-based building

A framework is offered (see Figure 3 above) which conceptualises the performance-based approach as an evolutionary cycle of innovation across industry and project contexts, and between social and technical systems.

Inter-relations with other Domains/Tasks:

As Domain 8 is a cross-cutting theme, the members have worked actively with the other Domain/ Task Groups.

Proposed Research Agenda:

The work undertaken in Domain 8 has delineated two schools of thought on the relationship between performance-based building and innovation: 'content' and 'context.' The proposed research agenda argues that these two schools are not in conflict; and there is significant value in recognising and integrating them to form an evolutionary approach which promotes continuous development and use. A framework has been offered (see Figure 3) which conceptualises the performance-based approach as an evolutionary cycle of innovation across industry and project contexts, and between social and technical systems. The framework has also identified new research possibilities to enable widespread PBB-based innovation. The model presents a number of areas that need to be further investigation – at the intersection between the arrows – on how projects should adopt PBB, namely:

- Innovation transfer issues – when moving from industry to project context at a social system level
- Innovation use issues – when moving from social to technical context within the project organisation
- Industry development issues – when moving from social to technical context within the industry context
- Capability development issues – when moving from industry to project at a technical system level
- Innovation diffusion issues – when moving directly from project context to industry context within the technical to social system level

It is anticipated that a concentration of research on these intersection areas will provide further colouration of types of innovation within the PBB approach. Innovation does not occur in a vacuum, but rather in a holistic, systemic environment, and there it must be explored in a systemic way to highlight the macro and micro systems of innovation. The synergies between the types of innovation need to be better understood, both positive and negative factors, so that areas of difference and commonality across both projects and nations can be identified.

	The 'content' school: PBB as the innovation (telescopic research)	The 'context' school: PBB as an enabler of innovation (periscopic research)
Aim	How to create the **general** conditions to support PBB	How to bring together various elements on **specific** projects
Type of Analysis	Broad, holistic, conceptual model, highlighting **what** elements are important	Good practice case studies illustrating **how** elements can work synergistically
Focus of Analysis	Generic industry level, highlighting differences by country	Project specific, highlighting interaction of companies in industry context
Broad Themes	Concepts of requirements	Concepts of requirements
	Measures of requirements	Measures of requirements
	Organising around requirements	Organising around requirements
	Delivering on requirements	Delivering on requirements
	Feeding forward experience	Feeding forward experience
	Capacity to deliver	Capacity to deliver
Output	Report: how to create the conditions to maximise the potential for appropriate PBB	Report: advice and illustrations on how to realise users requirements through PBB
Stakeholder Addressed	Government/ industry bodies	Clients and construction companies

Incentives for PBB implementation:

Numerous drivers for innovative PBB practices include competitive advantage, survival, achievement/ kudos, financial gain, reputation etc

Barriers to PBB implementation:

Numerous barriers have been identified that stifle innovation, including risk, cost, legislation, culture of client and project team, time etc.

Dissemination and Implementation:

The team has and is currently writing up several journal and conference papers. The Domain 8 website acts as a central portal for all project documentation. A UK workshop was held April '05 to disseminate the findings of the PeBBu network and encourage wider participation/ support/ awareness in PBB from both academe and industry. The team is seeking to find ways to encourage wider innovative practices within a PBB context.

Conclusion:

The Domain 8 work has produced a robust concept model which identifies and integrates the key elements needed to bring about successful innovation through performance based building. This concept

model has provided a basis a consensus definition to drive, monitor and improve performance based building.

ANNEX IX: STATE OF ART SUMMARY REPORT FOR DOMAIN 9: INFORMATION AND DOCUMENTATION

Domain Leader:

Prof. Colin H. Davidson, Univ. of Montreal, Canada.

Domain Members:

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Domain Website:

www.grif.umontreal.ca click on "réseau" (or on "English" and then on "Network") and then on the CIB W102 icon.
http://www.pebbu.nl/maincomponents/scientificdomains/terminateddomains/domain9/

Scope and Objectives:

The original proposal envisaged establishing a task-oriented international network of researchers and subsequently of practitioners concerned by and involved with performance-based building (PBB).

It is our belief that adoption of the performance approach to the design of buildings (PBB) and the subsequent specification of materials and products imposes novel requirements on the flow of information within and into the building process. While the adoption of the performance approach is not the only change that is impacting on the information requirements of the building process (the adoption of electronic communications and e-business, for example, are changing the way information can, and probably should, be made available to decision-makers), it has significant consequences.

Hypotheses:
Problem areas concern, for example:

- The information required in order to proceed from the functional programming step to establishing appropriate performance criteria.
- The information required in order to evaluate the performance characteristics of a design in the course of its being developed.
- The information required in order to specify materials and products in performance terms.

They are problem areas in the sense that not only are new kinds of information required (and they are often hard to come by) but also because the professional decision-makers will be working in novel ways and will be expecting that the information be presented to them in new forms and in new sequences.

Bearing in mind the contextual changes occurring at the same time (the adoption of electronic communications and e-business, for example), it can readily be understood that there is a double challenge to be taken up.

Research that is required to 'flesh out' the domain (and consequently provide the basis for the proposed network) by, for example, addressing the following points:

- The problem areas.
- The information acquisition habits.
- The need for information integration.

Conceptual Framework:

We have stated our understanding of the main problem areas in adopting the performance approach - in the form of the above hypotheses. On the strength of them, we have some feeling for the key information requirements that this approach implies, even if we know that much of this information is hard to come by and hard to use.

We are therefore interested in exploring ways so that such information as there is can be accessed. In other words, we plan to develop models of the interfaces between the designer, the specifier and the manufacturer in order to see what kinds of 'keys' are most appropriate to gain access to the information that is required at a given stage in the building design and construction process.

To do this adequately, we need to know more about:

- The problem areas. Do our hypotheses correspond to reality as perceived by those who are working on the performance approach? Is there a more detailed understanding of these problem areas and how they are broken down?
- The information acquisition habits. Do the decision-makers change the ways they access information when they are working with the performance approach?
- The need for information integration. While it is well known that to write a performance specification for a brick is easy but that it is not very useful per se, what work is being done to develop 'integrated' performance information (about performance criteria or performance characteristics)? Where is it being done? How can the much needed guidance be disseminated to those who prepare integrated performance information or to those who use it?

Methodology and Process:

Two workshops were organised and held in Belgrade (June, 2002) and Glasgow (June 2003).

Delegates made presentations. These described initiatives bearing primarily on PBB as such and not on the scope and objectives of Domain 9, namely the *information problems* engendered by (or related to) PBB.

In order to clarify the matter, the Domain Leader prepared a conceptual model of the information requirements associated with the various steps of the building design and production process; the model emphasise d the likely kinds of information that would be required at each step, showing how it shifted from humanities-related to technical-commercial as a project advances. The model was accompanied by variants corresponding to differing procurement strategies.

Papers were solicited and received from interested delegates; with a few exceptions, they were characterized by same broad focus (PBB as such, mentioned above) and failed to address the specific problem of concern. In other words, it was becoming clear that *PBB-related information* was not a well-understood subject.

A two-pronged Internet survey was then conducted: a) a search on the sites of all CIB full members and b) a general web survey. Both surveys used keywords aimed at identifying work related to the theme of

Domain 9. Surprisingly, the two surveys yielded no new useful or pertinent indications about work related to what we have called *PBB-related information*.

State of the Art:

We were forced to the conclusion that there is no "State of the Art" to be reported on. There appear to be virtually no protagonists who could usefully be coordinated through a network as originally envisaged.

It was therefore decided at the Glasgow meeting to recommend the closure of Domain 9 and to develop an alternative plan of action. This is described in the section "Proposed Research Agenda" below.

Inter-relations with other Domains/Tasks:

Only informal exchanges took place with members of other PeBBu domains or their leaders, other than by participating in PeBBu meetings held in Amsterdam and in Budapest.

Proposed Research Agenda:

Because of our findings that virtually no work is being done into what we now can "the problem of information about information" in the construction sector, and bearing in mind CIB's proactive initiatives under the broad heading of "Agenda 21 … ", a proposal was prepared regarding an international initiative that seemed appropriate and necessary. The document bears the title: Agenda 21 Information and Documentation and bears the date October 2004.

The executive summary of this document reads as follows:

> The building industry is seen to be recalcitrant in terms of improving its efficiency and adopting innovative ways of working; there are explanations for this, placing responsibility on the structure of the industry and on its use of information for decision-making. Re-engineering, systematic procurement and performance-based building (PBB) are recent initiatives that impact on the use of information, i.e. on the 'information problem'.
>
> Little work has been done on this 'information problem' – or more exactly, on the *problem of information about information* in the building sector. This suggests that research into this problem and its consequences is urgently needed, since information – in its two forms: general and project-specific – is an essential ingredient of all decision-making and of all knowledge enrichment.
>
> The building industry is highly fragmented and its participants work in contexts that are unfavorable to good communication and, above all, unfriendly to the systematic acquisition of information, even if it is recognized as necessary to support the many decisions that must be made.
>
> A conceptual model of the nature of information flows in the building process show what kinds of information are required at various phases of that process, within the context set by the chosen procurement strategies. However, it is necessary to understand the other changes that are afoot and recognize that they have repercussions on the nature and use of information, in order to see (a) in what ways they affect what information is needed and how it can be handled and, conversely, (b) whether the availability and use of well-adapted information might not in fact *facilitate* these changes.
>
> Research into information should therefore be linked to the three complementary areas (re-engineering, procurement and PBB) in the form of a coordinated program of research projects, *starting with* (but not limited to) the two-way impact of information on PBB and *vice versa*. This program of work should build on the scarce (but valuable) work that is being done in various centers or groups scattered worldwide.

A number of research questions are proposed, together with possible research hypotheses. Research proposals have to be solicited and should be coordinated internationally to optimize the use of research resources which are rare in this domain.

This research program *excludes* studies of performance-based building as such and it is *not* about information technology *per se*.

Funding for the program is not discussed, but obviously has to be a matter of concern if the best resources are to be mobilized *and* effectively coordinated.

This document has been widely circulated a) within CIB; over 150 copies were distributed to participants at the recent CIB gathering in Helsinki and b) within the Collaborative Network for Building Research – CNBR.

Presently, about 20 researchers from many countries are responding positively to a proposal to form a group of persons interested in a) setting up a network of contacts and b) preparing a joint research proposal for submission to an international funding body. CIB declares its moral support for the Agenda proposal.

This proposal is the subject of on-going work.

Incentives for PBB implementation:

Since the proposal described above is outside of PeBBu, this section does not apply. It should be stressed that PBB is only one of several features of the contemporary economic and technical environment that should be stimulating an interest in the information problem that concerns us here.

Barriers to PBB implementation:

Not applicable.

Dissemination and Implementation:

Though the Agenda 21 initiative just described falls outside the European-Union sponsored PeBBu project, it is no doubt interesting to report that considerable interest is building up around the proposal. A plan for implementing the proposal has been outlined in a form that is suitable for a truly international initiative aimed at a) networking researchers involved with the *problem of information about information*, and b) developing a coordinated set of activities on this subject.

Conclusions:

The Domain 9 project was terminated early, because it was found that there is an almost total lack of work specifically focused on information and documentation related to performance-based building. Instead, it seemed pertinent to address the more fundamental and truly international problem of information about information outside the constraints of the European-Union funded PeBBu project. This is now gathering momentum.

References:

Davidson, Colin H. (2004). *Agenda 21: Information and Documentation – a Research Agenda*, Photocopied report submitted to the International Council for Research and Innovation in Building and Construction – CIB and widely distributed, 36 pp.

ANNEX X: STATE OF ART SUMMARY REPORT FOR TASK 13: REGIONAL PLATFORM NORTH EUROPE

Task Leader:

Prof. Christer Sjöström, KTH, Sweden, christer.sjostrom@hig.se

Task Members:

Brandt E., SBi, Denmark; Trudsy E., DS, Denmark; Haugbølle K., SBi, Denmark; Olsen I., EBST, Denmark; Liias R., TTU, Estonia; Finne Ch., RTS, Finland; Virtanen M., Ministry of Env. Finland; Pulakka S., VTT, Finland; Vuorinen P., Finnishc Constr. Ind. Finland; Trinius W., KTH, Sweden; Marteinsson B., IBRI, Iceland; Zavadskas E. K., Un. VGTU, Lithuania; Jasuja M., CIBdf, Netherlands; Haagenrud S.E., NBI, Norway; Lindberg K., Statsbygg Norway; Dagestad B., Nt. Office of Building Techn. Norway; Nostdal P., Norway; Bjørberg S., Multiconsult Norway; Sjöström Chr., KTH, Sweden; Waara F., CTH–GSA, Sweden; Skarendahl Å., BIC, Sweden; Ewander H., IB, Sweden; Scheele A., BOVERKET, Sweden; Lasota G., National Fortifications Adm., Sweden; Radocea A., FORMAS, Sweden; Bohman H., Swedish Road Adm. Sweden Lee A., Un. Salford, UK

Task Website:

http://www.pebbu.nl/maincomponents/regionalplatforms/regionalplatform1/

Scope and Objectives:

The objectives for the North European Platform is to stimulate and facilitate a maximal alignment between the PeBBu activities and national research and dissemination activities concerning the development and implementation of PBB in the Nordic countries and the Baltic states. Specific objective to this regional platform at the project outset was to engage additional member-/observership from the region and in special from those countries not originally participating.

New members/observers are attracted from

- Norway
- Iceland
- Estonia
- Lithuania; the member has not been active
- Sweden (industrial and standard institute observers)

The Platform has performed the three Workshops scheduled in the project programme, and a number of additional Nordic and national workshops and seminars. The Platform network has aligned with other projects, e.g. on Lifetime Engineering and LCC, and standardisation networks with the purpose to support efficient stimulation and facilitation of PBB.

National PBB Platforms have been established in Sweden and Norway.

A number of project programmes and applications for funding have been launched on basis of the PeBBu networking and project results.

A North European PBB State of the Art and the regional perception of R&D needs is summarised in this report.

The objectives for each of the four Regional Platforms are to stimulate and facilitate a maximal alignment between the international PeBBu activities and national research and dissemination activities concerning the development and implementation of PBB in the countries that participate in PeBBu, through:

- stimulation and facilitation of the programming of such national activities
- facilitation of the input of typical national and regional characteristics into the international programming of the international PeBBu activities
- preparation for future national PBB implementation activities, including the national dissemination of PeBBu results,

and in support of achieving those objectives:

- to initiate and facilitate the establishment of National or Transnational PeBBu Platforms in the region, which includes:
- support to defining the scope and objectives of such platforms
- support to the establishment of required financial support structures for such platforms in collaboration with the PeBBu Secretariat and aiming for international financial support from the EU and other international sources
- support to regional, transnational and national PeBBu related events.

Specific Scope and Objectives of the North European Platform are:

- To involve additional Members/Observers in the PeBBu Network from the following already represented countries: Sweden. Finland and Denmark
- To attract new PeBBu Members/Observers from the following, not yet represented countries: Norway, Latvia, Lithuania, and Estonia

Accomplished Workplan:

Workshops

The PeBBu North European Platform has in accordance with the Work Programme held three Workshops with different themes.

Workshop 1, Stockholm, 4 September 2003, focussed a review of each of the PeBBu Scientific Domains work programme and the so far reported State of the Art for each Domain. The scrutiny was based on specific North European perception and priorities. The Workshop gathered 13 delegates from Sweden, Norway, Finland, Denmark, Iceland, Estonia, and in addition UK (PeBBu central SotA reporting) and the Netherlands (PeBBu officers). The delegates mainly represented North European PeBBu membership but also commercial construction sector organisations and building materials producers.

Workshop 2, Stockholm, 29 October 2004, took the form of a thematic seminar/workshop with the chosen theme "Performance Based Procurement (PBP) – a way to meet end-user requirements", as PBP is a highly focussed and prioritised issue in the region. The Workshop had the ambition to mirror all aspects of Performance Based Building from the perspective of the design and procurement process. In addition the Workshop aligned with and included presentations on other ongoing PBB relevant projects and activities with clear anchoring in the region, e.g. a Nordic study on "LCC in building and construction", the Nordic perception of the implementation and further development of the CPD, the Nordic input and work with Lifetime Engineering Methods. The Workshop, co-arranged together with BIC (the Swedish Construction Sector Innovation Centre), gathered 22 delegates from 7 countries. The workshop concluded with a listing of Observations, expressed as Challenges and Opportunities.

Workshop 3, Helsinki, 10 June 2005, focussed specifically on establishing an agreed input to the PeBBu R&D Agenda. The 8 present delegates representing the northern region PeBBu members established the

basis for an R&D Agenda that also included identified challenges and opportunities for innovation and market implementation issues.

In addition to the above programme-scheduled workshops a number of national and Nordic meetings, seminars, and workshops have been held. Some main events are reported below:

- Information Meeting on PeBBu in general and Domain 1 in specific to Swedish market actors and stakeholders, 19 June 2002, Stockholm, Sweden
  23 national Swedish participants
- Workshop on "Performance Based Building – the road to satisfied customers?", 2 April 2003, Stockholm, arranged by BIC (the Construction Sector Innovation Center), Formas (the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning), SIS (Swedish Standards Institute) and PeBBu (Domain 1 and the North European Regional Platform). About 30 participants from Swedish industry and authorities
- Nordic Workshop arranged by the Nordic project on "LCC in building and construction", financed by the Nordic Industrial Fund, 10 November 2003, Stockholm. The workshop focussed environmental assessment, life cycle costing, the setting of performance requirements and key values, and gave important input to the PeBBu work
- Nordic Workshop arranged by the project on "LCC in building and construction", 10 – 11 May 2004, Reykjavik, Iceland. The workshop was targeted on Service Lives and Service Life Planning. The PeBBu D1 work was contributed
- Swedish/Finnish/Norwegian/Icelandic meeting in Stockholm on standards for life cycle aspects in building, life performance and service life planning, and LCC, 31 August 2004, arranged by SIS and University of Gävle. About 25 delegates from building research entities and standardisation bodies in the above countries, the ministries of environment in Sweden and Finland, companies and authorities.

Overview of the technical progress made during the reporting period

Membership

New Members/Observers were, during the project period, received from:

- Norway
- Iceland
- Estonia
- Lithuania; the member has not been active
- Sweden (industrial and standard institute observers)

National Platforms

Two national platforms have been organised:

- The Swedish National Platform is established via BIC (the Construction Sector Innovation Centre). The BIC network comprises some 30 Swedish member organisations, predominantly industrial but also R&D and authorities
- A Norwegian National Platform was organised during 2004. It is operated by the Norwegian Building Research Institute and the membership includes market actors, authorities and standardisation bodies

In Finland and Norway the PeBBu project has received input, and results have been disseminated via seminars and meetings arranged primarily on standardisation issues. Danish and Icelandic active participation in both PeBBu and other connecting projects, e.g. the Nordic Industrial Fund financed project "LCC in building and construction" and the EU-funded LIFETIME network, has meant effective cross linking.

Education and training

In Sweden PBB is highlighted in academic courses at KTH (Royal Institute of Technology) and University of Gävle, predominantly at courses focussing materials and building technologies. Training courses

targeting professionals (design engineers, builders, real estate managers, e t c) are being arranged by SIS (Swedish Standards Institute) during the autumn 2005. The training courses focus the performance-based standards ISO 15686 on Service Life Planning and are primarily an outcome of the work by PeBBu D1 Life Performance of Construction Materials and Components. A guidebook on the service life planning process and the use of the ISO standards has been published in Swedish. An English version is being printed as a co-operation between SIS and the PeBBu project and will be published by the SIS publishing house.

Main Results with supporting evidence highlighting the innovations:

The following highlights are, in condensed format, the main observations of the three Workshops scheduled in the Work Programme, and disclose a Nordic perception of the subjects treated.

PBB State of the Art and Nordic perception (Workshop 1)
The PBB concept is largely meeting an increasing interest in the north European region, but a coherent picture of the state of art and interest is not easy to perceive. A conclusion may be that the sector industry is in general showing active interest in realising possible benefits and opportunities by performance based building on an over-all perspective, but performance based concepts has generally not penetrated into daily business. In the Nordic countries the regulatory and juridical framework is largely adapted to performance based approaches. However, differences appear between the countries as well as between sub-sectors of building and construction within countries. The public sector, with road and railway management as examples, is a forerunner. Within the house building sector PBB has generally not been adopted. There is as well and generally a lack of understanding among market actors that a strive for "green solutions" or sustainable construction requires performance based approaches.

With the wide scope of the PBB subject there exists neither a common apprehension of what a PBB path involves in terms of barriers, challenges, and opportunities, nor a common view on priorities in terms of actions needed nor R&D needs.

The participants at the 1st North European Workshop, as a result of the performed scrutiny of the PeBBu project, expressed concern about the so far low participation by standardisation, regulatory and juridical bodies in the project.

It would be premature, with reference to the state of the national SotA's, to affirmatively conclude on national characteristics or differences in the north European region. However, some observations are:

- the Nordic countries Denmark, Finland, Norway and Sweden, are in general at the same stage of development, in spite of the fact that regulatory instruments and codes differ between the countries
- Iceland has ratified the Construction Products Directive but has not reached as far in regulatory adaptation as the rest of the Nordic countries.
- The picture of the state of art in the Baltic countries is largely missing, but input at the 1st Platform Workshop indicates that Performance Based Building is in a "cradle stage", even if being met with interest. However, in the area of load bearing structures the former eastern countries very early adopted structural codes based on a performance concept.

The PeBBu project and the issues addressed are being met with interest, even if there are difficulties to initiate true concerted actions within the national markets.

Performance Based Procurement (Workshop 2)
The Workshop concluded with the following Observations identified as Challenges and Opportunities, to Performance Based Procurement and Performance Based Building:

- The legal level is not seen as a main problem or barrier, rather the market issues and how to promote market implementation
  - provide good examples of Performance Based Building, establish well-documented demonstrators

- show economic benefits of Performance Based Procurement and Performance Based Building

- Utilise the momentum on the market, which on a European level, is there partly due to the CPD (Construction Products Directive) and the EPBD (Energy Performance of Buildings Directive, 2002/91/EC). The CPD implementation is vital, but
  - progress of instruments to support full implementation of the CPD on the market is too slow
  - resources are scarce for pro-active development of standards supporting the implementation of CPD and for marketing of existing standard approaches
  - pre- and co-normative R&D is not enough in focus, seemingly not at all by national funds and too scarce by the EU funding programs
- The role of clients; the competent and demanding client is a goal
  - focussed education and training programmes
  - educational material, handbooks, e t c
  - education and training is in general a vital issue and should be directed to all stakeholders in the building process
  - PBB should be given a strengthened role in relevant academic education
- Tools supporting approaches for Service Life Planning are needed
- Maintenance and operation issues are not specifically addressed at the moment, but need to be more pronounced in focus
- Present concepts for dealing with intellectual property rights hamper innovation in construction and hampers initiatives

North European view on R&D priorities (Workshop 3)

The North European Platform, in its analysis and prioritisation of R&D, chose not to focus solely on R&D, but sought in addition to identify apparent Innovation and Market issues, as is also shown by the concluding Challenges and Opportunities from Workshop 2. The following is a summary of the R&D Agenda and accounts also for the outcome of Workshop 3. The summary is basically structured following the PeBBu project organisation in scientific domains, which implies certain overlaps and repetitions of R&D needs, priorities and goals.

On a *General Level* there is a need for:

- handbooks on PBB, well-documented demo projects and case studies accounting for application and experiences
- evaluation tools for the entire building life cycle
- adaptation of information (simplification) to meet user demands
- dissemination and co-ordination of dissemination of information on PBB as part of a market creation
- verification tools
- improved communication between actors/stakeholders and users on the construction market
- mechanism and methods for the transfer of performance requirements and knowledge including verification tools between different users of information

On the area *Life Performance of Construction Materials and Components* there is a need for:

- modelling of performance demand and supply, relating the building level with functional subsystems and the materials/products level
- further development of and focus on the Reference Service Life concept. This should include information and training measures and campaigns, work on data base issues (formats, compliance with IFC standards, e t c), R&D-support to generate data and data quality, and guidance for modification of Reference Service Lives in a service life planning process. The necessary standards and other regulatory instruments are primarily at hand, but the implementation and data generation needs support.
- focus on standards and application of standards in the innovation process

On the area *Indoor Environment* the needs focus

- guidelines and tools for handling requirements, attributes, and solutions in the building process including threshold values for demand of replacement

- design tools
- quality assurance measures to secure a healthy building outcome through the building process
- evaluation tools for the whole building life

On the area *Design of Buildings* the needs focus
- application of IFC (Industrial Foundation Classes) standard approaches in the design process.
- agreed approaches for management of performance information, which should include defining performance requirements, comparing achieved design with requirements, accounting of service lives used in the service life planning process (to constitute e.g. the basis for maintenance plans and to handle a life cycle perspective)
- demonstration of benefits including demonstration of achievements, cost efficiency of PBB approach, traceability and verification

On the area *Legal and Procurement Practices* the needs and priorities are summarised as conclusions of Workshop 2 where the North European Platform also concluded that the Legal and Regulation issues are not considered to be a main problem or barrier, rather the market implementation of PBB.

On the area *Innovation the North European Platform* concluded with an identification of a number of problems and questions not per se expressed as R&D issues or goals.
- There seem to be a common understanding that Performance Based Building approaches stimulate Innovation. Can this statement be proven, and if so, what is the stimulation mechanism? An ability to show a number of well-documented cases and/or general proofs may serve as good promotion of PBB.
- Part of the construction sector industry, e.g. the contractors, invest close to nothing in R&D, which creates well known problems. Innovation, on the other hand, may be solely market driven and not always an outcome of R&D, but does normally when occurring have effects on R&D. May market driven innovation initiated by PBB approaches act also as a stimulus to increased R&D investments?

State of the Art:

Please refer to the summarising conclusions from Workshop 2 and the R&D Agenda (Workshop 3)

List of deliverables:

Additional to the objectives that were identified for the establishment of regional platforms, no specific deliverables were required. The objectives to align the PeBBu activities with national research and dissemination activities through
- stimulation and facilitation of the programming of such national activities
- facilitation of the input of typical national and regional characteristics into the international programming of the international PeBBu activities
- preparation for future national PBB implementation activities, including the national dissemination of PeBBu results, and in support of achieving those objectives to to initiate and facilitate the establishment of regional PeBBu Platforms in the region, which includes:
- support to defining the scope and objectives of such platforms
- support to the establishment of required financial support structures for such platforms in collaboration with the PeBBu Secretariat and aiming for international financial support from the EU and other international sources
- support to regional, and national PeBBu related events.

Besides these common objectives for all regional platforms, the North European Platform more specifically should:
- involve additional Members/Observers in the PeBBu Network from the already represented countries Denmark, Finland and Sweden

- attract new PeBBu Members/Observers from the not yet represented countries Estonia, Latvia, Lithuania and Norway

All the above objectives have been reached, with the exception of the identification and involvement of a participant from Latvia.

Dissemination and Implementation:

From the North European Platform, workshops and seminars have been organised, partly directly as a PeBBu activity, partly in terms of thematic contributions to other seminars and workshops. A very prominent link to European and International standardisation activities in the field of Service Life/Life Performance and Sustainability in Building Construction has been established and strengthened. Based on the network, numerous project proposals have been initiated, both on EU, trans-national and national level.

With the established network in place, and the increasing contacts due to new project ideas in the thematic field, the momentum existing in the Nordic Region is intended to be used for increased cooperation on topics related to performance based building.

Assessment of European Interest

The PeBBu regional platforms have, among their objectives, had the role to seek to capture the perception and state of the art of PBB in their respective regions. The north European region reflections on these aspects are mirrored in this report. Performance based building approaches in building and construction are considered to be a prerequisite for market development including the necessary harmonisation of codes, regulations, and standards, an improved or true innovation climate and process in building, and to reach sustainable construction goals. It is, however, noted that the market penetration of PBB is slow. It is a common opinion of the PeBBu North European Platform network that the PeBBu project, and its regional focus platforms, has provided a useful mechanism to highlight the challenges and opportunities of PBB. The European interest in PBB approaches and development is pretty well and consistently documented in EU and national regulation and R&D priorities. It is important that the process of stimulating and focussing the performance based route in building and construction does not conclude with the ending the PeBBu project. The examples of national platforms set up in the north region will have a responsibility to stimulate further work, but coherent European programmes focussing the area are recommended. The focus should be on shaping the stimulus mechanisms for real market penetration.

Expected Impacts (European or world-wide)

The expected European impacts are sketched in the text above, and it is not perceived that the world-wide impacts would markedly differ. It is, however, important to take in to picture the experiences with PBB codes that are appearing in other parts of the world, e.g. New Zealand.

Management and co-ordination aspects:

The North European Platform has successfully achieved the project objectives.

Key persons to contact for project follow-ups are:

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Conclusions:

Please refer to the summarising conclusions of the Workshops and the input to the R&D Agenda presented above.

Acknowledgements:

The North European Platform gratefully acknowledges the active work from the PeBBu member and observer organisations, and all the contributions by companies, standards organisations, and authorities in the networking. Warm thanks goes to the Construction Sector Innovation Center (BIC), Sweden, and the Nordic project "LCC in building and construction" for co-arrangement of several successful events.

Publications:

Skarendahl, Å., Sjöström, Ch., *A Swedish National Platform on Performance Based Building,* PeBBu News Article, April 2004

Sjöström, Ch., Lair, J., *Performance Based Building – Some implications on Construction Materials and Components,* proc. of the 2nd Int. Symposium on Integrated Lifetime Engineering of Buildings and Civil Infrastructures, ILCDES 2003, Kuopio, Finland, December 2003

(This article focuses primarily the Domain 1 work, but also introduces the complete PeBBu project)

Sjöström, Ch., Caluwaerts, P., Jernberg, P., Haagenrud, S., Ilomäki, A., Davis, H., *Product Declarations with respect to Durability – A progress report,* 10DBMC International Conference on Durability of building Materials and Components, Lyon 2005

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Trinius, W., Sjöström, Ch., *Service Life Planning and Performance Requirements*, Building Research and Information (March-April 2005) 33(2), 173-181

Trinius, W., *Modules of Environmental Assessment related to durability and service life*, 10DBMC International Conference on Durability of building Materials and Components, Lyon 2005

ANNEX XI: STATE OF ART SUMMARY REPORT FOR TASK 14: REGIONAL PLATFORM WEST AND CENTRAL EUROPE

Task Leader:

ir. Luk Vandaele, Belgian Building Research Institute, Belgium

Task Members:

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Task Website:

http://www.pebbu.nl/maincomponents/regionalplatforms/regionalplatform2/

Scope and Objectives:

The specific objectives for the Regional Platform are:

- To stimulate and facilitate a maximal alignment between the international PeBBu activities and national research and dissemination activities concerning the development and implementation of PBB in the countries that participate in PeBBu, through:
  - Stimulation and facilitation of the programming of such national activities
  - Facilitation of the input of typical national and regional characteristics into the international programming of the international PeBBu activities
  - Preparation for future national PBB implementation activities, including the national dissemination of PeBBu results, and in support of achieving those objectives.
- To initiate and facilitate the establishment of National or Transnational PeBBu Platforms in the region, which includes:
  - Support to defining the scope and objectives of such platforms
  - Support to the establishment of required financial support structures for such platforms in collaboration with the PeBBu Secretariat and aiming for international financial support from the EU and other international sources
  - Support to regional, transnational and national PeBBu related events.
- To attract new PeBBu Members/Observers from already participating countries in the region: UK, Ireland, The Netherlands, Belgium, France and Germany.
- To attract new PeBBu Members/Observers from the following, not yet represented countries: Switzerland and Austria.
- To provide input into the PeBBu website, in terms of data/information/news articles concerning national/transnational/regional PBB related activities and events.

Conceptual Framework:

No specific conceptual framework of PBB has been adopted by the Task. Reference is made to the conceptual framework as defined in the different domains of PeBBu.

Methodology and Process:

1. National reports
   National contacts were requested to draft a national report stating the state of the art on PBB in their country, regarding the PeBBu defined domains.
2. Platform meetings
   Two regional platform meetings were organized:
   - Brussels 30th September 2003
   - Delft 25th August 2005
3. Final report
   The final report summarizes the findings of the group and gives a synthesis of the PBB approach in the six countries involved in the regional platform.

State of the Art:

Critical overview of the technical state of the research

All members were requested to draft a National State of the Art report, reviewing the 9 PeBBu domain items from the national perspective. First drafts were circulated for only a limited number of countries. These reports were drafted each along its own format. Based on the first assessment of these reports, the Network Secretariat ordered University of Salford to come up with a common format and a synthesis. The guidelines for this common format were applied by some of the member countries in preparation of the first platform meeting.

During the first regional Platform meeting in Brussels on 29-30 September 2003, the following countries were represented: the Netherlands, United Kingdom, Ireland, France and Belgium. Germany was not represented and did not send any contribution.

The national contacts had been requested to invite one or two stakeholders from their country involved in a PBB action. Only Belgium responded to that opportunity with two additional persons.

Each national representative gave a review of the national state of the art on performance based building in his/her own country. The main conclusions from the national reports are summarised in the following subsections.

Background description of construction in West and Central Europe

There is a diversity of influential factors that make the construction sectors in the West and Central European countries quite different from each other. The organisation of the profession and the responsibility of the architect, the contractor, the project developer, …the regulation and control by the authorities, …can be very different.

One common great influence over the European construction approach is exercised by the Construction Products Directive ("Whereas performance levels and requirements to be fulfilled by products in future in the Member States shall be laid down in classes in the interpretative documents and in the harmonized technical specifications in order to take account of different levels of essential requirements for certain works and of different conditions prevailing in the Member States"). The interpretative documents give the six essential requirements (Mechanical resistance and stability; Safety in case of fire; Hygiene, health and environment; Safety in use; Protection against noise; Energy economy and heat retention).

These requirements are performance based.

Status of PBB in West and Central Europe

In most of the countries PBB is present in legislation and regulations, especially for some domains, more and more depending on the European requirements: fire safety, hygiene, health and environment (indoor climate), protection against noise, energy economy and heat retention (energy efficiency), accessibility.

Other requirements will be enforced in a performance way: mechanical resistance and stability, safety in use, etc…

PeBBu domains

Building materials & components

The products which are manufactured according to a standard, are supposed to have a certain life time. Standards are made for traditional construction products which have already proved to have a certain life time.

The technical approvals give an assessment of the fitness for use for new products and systems.

Where in a performance based approach, new materials and new applications for traditional materials are encouraged, technical approvals can often give the answer.

The technical approvals are based on performance based guidelines.

Also the standards are more and more performance based.

There is now a transition period in Europe: more and more harmonised European standards and European Technical Approvals are becoming adopted and these are the basis for the CE marking.

Indoor environment

A performance based approach for regulations for indoor air quality, indoor climate and energy efficiency is more and more common.

An interesting onset to PBB of mechanical ventilation systems was developed and applied in the European project Tip-Vent. The work depicts how the performance-oriented approach could be applied at the building, system and component level of a ventilation system, assessing both technical and process related issues. Furthermore, technological and process related improvements are proposed to support the implementation of performance-oriented approaches.

The REVIS research project developed a number of indices for the quality of daylight transmitting products. The idea was that novel daylight components in the building envelope can improve both the daylight quantity and quality in the interior and control the solar energy transmission. It was not possible yet to compare daylight transmitting products with respect to their capabilities to reach a deep distribution of daylight into the adjacent room and to prevent glare (comfort aspects). The overall objective of the project was to develop detailed daylight product information that is needed for a Europe-wide uniform comparison and selection of innovative products.

Noise regulations are in most cases performance based.

Building design

In some cases designers are using - in a limited way - the performance concept in the design phase of a building project. Contractors respond with a traditional descriptive solution for it. The benefit arises from the possibility to implement innovative solutions. When such a project has to be realised in an open tender procedure, the costs of submission deters the contractors.

In Belgium there exists a "Method for assessment of the quality of the housing design". The quality aspects are: dimensional performances, functional performances, technical performances, qualities of the environment and the economical performances.

Built environment

The countries are zoned in terms of purpose, for example residential, industrial/ commercial areas etc.

Building permits are required for all or most of the construction works.

The municipality can levy tax on some existing construction works for correction goals, i.e. as a measure against degradation of an area or as a pressure for moving of some activities.
Furthermore, long term thinking on urban planning has expanded beyond spatial considerations to the full range of themes associated with the built environment and, to some extent, their necessary integration. The more dominant themes to be considered are: Urban Planning; Transportation; Demographic trends; Waste Management; Environmental Impact Assessment.

Organisation & management

The easiest way to understand and elaborate a concept is through pictures. Photos, graphs, plans and drawings can make the briefing process clearer, more interactive and user friendly. Pictures, sketches etc., are means of understanding what the user requires. When presented with a visual representation, a client can envisage the impact and conflicts that may result from their requirements.

The goal is to provide enough input to allow and stimulate an overall and structured discussion around clients' characteristics, needs and requirements.

More and more an overall organisation and management urges itself, although not so much for individual houses.

Legal & procurement

There is a great difference between the private and the public approach.

In the private sphere there is much more liberty than in the public sphere.

The Public-Private Partnership (PPP) has been applied in several countries. The tender is based on performance based specifications.

This scheme involves a consortium consisting of financing bodies, designers, the builder and those who will manage the built facility in use for a period of 20 to 30 years.

In the UK, the government is experimenting with the "Occupier Brief". This brief is set up in the context of a DFBM (Design-Finance-Build-Maintain) contract with a consortium that has to deliver and maintain fully facilitated workplaces for the organisation to be accommodated. The Occupier Brief describes the quality level that the facility has to have on delivery, in terms of performance specifications. It has to be considered in conjunction with the so-called 'Output Brief' that describes the level of quality that has to be maintained during the period of use of the facility. The Occupier Brief sets the standards and requirements of performance of the spaces occupied by the client organisation.

The Private Finance and Investment (PFI) is in fact related to the PPP.

In Belgium the PPS is a newly allowed scheme of mixed public and private sectors for the procurement of social housing projects. These projects must be developed using the Performance based Technical Specifications for Social Dwellings (performance-based specifications for the building as a whole and for the different functional building parts)

"Vlabo" uses these specifications to realize 50 projects of 10 to 100 dwellings.

"Domus Flandria" used these specifications in the period of 1993 to 1996 to build about 10,000 dwellings via the Flemish Society for Social Housing (Vlaamse HuisvestingsMaatschappij).

In Ireland this scheme (PPP) involves a consortium consisting of financing bodies, designers, the builder and those who will manage the built facility in use for a period of 20 to 30 years. The facility is funded partially by the government with the remainder financed by the consortium. The consortium must also raise the funds to finance the running of the facility during its life time. As the consortium has such a long association with the use of the facility, the concept of a Performance Based Building model is thereby promoted.

In The Netherlands the "Building Decree" is a framework for all building activities and is completely performance based. The Building Decree is on the national level the administrative order with technical requirements. Compliance with the Building Decree is a condition to get a building permit. The Building Decree is also mandatory in the situation where a building permit is not required (permit-free construction). The practitioners (designers, building contractors, suppliers, consultants etc.) still have problems to really understand the content of the Building Decree.

In France, the public procurement of construction works is governed by a performance based reference document called "Code des Marchés Publics". Article 36 concerns the "performance based call for tenders" for all the markets of Local Authorities (including buildings), whereas article 37, dedicated to the design/realisation procedure, is specific to buildings. A codification of performance has been initiated in the 90', in order to offer a common language to all actors of construction according to the ISO 6241.

Building regulations

Building regulations are, especially for some domains, more and more depending of the European requirements, performance based: fire safety, hygiene, health and environment (indoor climate), protection against noise, energy economy and heat retention (energy efficiency), accessibility.

Other requirements will be enforced in a performance way: mechanical resistance and stability, safety in use, …

The Construction Products Directive (CPD 89/106/CEE), that aims at the facilitation of "free traffic of goods" within Europe, is in the EU countries the major performance based document, from which issue Harmonised European Product Standards and European Technical Agreements (European technical specifications). Nevertheless several regulations, procedures and guidance documents are still specific to the different countries. As far as possible these documents are now written in terms of performance approach.

The performance concept is accepted by the building industry as it is applied in building regulations and building standards. A weak point is how to formulate such specifications and how to prove the performances are met.

As a consequence of high level and abstract formulation of regulations, the building industry asks for handbooks or guidelines with solutions that are proven in practice and which fulfil the performance requirements.

Innovation

Innovation has been given an enormous push with the introduction of performance based legislation, especially for the domains: fire safety, hygiene, health and environment (indoor climate), protection against noise, energy economy and heat retention (energy efficiency), accessibility. The supplying industry, i.e. product development, already embraced the performance concept at an early stage. However, it was only when the building process, i.e. the building contactors, was confronted with the performance based legislation and was clarified the possibilities of PBB, that innovation became really possible.

Information & documentation

Research can only be profitable to the building industry, if it contributes to the improvement of the buildings' performances and efficiency with regard to the design and fabrication of the used materials and systems or the design and execution of the building and its environment.

The research results should thus be valorised by means of an optimal information transfer. The latter must take place on different levels in order to affect the definition of the performances and the possible ways to achieve them at the same time.

In the Netherlands Bris Store, a knowledge-based computer system, is developed and can be used stand alone, by intranet and by internet. Bris Store contains a comprehensive full text database of all documents pertaining to administrative and technical building regulations, including case law and private evaluation guidelines, including all links between elements of these regulations.

Other domains

Fire safety & engineering

Normally all countries have regulations for fire safety and engineering.

In Belgium the buildings are classified in types and each type is divided in:
1. Site and access roads
2. Compartmentalizing and evacuation
3. Requirements for some building parts
4. Requirements for the construction of compartments and evacuation spaces
5. Construction requirements for some premises and technical rooms
6. Equipment of buildings

These basic regulations define the minimum requirements for the interpretation, the construction and the equipment of buildings.

Accessibility

Accessibility for disabled persons to buildings accessible for the public.

Wheelchair toilet rooms and bathrooms are compulsory. Differences in height between floors and between ground level and the adjoining floor may not excess 2 cm. If so, a ramp or wheelchair lift is compulsory.

In Belgium the building permit is only given after verification of the fulfilment of the requirements.

Energy & water management

The European Commission (CEC) has published the Energy Performance Directive (EPD). This has to be implemented in national regulations by 2006. The establishment of a general framework of a common methodology for calculating the integrated energy performance of buildings in Europe is under preparation.

European directive 98/83/EC treats the quality of drinking water. Products for drinking water systems should be CE-marked in compliance with the CPD and the Drinking water Directive. Performance criteria, related to emissions are developed. The process of standardisation has been started.

Education & training

Courses and conferences for contractors and architects are more and more necessary.

Also the universities have more and more interest in a performance based approach for building constructions.

Intelligent buildings

Domotics and Immotics are made for everyone, particularly for those who want to find a positive evolution in their living and working conditions, in terms of degree of comfort, safety and accessibility, communication and easiness of use.

Design, construction and management of intelligent buildings, supplied with enough flexibility to adjust to new technologies, may not be improvised.

It demands cooperation of consultancies, contractors, maintenance specialists and other Facility Management.

Structural design & engineering

Eurocodes

Construction products directive (CPD)

Objectives of the CPD:
- European Internal Market for construction products by technical harmonisation.
- Construction products are fit for their intended use.
- Free circulation of goods in the European Internal Market.
- Competitiveness of European enterprises.

Proposed Research Agenda:

Within the PeBBu Domains Research Agendas have been developed. They generally have not been made available to the Regional Platforms. It is however assumed that these agendas, to a large extent, will state the research requirements for the specific domain, also at national level.

In this (concept) Research Agenda for the Regional Platform West and Central Europe, general keywords are used to refer to the Research Agenda for the specific domains. The point-of-departure is the Dutch situation. Considering the overlap parts may well be applicable to the other countries. This however does not account for the building regulations domain.

Domain 1 Building materials & components

At material and component level the issue of labelling will form an important aspect, also in relation to the CPD. Developments should be directed in a swift and sensible labelling system that fulfils the PB requirements of the end-users. It however should also take into account the wishes and possibilities of the suppliers.

Domain 2 Indoor environment

The Research Agenda for the indoor environment indicates numerous research items (basic and topical) that also account for the West and Central European situation. It is argued that a lot of the indicated developments have an overlap with the other domains and are required to bring the application of the performance based approach closer to its original intentions.

Qualification/labelling of buildings with respect to health, comfort, energy, etc. is a research item. I.e. these performance qualifications are used for promoting buildings.

Domain 3 Building design

Performance Based Design has been focussed at the evaluation of the performance indicators. However, design support to design to performance requirements is not yet very well developed. Especially support in the early stages of design (concept design) is important in combination with the integral performance evaluation.

The position of the end-user/initiator should be strengthened throughout the design, construction and use phase of a building. Performance guarantee, applying agreed on and objective criteria should be used for that.

Domain 4 Built environment

For the built environment similar remarks can be made as for the indoor environment and the building design. The complexity is found in the more difficult identification and conflicting interests of the end-user(s).

Domain 5 Organisation & management

Performance Based Building is only possible if the communication and information exchange is open and free. Organisation and management should be centred on this.

An important item to support this will be the documentation of all building related information in an open and clear structure, i.e. a blueprint of the building from initiation to demolition. It should at least contain information on the statement of requirement, criteria for evaluation of performance, evaluation procedures, actual solutions and evaluation results.

Domain 6 Legal & procurement

An overlap is found with the Building Regulations Domain in which some items are mentioned.

An important aspect for the introduction of PBB, from the legal point-of-view will be the agreed on evaluation/verification procedures for acceptance of results and for performance guarantee. In relation to that liability will be an important topic.

Domain 7 Building regulations

This is different from one country to another.

The first issue that should be taken up is a thorough inventory of all functional reasons for each PB requirement. This shall be done by historical research of each requirement. Furthermore, the leading research priorities are heavily weighted towards verification and "Verification methods". This is a theme that repeats itself in the discussion of performance based regulations. In order to verify compliance we need to be able to measure performance.

Process improvements

Role of certification; At the moment only product certification is recognised in the process of permit allowance. It might alleviate the process of permit allocation when process certification was allowed for the submitters of permit requests.

"Environment" permit. Several procedures for several permits, like construction permit, demolition permit, environmental permit and permit to use, have to be run to realise and use a new building. It is assumed that the combination of these procedures into one "environment" permit will alleviate the administrative burden and will strengthen the position of builder and future occupant.

Domain 8 Innovation

Developments indicated in the research agenda should have the improvement of innovation possibilities as the point-of-departure. This aspect is one of the driving forces for PBB.

Research in this area should be focussed on how to support and optimise innovation effort in building design and use.

Domain 9 Information & documentation

This domain is closely related to domain 5 Organisation and management.

Incentives for and barriers to PBB implementation:

Regulations should not be a barrier for innovative concepts.

For practical reasons, it is not possible that standard assessment procedures include all such new concepts. Therefore, alternative methods for assessing the performances of these concepts and technologies must be available.

Practices based on performance principles give generally satisfaction to the experienced users. But actually, the use of such practices is made difficult by the combination of four factors:

- The complexity of the construction (due not only to sophisticated technical choices but also to the multiple means to. The line between the domains of excellence of PBB and prescriptive approaches is not easy to draw but it should probably separate simple and "complex" projects, projects led by ordinary and "competent" clients, projects with low or important stakes.
- The importance of regulations. The motivation for an adoption of performance regulations is to open innovation and to allow “free” design. The regulation is also easier to update.
- The juridical uncertainties (feared due to the exceptionality of the practice).
- The building permit procedure which restricts the innovation.

The feedback from experience provided by field actors having experimented the performance based call for tenders reports that there is a transfer of work and time consumption to the contractors which they admit with difficulties, and the resulting price is generally higher than with a prescriptive approach.

Dissemination and Implementation:

It was proposed for each country to set up a national platform to foster the implementation of PBB. However none succeeded. This remains however a task for the national contacts to disseminate the results of the project at national level.

Conclusions:

A lot of national regulations and traditions/habits influence the way of thinking. Therefore, some diverging interpretation of the approach in other countries may occur. The platform meetings helped a lot in overcoming the barriers of understanding the national approaches.

ANNEX XII: STATE OF ART SUMMARY REPORT FOR TASK 15: REGIONAL PLATFORM EAST EUROPE

Task Leader:

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Task Website:

http://www.pebbu.nl/maincomponents/regionalplatforms/regionalplatform3/

Scope and Objectives:

The East European Regional Platform has been established in the participating EU and EU Associated countries to stimulate and facilitate the national PeBBu activities, to make an input of typical national and regional characteristics into the international programming of projects and to prepare for the necessary future national implementation activities.

Conceptual Framework:

The countries represented in the PeBBu Regional Platform from East Europe are Bulgaria, Czech Republic, Hungary, Poland and Slovakia. East Europe is a very special region of Europe due of its unique historical, political, educational, and economical conditions. In most of the East European countries, the concept of PBB is quite new and mainly present in regulation/legislation and/or research.

A major task of the Platform was the preparation of the **EEP Status Report** for the East European Regional Platform (EEP). The EEP Status Report is based on national reports and status in the countries.

The framework of the EEP work was based on **National State of the Art Reports**, PeBBu workshops, special PeBBu EEP workshops, PeBBu documents, Contribution of the PeBBu EEP members, Relevant literature and the scientific background of the task leaders.

Methodology and Process:

The East European Regional Platform of the PeBBu network held its **1st Workshop** in Budapest, 28th March 2003. The participants started to analyse the situation of the construction sector in their countries and the status of PBB. The task members prepared detailed National State of the Arts reports. The first version of the EEP State of the Art Report was prepared by the task leader with the contribution and comments of all partners. The Platform members had the **next discussion** of the Platform's work on the International PeBBu workshop in Manchester on the 13th of January 2004.

The Platform held its **2nd Workshop** also in Budapest, 8-9th July 2004. The national situations were presented and discussed focusing on the domains, new PeBBu tasks and on best practices of PBB. PeBBu opportunities after the EU extension were outlined, research mapping in the region and national platforms were discussed. On the meeting Romania was represented as observer. After the workshop the task leader prepared the 2nd EEP State of the Art Report with the contribution and comments of all partners.
The **3rd EEP workshop** was organised in the 11th and 12th of April 2005 in Bratislava. Special priority themes were defined and tasks related to them were discussed (housing; durability; energy; indoor comfort, recycling and renovation). Discussion was made about envisaged future implementation of PBB in the region, ideas, solutions, visions and actions. Best practice examples of PBB were also presented. Dissemination strategies were discussed and main action points were agreed.

The **4th and last EEP workshop** was organised in the 21st and 22nd of July 2005 in Sofia. On this workshop the task members presented the worked out priority themes defined on the Bratislava workshop. Further best-practice examples were presented and final PeBBu tasks approved. After preparing the "final draft" of the EEP Status Report, it was sent for commenting to all partners and also to the PeBBu Domain leaders. After integrating all received comments, the final version of the EEP Status Report was prepared during August 2005.

State of the Art:

The **similar historical background** after the 2nd World War of the countries that are members of the East-European Regional Platform of PeBBu determined the opportunities and the barriers of spreading the PBB concept in the region. All of the EEP countries belonged to the **former soviet block** and after the systems' changing went to a **transition period** with new kind of difficulties.

As regards the **general status of PBB** in the EEP countries**,** building activities are the **least performance-based among the PeBBu regions** but after the EU extension it is expected that also the introduction of the performance concept will accelerate. **In Bulgaria** the concept of PBB is quite new and mainly present in regulation/legislation and research. Most of the building codes and regulations are performance based and in the first stage of the building process stakeholders work with performance-based tools. However later in the process the strictly prescriptive detailed design allows only few possibilities for the contractor. **In Hungary** the performance concept is known from 1971 and several research projects have been directed to PBB. **In Poland** the idea of the performance concept has appeared in scientific consideration on the break of the 1980's/90's. Although the philosophy of the performance concept was carried from the Directive CPD 89/196/EEC to the Polish Building Code, practical implementation of performance demands remained away from the concept. **In Slovakia** since 1992 in the Building Code the requirements have been issued from the EEC Council Directive of 21/12/1988. The current research activities concerning the PBB are separated in particular fields of interest. The attempt to a more complex approach is reflected in the development and application of the methodologies of the energetic and environmental audits.

In the countries of the EEP in the construction practice the successful PBB usually depends explicitly on the **responsibility and possibilities of all decisive partners and on their quality**, but mainly on architect - client cooperation. The construction participants ordinary do not work in interdisciplinary teams and do not approach the construction in a wider context. The most important field, where the performance concept has been introduced is the **technical approval** of innovative products and related testing work. The most important fields, where further actions are needed are the design, procurement, budding and the control of the execution work in the platform's countries. Entering the EU in 2004 May, the **harmonization processes** in the region's countries become more and more intensive. **CPD** determines the codes and decrees in all countries. The base would be the nominated Institutes of the countries for notification, which can act as a bridgehead of PBB.

A more general application of PBB would have several **advantages and opportunities** in the countries of the EEP, like the stimulation of new materials, techniques and competition, better performance of buildings, reduction of cost and risk and failures, more freedom and less barrier in design, more correlation with users' requirements, etc. However, **strong barriers** are still against PBB. It is hard to achieve a breakthrough in habits joint to prescriptive regulations. There is a significant need for education and training and it takes a lot of time to become familiar with the performance-based approach. Other barriers are the lack of relevant indicators and testing methods, the lack of holistic life-cycle approach, the interest of producers, the financial barriers, the weak credit systems, the segregation and fragmentation of design, engineering and construction or the attachment to traditionalism and routine.

The **EU extension** can strongly influence many fields and so the construction sector in the countries of the EEP, most of them already member of the EU. **New opportunities and support of PBB** can be related to the free transfer of goods, services, information and people, more possibilities for innovations, more competitiveness, duty free prizes, more open society, European standardization, education and research support, minimisation of regional and social differences, etc. **Obligations** are another aspect that comes with the EU extension and these should be considered rather as opportunities. The necessity to **improve legislative framework** in the construction arise an excellent opportunity to implement the PBB approach. This opportunity could be very well detected in the widespread implementation and **success of CPD** in these countries. It is a strong believe of experts, that the **increasing competition** in the market will lead to a better understanding of performance based approach for the building industry.

Inter-relations with other Domains/Tasks:

Another related task of the EEP was a Status Report made for the NAS (Newly Associating States of Europe). The **NAS Status Report** provides many further PBB related information for these countries and focuses on status and the common features as a consequence of the common historical background and analyses the situation related to historical periods as the time of socialism; the transition period and the present time after the EU accession. Vision to the future and overall strategies of PBB implementation is also described in the NAS Status Report. Thus, the two reports complement each other and a complete overview of the status and future of PBB of the EEP/NAS countries is provided by the EEP Status Report and the NAS Status Report together. The task is inter-related with all PeBBu Domains and with the new PeBBu tasks, the issues of which is analysed in both the PeBBu EEP and the NAS Report with slightly different approach.

Proposed Research Agenda:

Nr.	RTD issue related to PeBBu Domains (D1-D8) and Priority themes (P1-P3)	Prio-rity	Related Domains & themes
I	D1: Life Performance of Building Materials and components		
I.1	Integrating **performance issues in quality assurance and in diagnostics** and renewing the building stock	I	
I.2.	Improving **durability and life performance** of building materials and components	2	P3
I.3.	Assessing impact of **energy-efficient measures** on the building structure	I	P2
I.4.	Benchmarking / finding relevant **LCC or LCA tools** for the NAS situations and organising a comprehensive database	I	
I.5.	Promotion of **local materials, methods and systems**	2	D7

1.6.	**Recycling / reusing** of building materials and components	2	P3
2	**D2: Indoor Environment**		
2.1.	Addressing issues of **ecological and healthy buildings** by performance criteria, improving indoor and outdoor air quality, indoor comfort and microclimate	1	
2.2.	Assessing impact of **energy-efficient measures** on indoor environment	1	P2
2.3.	Resolve conflicts between having a good **insulated** building and **efficient ventilation**	1	P2
2.4.	Resolve conflicts between **acoustic needs and other performances** (e.g. thermal conditions, visual comfort, etc.)	2	P2
2.5.	Database about **harmful as well as healthy** materials to be further developed	1	
3	**D3: Design of Buildings**		
3.1.	Approving **design solutions** and construction works on a performance basis	2	
3.2.	**Testing performance based design** and tools for comparing design solutions	1	
3.3.	Benchmarking / finding relevant **LCC or LCA tools for testing** how design solutions allow **adaptability and flexibility of buildings** in the NAS situations	1	D1
3.4.	Developing **Intelligent buildings** (BMS) and integrated systems (including monitoring and management of buildings)	2	
3.5.	Incorporating **safety aspects** of operation and maintenance in building design	1	
3.6.	Providing **higher architectural value** of buildings and the built environment and **evaluating** aesthetical / architectural quality	1	
4.	**D6: Legal and Procurement Practices**		
4.1.	**Demonstration models for better cooperation** of the stakeholders in the building process on the basis of higher performance achievement	1	
4.2.	Developing **efficient and reasonable safety systems** and relevant regulations	1	
4.3.	Integrating **and evaluating sustainability** issues in the legal and procurement practices	1	
4.4.	Providing a good balance between **real testing and simulation** of performance issues, developing tools for validation	1	
5.	**D7: Regulations**		
5.1.	Improving **building regulations on performance basis**, better understanding and defining of the economic impact of performance based regulations	1	
5.2.	Developing concepts for defining the **performance limits at certain** - traditional and widely used - **materials, technologies and structures** and create relevant performance targets, requirements and regulations.	2	D8
5.3.	Develop **housing regulations** for the NAS context to match with the housing regulation systems of the north/western European countries	1	P1
6	**D8: Innovation**		
6.1.	Developing **financial and institutional support systems** for stimulating innovation in building and construction	1	D6, D7

6.2.	Promoting the best practice examples and **demonstration activities**	I	
6.3.	**Developing regional networking** to promote innovation	I	
7	**P1: Housing**		
7.1.	Developing tools and methods for improving **housing affordability**	I	D6,D7,D8
7.2.	Improving the **complex performance of housing projects** (regarding flexibility, privacy, accessibility, energy-efficiency, durability, sustainability, mobility, safety and security, value of use and aesthetics, etc.)	I	All
7.3.	Developing new programmes and systems for sustainable **social / non-profit rental housing**	I	D6, D7
8.	**P2: Energy**		
8.1.	Improving thermal performance, **energy-efficiency and water management** in building	I	
8.2.	Further research on **renewable sources of energy** to find cheaper, reliable and efficient solutions	I	
8.3.	Increasing awareness via **pilot projects** of demonstrating the use of renewable energies (heat pump, solar, PV, bio-gas)	I	
8.4.	Informing clients / users about **energy-efficient solutions** and promoting them to use	I	
8,5,	Making a **road map** for the coming 10 years for **increasing the energy performance**	2	
8.6.	Wider implementation of **heat recuperators**	2	
9.	**P3: Renovation and Recycling**		
9,1,	Improving techniques and organisation of **construction waste management**	I	
9.2.	Developing **new recyclable materials as well as materials from recycled raw materials.**	I	D1
9.3.	Improving system for **non-destructive diagnostic methods**		
10.	**General issues (Cross-cutting)**		
10.1.	Developing and applying new **methods of measurements, testing and verification** and appropriate **indicators** related to complex performance issues	I	
10.2.	Further development of performance related methods, technical solutions and regulations in **structural engineering** and **fire safety engineering**	2	D1
10.3.	Improving the **sustainability of urban environments** and settlements	I	
10.4.	Addressing performance criteria of **life-cycle issues, durability, adaptability and maintenance** on a higher level	I	D1, D3, P3
10.5.	Developing decision support toolkit to **assess the building condition with regards to it's future**: to assist decision-making regarding demolition contra renovation of buildings (including condition of materials and structures, space, user needs, real estate value etc.)	I	D1, P3
10.6.	Creating conditions for making **flexible, adaptable designs and improving functional performances** (open design) via appropriate regulations, education of building professionals,	I	D3, D7

	informing users/clients		
11.	**Other issues**		
11.1.	**Whole-Life Education** of PBB ideas for all building and construction students and professionals	1	
11.2.	Teaching **PBB principles from primary school level**	2	

Barriers to PBB implementation:

Several **common barriers** were defined in the EEP countries partly related to the time of socialism and others related to the transition period. Some of the barriers has national feature but most of them has rather a regional character. The EU extension provides new opportunities also for PBB in these countries, but some new barriers can emerge as well.

The strong barriers of the artificial social, political and economical system **before 1990** had a consequence of overall poorness comparing to the western countries. As regards the practice of construction, mass production of high rise concrete block houses, the low wages of architects and professionals, the ad hoc improvisation character and low quality of execution, the domestic feature and low quality of the building material industry all worked against the Performance Based approach. Lack of row materials and building products were general. The Standardisation process was based on opportunities of East-European cooperation, user requirements were not considered.

After the collapse of the soviet systems **in the transition period** privatisation of the domestic building industry was rather fast and international big companies became new owners and realized large investments. These International companies basically make their research and development at the home country, and rarely invest in research in the new countries. SMEs became dominant in the design and engineering practice. The state withdraw from the building market, housing subsidies was dramatically cut, state investments became rare and low budgeted, inflation was dramatically high (over 30 %). As a consequence, building industry has been declined. Ministries responsible for the building sector were ceased and the responsibility for the sector spread to several other ministries with the consequence of inefficient problem solving. There is a great backlog in building maintenance and retrofitting. The segregation and fragmentation in building construction industry and the traditional approach to build as cheap as possible makes a rather great increase in building failures, basically in the residential sector, where the builders are mostly not professionals. Housing promotion is very low in all countries, the majority of the new dwellings are still built in do it yourself practice or by black workmanship. Black market is very high in the building products field as well, partly due to the relatively high VAT.

The conservatism of the construction sector doesn't promote innovation and change. Best Practice examples are not directly related to performance, and as investment in building is risky, lot of inventor want to rely rather on proved and safe solutions. There is a low demand for the construction work in the domestic market. Smaller enterprises have no financial reserves and neither bank credits are available for them, which causes a high risk in surviving. The consequence is the decrease in the competitiveness in the construction market. Another special barrier is that older generation suffers from lacking speaking ability in foreign languages, English is very rarely spoken by the generation older than 40 years. That makes a strong barrier in implementing PBB materials not in domestic language.

Some new barriers can emerge with the **EU extension**, like market deformations (temporary), the influence of strong interest groups, cartel agreements among producers, State budget deficit restriction, new tax policies, etc.

Incentives for PBB implementation:

Concerning the **envisaged future implementation of PBB** in the Region, in general only some participants of the construction design process are aware of PBB importance in practice. The construction

companies formulate the need of PBB as the need of the complex quality of construction, which should be provided by the quality management. The barriers of wider PBB application in practice are seen in the cases when the particular construction participants do not consider the construction and its results as one complex system. The liability and responsibility is supposed to be a dominant factor enhancing the PBB. The increase of the education and knowledge level and the level of a systemic approach in the construction process are also fundamental conditions. The role and the quality of an architect is fundamental in the environment where the main criteria of a client's decision-making has economical character.

Strategies for a wider PBB implementation:

In EEP countries can be developed on the bases of the State of the Art analysis. Related to the issues of building materials and techniques, improving durability of constructions, developing new materials and techniques and increasing the use of local materials are priority aims. In the energy domain it is important to improve the energy-efficiency of buildings, to implement Energy Performance Directive, BEM and Building Energy Pass. The domain of indoor environment should have high priority. Regarding building design and the construction process, it is important to increase the level of cooperation, communication and tenant/user participation in decision-making during the whole construction process on performance bases. Further aims are to increase environmental sustainability, to develop and apply quality management and environmental management systems, to develop and apply efficient Decision Support Systems, to improve the transparency of tendering and to apply Post-Occupancy Evaluations. As regards legal & procurement practices and regulations main strategies are to develop national Standardisation processes and building regulations on performance bases, to work out efficient and more responsible construction and housing policies, to increase the quantity and quality of residential buildings and to develop complex programs for building renovation and urban renewal. Concerning innovation and R&D, governments should increasingly promote this domain. Priority issues are to develop performance indicators, measurement, testing, monitoring and simulation tools and efficient control systems of technical and environmental performance and architectural quality. Some strategies related to social and economic aspects are to implement efficient housing subsidy systems, to decrease financial barriers of construction, to increase the availability of bank credits and to develop the methods of building insurance. Other priority issues are to spread the concept of intelligent buildings, to improve the visual/architectural quality of buildings and the built environment, to integrate PBB thinking in education and training and to take benefit from the dynamic building industry.

Dissemination and Implementation:

National Platforms:

- (ÉMI npc has started to establish a PeBBu National Platform with different stakeholders)

Education and training:

- PBB education in the university courses PBB in training activities organised in the countries (e.g. in ÉMI).
- Summer school for young research scientists (PhD students and young doctors) to exchange experiences and to establish new research teams

Conferences and workshops:

- various national and international conferences and workshops organised partners' institutes
- national and international conferences and workshops with participation of PeBBU task members
- meetings of other EU supported projects organised in the EEP countries

Publications:

- Magazines and technical journals dealing with building, architecture and design

- National report send to key institutions responsible for building sector Web publications on web-sites well-known by architects and civil engineers web-sites managed by the EEP task membersCIB publications.

Conclusions:

In conclusion, the importantce of the Regional Platforms was clearly showed on the various PeBBu workshops and events. The national situation of the EEP countries show similar characteristics and problems of the countries in the region partly originated from regional, climatic factors and partly from the similar historical backgrounds. Relatively small number of best practice examples of PBB can be seen in the region and still plenty of barriers are against PBB. The EU extension has a significant positive effect on PBB in the region. Obligations are an important aspect that comes with the EU extension. Dissemination of the PBB concept and raising the awareness of it is important in all countries of the region. National PeBBu Platforms would be important to develop in order to raise the awareness of PBB and overcome the barriers of languages in the participating countries.

ANNEX XIII: STATE OF ART SUMMARY REPORT FOR TASK 16: REGIONAL PLATFORM MEDITERRANEAN EUROPE

Task Leader:

Paolo Cardillo

Task Members:

Paolo Cardillo (ITC-CNR - Italy), Giuseppina Varone (ITC-CNR - Italy), Rachel Becker (Technion – Israel), Monica Paciuk (Technion – Israel), Eduardo de Oliveira Fernandes (FEUP University of Porto – Portugal), Kyriakos Papaioannou (Aristotle University of Thessaloniki – Greece), Pilar Linares Alemparte (Ietcc – CSIC Spain), Vlatko Bosiljkov (ZAG – Slovenia), Friderik Knez (ZAG – Slovenia)

Task Website:

http://www.pebbu.nl/maincomponents/regionalplatforms/regionalplatform4/

Scope and objectives:

- to stimulate and facilitate a maximal alignment between the international PeBBu activities and national research and dissemination activities concerning the development and implementation of PBB in the countries that participate in PeBBu, through
- stimulation and facilitation of the programming of such national activities
- facilitation of the input of typical national and regional characteristics into the international programming of the international PeBBu activities
- preparation for future national PBB implementation activities, including the national dissemination of PeBBu results

Conceptual Framework:

The work of Regional Platforms was conceived to gather useful and available information and to contribute to the research activity of the Scientific Domains. To this end, it was first of all necessary to outline the State of the Art of each country represented within the Mediterranean Platform. The discussions and exchange of views which took place among each country's experts during the three Platform Workshops, allowed to outline at first the affinities among Mediterranean countries, then those blind areas that need further research as a priority. The last phase of the work was specifically aimed at the definition and finalization of a Regional RTD Agenda where, under the heading of each Scientific Domain of the project, future needs for research and development have been listed by outlining the topics that are specifically critical and relevant to the Mediterranean area.

Methodology and Process:

During the four years of the Project, three Workshops of the Mediterranean Platform were held:
Milan, 19th September 2003 - Minutes

Milan, 17th September 2004 - Minutes
Rome, 8th July 2005 Before the first two workshops of the Mediterranean Platform, each partner of the Platform produced a national State of the Art report which were then discussed during the meetings and were used to outline the topics of the South-European Region. The results were summarised in two Regional State of the Art reports. As a final result, during the last meeting, the Mediterranean RTD Agenda was elaborated and finalised before being circulated to the Domain Leaders.

All documents produced, as referred to above, can be found on the PeBBu website.

State of the Art:

The South European Platform, bringing together Italy, Spain, Israel, Portugal, Slovenia and Greece held two Workshops in Milan in September 2003 and September 2004 and one in Rome in July 2005.During the two meetings the discussion about the national State of the Art of the six countries represented in the Platform underlined some essential aspects of the performance approach that can be associated with the Mediterranean context, namely:

- influence of diversity factors with the other European Platforms;
- major scientific areas to be carefully dealt with within the Mediterranean countries.

It is quite evident that the main diversity factors with respect to other European countries are, generally speaking, of a climatic, geographic and socio-cultural nature.

It is also clear that not all the subjects falling within the scope of PeBBu are affected in the same way by the above factors that may sometimes come into play all together.

The performance reference to climatology, the great variability of geographical conditions and the diversified natural and "traditional" anthropized habitats becomes explicit when dealing with issues related to the first two macro-areas **Building Technique and Building Design.**

It must be here underlined that the modern built-up environment has been entirely aimed at growth, which caused those huge unbalances of cultural, geographical, material, energy resources that so strongly contributed in determining the present conditions of environmental degradation that has now become almost irreversible.

The performance approach philosophy broadens the field of investigation in order to take in as many players and actors as possible to take part in the building process, therefore becoming the most suitable tool to solving problems also in more specific realities, even if there are still many obstacles on the way to its full implementation.

Over the last decades many theories and modellings have been elaborated, among which it is worth mentioning the environmental performance indicators allowing to measure performances of an organization. In particular, OECD - Organisation for Economic Co-operation and Development, has developed an international scheme known as Determinant Forces – Pressure – State – Impact – Response (DPSRI), whose simplified variation Pressure – State – Response is also known as (PSR). An interesting application to sustainable urban planning is at present under way in Portugal, as described by Eduardo de Oliveira Fernandes from FEUP (Portugal) in his news article titled "Performance Indicators for Sustainable Urban Planning", which is published on the PeBBu website.

The performance approach to the **building regulations** has suffered a certain delay with respect to the other EU countries even if the most recent legislation of all the Mediterranean countries is permeated with this concept. In this context, the factors of difference with other countries are mainly linked to the culture and tradition of the concerned countries and to their geographical position. In the first place, Mediterranean towns have an extremely rich historical and architectural heritage which needs preservation and very often this need becomes an obstacle to the performance concept.

The main novelty of the last years concerns the need to make a legislation which is restrictive and limiting coexist with a performance-based legislation. An evident example is fire legislation where, following the spreading of calculation tools and fire simulation models, the prescriptive regime is now shifting towards a system that in the future will guarantee the first performance-based applications. At present, in Europe, the performance criterion has not yet been codified since it proved to be objectively hard to find the right balance between specific needs of preserving cultural resources and the measures to be taken to protect the right to safety.

Due to its geographical location, the Mediterranean area is extremely vulnerable to seismic risks. As a matter of fact, over the last twenty years, seismic engineering studies have made great progress, which is synthesised in the different sections of Eurocode EC8, which will make the basis for the future seismic regulations of the European Union member states.

EC8 served as a basis for the drafting of the new Italian standards whose main feature is the shifting from a prescriptive to a performance-based approach.

Essentially, it is no more question of applying more or less complex design, analysis and verification rules that are often used with no awareness of the objectives of the project. It is rather question of starting from objectives and from the precise statement of the performances the building structure must ensure and of the requirements needed to achieve such performances, up to the formulation of criteria and rules targeting these objectives. In particular, it is specified that: "The purpose of standards is to guarantee that in the event of an earthquake, human life be protected, damages limited and the main facilities to be used for the intervention of civil defence teams be fully working".

Also in Slovenia the discussion about the new approach to seismic regulations is very lively.

The news article by Vlatko Bosiljkov and Matei Fischinger from ZAG (Slovenia), titled "Earthquake Related Performance-based Engineering", published on the PeBBu website, relates about the outcomes of an international congress held in Slovenia in June 2004. To sum up:

Advanced experimental facilities have become available worldwide; for example, NEES, E-Defense, JRC, NCREE, etc. Experiments on complex structural systems at larger scales become more practicable; they provide great opportunities for more accurate characterisation of various limit states of structures and ultimately for accelerated enhancement of PBEE. New experimental facilities, techniques, and devices require new approaches to research and development.

CPD - Construction Products Directive 89/106

The CPD raises many uncertainties in manufacturers, professionals and building contractors and in users themselves who are not sufficiently informed about the meaning of "EC marking".

For instance, manufacturers complain about the inadequate definition of methods to be used to assess the compliance with the requirements of the Directive which, for certain products, provides for the introduction of new tests that have not been envisaged so far by the relevant product standards.

Also professionals and building contractors have their own doubts on the subject of the CPD: even if they are not directly involved in the EC marking, professionals play an essential role in the construction process of a building and by virtue of their responsibility they claim for an inspector to supervise the works in progress since they are aware that the EC marking alone can not guarantee the final quality of the construction work.

On the other hand, building contractors demand homogeneous assessments throughout the different member states: have certification, inspection and testing bodies been notified following the same parameters? Will the controls of the whole EC-marking process and market control be carried out following the same criteria?

Best Practice

An excellent example of Best Practice was presented by Rachel Becker and Monica Paciuk from Technion (Israel) in their news article published on the PeBBu website. The article illustrates the new building of the Faculty of Civil and Environmental Engineering at Technion, which was built following a performance-based approach that could be evidenced both at programming and building stages.

Proposed Research Agenda:

DETERMINANTS OF THE MEDITERRANEAN REGION:

- climate - geography
- people - culture
- technology - knowledge

Objectives:

- To specifically pinpoint future research and development needs on Performance-based Building in the PeBBu Mediterranean Platform
- To take into account among the main determinants of the built environment: climate / geography, people /culture, technology / knowledge

Domain 1 - Life Performance of Construction Materials and Components:

1. Life Cycle of Building Materials and Elements
- Identification of factors affecting deterioration or failure.
- Prediction of life cycle based on accelerated tests.
- Impact of repair and maintenance operations.

2. Behaviour of Building Materials in Mediterranean Climates
- High strength concrete.
- Cladding systems: natural stone, renderings.
- Clean materials.
- Identification of factors affecting deterioration or failure.
- Variation of hygrothermal properties of insulating materials due to moisture accumulation.
- Deterioration of concrete as a result of chloride ingress and carbonation permeability.

3. Labelling of Clean Materials
- Promotion of national/European labelling systems.
- Integration in the CPD objectives and targets.

4. Construction Waste
- Quantification of waste generated in construction sites.
- Minimization of construction waste.
- Feasibility, environmental and economic aspects of recycling and reuse of construction waste .
- Recycled aggregates for concrete.
- Disposal of construction waste.

Domain 2 - Indoor Environment:

1. Human and Engineering Factors
- Mutual effects and integrated aspects of human comfort (spatial, functional, thermal, visual, acoustic, indoor air quality).
- Global user satisfaction indices.
- Consideration of the adaptive comfort model for the non air-conditioned buildings or historical buildings.

2. Indoor Air Quality
- Development of performance criteria based on cost/benefit analysis.
- Link between indoor air quality and ambient air (critical in the Mediterranean context).

- Ventilation management for proper indoor air quality.
- Use of clean materials.

3. Risk Analysis & Optimization
- Methodologies for optimal design accounting for risk and life-cycle cost.

4. Infrastructure for the Implementation of Performance-based Regulations
- Re-organisation of the regulatory design approval process.
- Computerized design platforms for overall performance-integrated CAD.
- Methodologies for the evaluation of building performance.
- Design tools for the implementation of performance-based code requirements.
- Auditing methods and practices.

Domain 3 - Design of Buildings:

1. Human and Engineering Factors
- Mutual effects and integrated aspects of human comfort (spatial, functional, thermal, visual, acoustic, indoor air quality).
- Global Mediterranean user satisfaction indices.
- Universal design and accessibility.

2. Design Process / critical methodology for the Mediterranean buildings

3. Infrastructure for the Implementation of Performance-based Regulations
- Re-organisation of the regulatory design approval process.
- Computerized design platforms for overall performance-integrated CAD.
- Methodologies for the evaluation of building performance.

4. Risk Analysis and Optimization
- Methodologies for optimal design accounting for risk and life-cycle cost.

5. Performance Specifications for Special buildings
- Underground construction for regular and special occupancies.
- Intelligent buildings.
- Tall buildings.
- Office buildings with innovative workspace arrangements.
- Historical buildings.

6. Thermal and Energy Performance of Buildings
- Requirements for spaces with special occupancies (schools, dwellings for challenged people, protected living for the elderly, hospitals, etc.).
- Special design solutions/features geared toward energy efficiency and use of renewable energies. Architectural and engineering integration.
- Monitoring and evaluation of demonstration projects.
- Bioclimatic design.
- Transmittance of thermal bridges.

7. Indoor Air Quality
- Development of performance-based criteria.
- Design tools for the implementation of standards.
- Specification of clean materials.
- Interaction between different systems of ventilation (natural ventilation, a/c, kitchen exhaust, opening for combustion air, smoke control, etc.).

8. Building Acoustics
- Effects of architectural layout on acoustic comfort.
- Conflict between acoustical needs and natural ventilation requirements due to the specific Mediterranean cultural context of urban areas (more noisy).

- Noise propagation through ventilation shafts.

9. Sustainable Construction
- Performance-based methodology for sustainable building design.
- Implementation guidelines for various building occupancies.
- Short term and long-term cost/benefit analyses.

10. Fire Safety Engineering and Evacuation Measures
- Integrated performance approach in the design for fire safety.
- Fire safety performance in existing and historical buildings.
- Evacuation of challenged people.
- Human behaviour and orientation in complex buildings.

11. Earthquake engineering
- Performance-based methodology in existing and historical buildings.

12. Protection against dampness
- Verification method to assess dampness in the building envelope.
- Windows behaviour to water penetration according to wind exposure, height, etc.

13. Waste disposal
- Waste production in buildings other than residential.

14. Protection against radon
- Building solutions (concrete and brick systems) able to provide adequate protection.

Domain 6 - Legal and Procurement Practices:

1. Customized Design-Build Contracts
- Build – Operate – Transfer.
- Build – Own - Operate – Transfer.
- Privately Financed Initiatives.
- Public – Private Partnership

2. Conflict Resolution Mechanisms for Construction Projects

3. Accreditation of Construction Professionals
- Architects and Engineers.
- Contractors.
- Foremen.
- Manual workers, etc.

Domain 7 – Regulations:

1. Infrastructure for the Implementation of Performance-based Regulations
- Re-organisation at the regulatory design approval stage.
- Re-organisation at the entrepreneurship and contracting levels.
- Re-organisation at the planning and design stage.

Domain 8 – Innovation:

1. Value – Analyses of Construction Projects
- Development of methodologies.
- Development of systematic tools.

2. Life –Cycle – Cost Analyses
- In complex situations.
- For multiple stakeholders.

3. Integrated Management of Quality, Safety and Environmental Protection in Construction
- Direct and indirect costs and benefits.

4. Public Policy for Construction and Housing
- Long-term planning for human resources.
- R & D needs.
- Technological advancement.
- Land use and re-use

Incentives for PBB implementation:

- More information at all levels of the building process
- More appropriate training of the professionals involved
- More clarity at legislative and regulatory level
- Clearer definition of responsibilities

Barriers to PBB implementation:

In general terms, the main barriers to the implementation of the Performance concept in building are well illustrated by the Israeli situation.

The main barrier for strict adoption of solely performance-based regulations is the reluctance of designers and builders to accept responsibility for explicitly defined consequences. In general many of them prefer regulations that define accepted solutions (Descriptive Approach), as compliance can easily be proven by the presentation of detailed drawings and construction brief. To prove compliance with performance-based regulations, calculations and/or laboratory certificates must be added, a fact that usually implies a larger working load for the engineers on the design team. In addition, checking compliance requires more skilled personnel. The shift from solely descriptive regulations to the adoption of mandatory Performance Requirements Standards thus encounters some difficulties at the design stage (mainly due to lack of knowledge amongst professionals in some areas of building physics), as well as in the enforcement stage (mainly due to lack of skilled personnel at the local municipalities).

In addition to that and with reference to the other countries, further barriers are:
- Needs of fire prevention and seismic risk of the historical and architectural heritage often collide with the performance approach
- Uncertainty about risk and liability
- Professionalism of the client
- Fear of undermining architectural profession
- Most important quality aspects cannot be formulated in terms of performance

Dissemination and Implementation:

During the last year the Platform contributed to the dissemination of PeBBu results through news articles published on the PeBBu website.

An important point of discussion within the Platform, in agreement with the PeBBu Programme Manager, was the preparation of a dissemination plan at national and European level.

This dissemination plan envisages the following:
- at European level, Workshops and news-articles;

- at national level, translation in each country's language of the PeBBu results and their publication on specialised reviews and newsletters of the building sector and, most important, information and communication destined to specific professional associations (architects, engineers, constructors, users, etc.) in order to reach all the actors involved in the building process and to fill all gaps related the knowledge about the Performance concept which is still evident in some specific building categories.

Conclusions

With regard to the Mediterranean Platform, the work carried out throughout the whole Project led to the drawing up of a Mediterranean RTD Agenda which was discussed in detail and finalised during the last Platform Workshop meeting held in Rome in July 2005.

On the basis of the specific differences of the Mediterranean Region with reference to the other European Regions (climate-geography, people-culture, technology-knowledge), the Regional RTD Agenda defines a list of research needs related to each Domain, deemed to be a priority for the South-European Region.

ANNEX XIV: STATE OF ART SUMMARY REPORT FOR UP1: USER PLATFORM 1 - BUILDING OWNERS, USERS AND MANAGERS

Task Leader:

Dr. Tim Yates and Dr. Josephine Prior, BRE, United Kingdom

Task Website:

http://www.pebbu.nl/maincomponents/userplatforms/userplatform1/

Scope and Objectives:

The specific objectives for each of the three User Platforms were:

- To engage high level representatives of actual PBB stakeholders in decision making on the programme as to be performed by the PeBBu Network and in the evaluation of the results of this programme
- To stimulate and facilitate input of the PBB actual stakeholders opinions into the programming and execution of international PBB related research and dissemination projects during all stages of the PeBBu Network programme.
- To prepare for the respective stakeholders support to future implementation activities.

The User Platform was also available to make incidental responses at the request of the Network Secretariat to selected strategic network documents, for which the inclusion of the respective stakeholders opinions wa important, including in particular:

- Strategic programming documents per PeBBu Domain
- Definition of the needs for research as to be included in the structure for the PeBBu Mapping activity

Within the work plan of the User Platforms, two workshops were envisaged during duration of the PeBBu Project. The first of these workshops was planned for the 2nd of October, 2003 in Brussels, Belgium. However, this was postponed (see below). As a result of this cancellation it was decided to develop a questionnaire as an alternative approach and so the second workshop planned to take place in the first half of 2005 was cancelled and a presentation on the questionnaire made at the CIB Conference in Helsinki.

Methodology and Process:

The first user platform meeting was scheduled for October 2nd 2003 in Brussels but it was postponed for a number of reasons. These reasons included: not being able to attract enough high-level organisations since PeBBu was still in a more theoretical stage of research and development and it was premature to expect such high-level representatives in a meeting without any funding. In addition, there were a number of unexpected cancellations amongst those expected to attend due to illnesses and holidays.

As a result of the problems with the first workshop it was decided that alternative approaches to facilitate the required input into the PeBBu network of the interest of actual stakeholder representatives should be examined. One of the proposed new approaches, which seem feasible and practical at that time, was to approach the respective stakeholders in all user platforms individually. Another suggested approach was to conduct a survey amongst building owners, municipalities, construction firms, etc. to judge their interest and knowledge and then approach them to join this user platform. The aim was to obtain 10-15 key and interesting stakeholders in the platforms.
The agree alternative approach was a combination of the two alternatives - to identify stake holders through the domain members and national contacts and to ask them to complete a short questionnaire developed specifically for the User Platform and made available via the BRE website.

State of the Art:

The User Platforms are different from the other Domains in that they were not required to produce a state of the art document since their main objective was to act as a focal point for the collection of the views and ideas of stakeholders. It is must be accepted that there will be 'time lag' between the evolution of ideas – particularly those originating in academic institutes and perceived as 'research' – and the acceptance of those ideas by the stakeholders. It should also be noted that there may be considerable resistance to the take up of new ideas unless there are sound business reasons to drive the change forward – and the usual drivers are financial benefit or mandatory requirement.

However, it is possible to begin establishing a benchmark for the extent to which stakeholders have taken up the concept of PBB and to use this to identify areas where PBB could be applied but where there is little current take up.

A brief look at a number of areas where there has been some acceptance of PBB seems to indicate that take is in rather narrow and specialised areas – rather than as part of an holistic approach to construction and the built environment. For example in the US FEMA advocated the use of PBB in the mitigation of damage in seismic areas. Over the past ten years, leading structural engineers have promoted the development and application of performance-based seismic design concepts. FEMA say that with performance-based design, buildings are designed to withstand an acceptable level of damage, typically described as a performance level. Building owners should make the determination, with their structural engineer, of their building's desired performance level. Performance levels can include:

- Immediate occupancy,
- Life-safe, and
- Collapse prevention

Also in the US sustainable construction has also developed in PBB approach. The US Green Building Council advocates LEED (Leadership in Energy and Environmental Design) for Existing Buildings (LEED-EB) which is designed to maximize operational efficiency while minimizing environmental impacts. It provides a recognized, performance-based benchmark for building owners and operators to measure operations, improvements and maintenance on a consistent scale. LEED-EB is seen as a road map for delivering economically profitable, environmentally responsible, healthy, productive places to live and work.

There are many other examples of where a performance based approach is applied to energy efficiency and to high performance building and this probably reflects a desire to achieve an agreed end point whilst leaving so flexibility in the solution. Any emphasis on a performance based approach to energy requirements naturally extends to facilities management where a performance based approach can cover all aspects of heating and ventilation, and even be extended to the requirements of floors in order to maintain a safe environment.

One route to mandatory uptake is the development of performance based building regulations. There are now a number of examples of PBB regulation, for example in New Zealand and in Australia. The Building

Code of Australia is produced and maintained by the Australian Building Codes Board provides a uniform set of technical provisions for the design and construction of buildings and other structures. It is fully performance based and allows for state variations to provide additional requirements or cater for specific community expectations. A similar approach is being considered in the UK and the forthcoming EU Eurocodes for structural design will also provide scope for PBB.

Inter-relations with other Domains/Tasks:

The initial plan was that the Platform would be established by the time the first report that synthesised the findings of the nine Domains was complete and that the User Platforms would then discuss this document and provide a 'steer' for the later Domain meetings. As such, the User Platforms were a key part to play in the overall programme and as they provided a feedback mechanism for the researchers in the Domains.

Proposed Research Agenda:

User Platform I was not required to develop a research agenda but the results of the questionnaire has identified. The responses to the questionnaire showed that the respondents believed that the design brief and design stage were the times where PBB could be most influential. This is an interesting finding for two reasons – firstly because these are potentially the most influential stages because without 'buy in' at the design stage PBB is very difficult but the findings also show that the concept of PBB has not reached into the construction and occupation phases. This finding is in many ways reinforced by a later question that found that the materials and components and the whole building facility could be influenced by PBB – but the implications are that this occurs at the design stage and not later on.

It is clear that there are a number of areas where there is a take up of PBB and it important that these are widely disseminated to illustrate the benefits of PBB to other areas in the design, construction and use of buildings – and to show that there are economical benefits which can be obtained. However, with the shift towards more sustainable development there is a clear requirement to demonstrate that there can also be social and environmental benefits from a performance based approach.

Dissemination and Implementation:

Deliverable	Intended Use	Target Audience	Dissemination
Workshop Report I (Not complete due to cancellation of the Workshop)	To inform the R&D agenda for the Domains	Internal to PeBBu Domains	This would have been circulated internally via PeBBu via Website
Report on Questionnaire Findings and Final Task Report	To establish a benchmark for PBB in amongst Owners, Users and Managers	Building Owners, Users and Managers EU Project Leader	Circulation to all respondents and PeBBu Domains and EU

This User Platform allows an assessment to be made of interest in performance based building to be made at two levels. The first is within those associated with the project where there was a lot of support and enthusiasm, but this is in stark contrast to the initial support from owners, users and managers. The questionnaire received better support but there is clearly a considerable gulf between the enthusiasm of the academic world for PBB and the actual uptake of those responsible for buildings.

This Task is not expected to have any great impact in Europe or worldwide but it has been important in clarifying the gap between the latest research thinking and the uptake by high level stakeholders.

Conclusions:

This User Platform allows an assessment to be made of interest in performance based building to be made at two levels. The first is within those associated with the project where there was a lot of support and enthusiasm, but this is in stark contrast to the initial support from owners, users and managers. The questionnaire received better support but there is clearly a considerable gulf between the enthusiasm of the academic world for PBB and the actual uptake of those responsible for buildings.

ANNEX XV: STATE OF ART SUMMARY REPORT FOR UP2: USER PLATFORM 2 – BUILDING AND CONSTRUCTION INDUSTRY

Task Leader:

ir. Luk Vandaele, Belgian Building Research Institute, Belgium

Task Website:

http://www.pebbu.nl/maincomponents/userplatforms/userplatform2/

Scope and Objectives:

The User Platform is one of the communication means with the major stakeholders in the field, in this case, User Platform 2, the building and construction industry: construction companies, contractors, design and engineering offices, manufacturers of construction products and building components, assessors of innovation, project managers acting on behalf of the client.

The overall objectives were:

- to engage high level representatives of actual PBB stakeholders in decision making and in the evaluation of the results of this programme
- to stimulate and facilitate the input of PBB actual stakeholders' opinions into the programming and execution of international PBB related research and dissemination projects
- to prepare for the respective stakeholders support to future implementation activities

Conceptual Framework:

No specific conceptual framework of PBB has been adopted by the Task. Reference is made to the conceptual framework as defined in the different domains of PeBBu.

Methodology and Process:

Platform meetings

One platform meeting was organized in Brussels on 2nd October 2003. However, the meeting had to be cancelled due to the lack of participants.

Questionnaire

Since the concept of meetings with representatives of European stakeholder organizations from the building and construction industry did not work, it was decided to develop a specific questionnaire to obtain the views on PBB from these target groups.

Final report

The final report summarizes the findings from the responses to the questionnaire.

State of the Art:

A first workshop with representative stakeholders was scheduled to be hold in Brussels, Belgium, at the BBRI head office, on 2nd October 2003, following a series of other PeBBu meetings (regional platform, technical committee). Representatives from the major European stakeholders in the construction community were invited. However, for a number of reasons, too few people were able or interested to attend. Therefore, the meeting was cancelled.

After the Mid Term Assessment, it was decided to alter the working method for this task. It was deemed more efficient to approach the stakeholders in a different way through a questionnaire.

This questionnaire has been developed in collaboration with Prof. Rachel Becker of the Technion – Israel Institute of Technology.

First try-out of the questionnaire was done with 2 major Belgian building contractors and a consulting engineer.

It proved to be too specific for the respondents. Therefore, it was decided at the Porto meeting to reshape/tailor it to the specific respondents.

A request to national contacts to distribute it on a national level was not successful.

Since the questionnaire form was a bit too heavy for handling and for attracting people to commit themselves to complete it, it was tried to ease the handling by introducing an electronic interactive form, made in Designer and Distributed as a pdf file. Even then it was not very successful and only few people took the effort to complete it.

In a last attempt, after suggestions at the regional platform meeting in Delft, 25th August 2005, the questionnaire was transformed into an internet based format, linked to a database to collect the responses. The questionnaire was available via a hyperlink on the PeBBu domain. However, interaction with the national contacts was still very poor and only few replies were received.

Inter-relations with other Domains/Tasks:

The first meeting was organized in conjunction with the first meeting of the Regional Platform West and Central Europe in Brussels.

National contacts were requested to support the distribution of the specific questionnaire to at least five representative persons from the national building and construction industry.

Proposed Research Agenda:

The Research Agenda was a specific topic in the questionnaires distributed. However, only few respondents made the effort to go through the end of the questionnaire where the research agenda table could be completed.

Therefore the response is rather poor.

From the few responses, the following topics emmerge:

- Acoustic comfort
- Hygrothermal and energy performance: Research on the consumption of the building
- Research in simplified monitoring of indoor air quality. Increase the number of IAQ parameters to be measured.
- Communication tools between project partners
- Responsibility of the contractor and financial implications
- Risk analysis in case of no preliminary study of soil, or environmental impact, …
- Need to normalise the non-technical aspects:
    - Who is responsible?

    - What are the rules of the game?
    - How to deal with aesthetics? Not quantifiable. Expressed as 'one class higher than reference building Y'
- Co-ordination with existing local regulations and standards.
- Insurances and liabilities
- Correlation between different countries in relation to building methods

Incentives for PBB implementation:

Respondents indicate the following opportunities from the PBB approach:

- High level of technical solutions that can be achieved.
- Performance based regulations (e.g. energy performance) means extra business for consultants, etc.
- more freedom to the contractor to present his own solutions.
- Bigger markets
- Better approach in case non common technologies are proposed

Barriers to PBB implementation:

Respondents indicate the following barriers and difficulties in case a PBB approach is proposed:

- How to model thermal comfort, energy consumption, etc
- Communication with the persons responsible for the project. Sometimes it is easier to specify technical solutions rather than describing their performance.
- The uncertainty and different approach philosophies. The sensibility of customers to indoor air quality issues and the willing to improve it.
- Special studies, such as structural engineering (concrete) and special techniques (building services) should be optimised.
- The contract should be not as a percentage of the costs of the special techniques, but as a lump sum combined with an incentive for improved performance (lower energy consumption, shorter execution time, …)
- The contractor has a new role due to the PB brief: from simple executor of prescriptions, he now is involved in more engineering, more simulations, more coordination,… The communication with the other partners (architect, engineers, project developer, ..) in the team is important. This increased liability is translated into financial terms.
- Physical, measurable performances: no problem, but there is a need to normalise the non-technical aspects:
    - Who is responsible?
    - What are the rules of the game?
    - How to deal with aesthetics? Not quantifiable. Expressed as 'one class higher than reference building Y'
- The brief should specify why certain performances have to be met. If you don't know why, then you also don't know how important it is for your client. In some countries certain demands will be easy (read: cheap) to fulfil while in other countries these same demands can be expensive.
- A performance based brief written by a foreign client may contradict local standards and regulations.
- A performance based brief causes a lot more uncertainties at the start of studying the project.
- How to prove the performances? Checking if the execution of the project meets the performance based specifications will be more difficult
- Correlation between different countries in relation to building methods
- Knowledge and new building details/design

- Lack of knowledge of the people who have to execute the work. They are not familiar with the regulations and scientific backgrounds of it.
- No project has been realised on the basis of these performance-based regulations. The intended projects appeared to be too expensive which is an indication of the difficulties contractors have with such kind of documents
- The introduction of PBB has to be accompanied by supporting actions, training, etc, of the executors of projects to learn them how the performance-based specifications can be achieved.

Dissemination and Implementation:

Via the general PeBBu actions. No specific dissemination is foreseen.

Conclusions:

The building industry in general is not ripe for general application of a performance based approach in building projects. They indicate a lot of barriers and difficulties.
However, some of them recognize also the opportunities in this new approach.

ANNEX XVI: STATE OF ART SUMMARY REPORT FOR UP3: USER PLATFORM 3 - INTERNATIONAL PRE-STANDARDIZATION

Task Leader:

Nigel Smithies, BRE, United Kingdom, email smithiesjn@bre.co.uk

Task Website:

http://www.pebbu.nl/maincomponents/userplatforms/userplatform3/

Scope and Objectives:

The purpose of the International Pre-Standardization Platform was:

To stimulate and facilitate the transfer of Performance Based Buildings research results and pre-normative knowledge into (pre-) standardization processes.

To stimulate and facilitate the transfer of actual knowledge about the characteristics of Performance Based Buildings standardization issues into their respective research projects.

To facilitate co-ordination between International, European/regional and National Standards Bodies in the area of into (pre-) standardization processes associated with Performance Based Building

The specific objectives for the Platform were:

The organisation and provision of two international workshops towards the beginning and the end of the Thematic Network programme.
The provision of a detailed report which will include:

- International status concerning the inclusion of the principals of Performance Based Building in National, European/Regional and International Standards
- An assessment of results available from research on Performance Based Building as concerns possibilities for inclusion in Standards together with an indication of further research required in support of future standardization.
- Recommendations to standards organisations.

It was considered that the International move towards Performance Based Buildings and the development of Performance Based regulations and codes indicated that International interest in the PeBBU project will be strong.

In order for ongoing work in the development of performance based buildings and performance based concepts to be implemented or applied it was considered necessary for the requirements to be embodied in Standards, Code and Regulations.

The main Standardisation bodies were regarded as including ISO, CEN, CENELEC, ANSI, ASTM etc.

However, it quickly became apparent that collective communication with the main Standardisation bodies was not practical or beneficial to the project as the development of standards takes place within the Technical Committees and Sub-Committees. Some Technical Committees and Sub-Committees were identified – in particular within ISO and CEN and although the brief for the Standards bodies is to produce performance based standards where ever possible, it became apparent that many of the standards under

development were equipment/product standards and a large conceptual leap and a considerable period of gestation/development would be required to establish any meaningful understanding of the PeBBU concept within the product standard community.

The definition of standardisation bodies and pre-standardisation bodies was then widened considerably to include Regulators, Code Developers, Technical Approvals Bodies, Building Code Officials etc and a meeting was convened in Brussels. It was quickly recognised that the development objectives within PeBBu would interact with aspects of the Essential Requirements as covered by the EU Construction Products Directive (CPD) therefore a new Task was established – Performance Based Building and the Construction Products Directive (CPD) under the leadership of Eric Winnepennincks, Luck Vandaele and Piet Vitse of the Belgium Building Research Institute.

Therefore the bulk of the initial interest in pre-standardisation had now moved significantly into the area of standards, codes, approval bodies and European Directives, this making the interested parties even more product standardisation focused and prescriptively biased.

Presentations were given to several Technical Committees within ISO including TC21 and TC 92 – the two main fire safety committees.

Specific Objectives of the task

The specific objectives for the Platform were:

> The organisation and provision of two international workshops towards the beginning and the end of the Thematic Network programme the workshops were intended to attract individuals from the Pre Standardisation and Standardisation communities.
>
> The provision of a detailed report to include:
> - International status concerning the inclusion of the principals of Performance Based Building in National, European/Regional and International Standards
> - An assessment of results available from research on Performance Based Building as concerns possibilities for inclusion in Standards together with an indication of further research required in support of future standardization.
> - Recommendations to standards organisations.

The Platform was also there to generally promote the concept of performance based objectives or criteria within the standardisation arena and help promote the general movement away from the traditional area of highly prescriptive codes and standards.

Accomplished Workplan:

The establishment of the User Platforms, including User Platform 3 proved to be a very difficult process. The initial plan was that the Platform would be established soon by the time the first report that synthesised the findings of the nine Domains was complete and that the User Platforms would then discuss this document and provide a 'steer' for the later Domain meetings. As such, the User Platforms were a key part to play in the overall programme and as they provided a feedback mechanism for the researchers in the Domains.

The main standardisation/pre-standardisation platform meeting was held in Brussels on 24 June 2003. The main attendees were from European organisations including CEN Secretariat, EOTA and the European Commission. It became apparent during the course of a series of presentations that the development objectives within PeBBu would interact with aspects of the Essential Requirements as covered by the EU Construction Products Directive (CPD) and subsequently, following a second meeting in Belgium on 1 October 2003, a new Task was established – Performance Based Building and the Construction Products Directive (CPD) under the leadership of Eric Winnepennincks, Luck Vandaele and Piet Vitse of the Belgium Building Research Institute.

A planned final meeting of Platform 3 was not held, however, Presentations were given to several Technical Committees within ISO including TC21 and TC 92 – the two main fire safety committees.
This Platform aroused considerable European interest largely because it was perceived as a new initiative which might interfere with other developments within the European Arena – in particular the EU Directives and the Essential I requirements of the Construction Products Directive. The initiative did further raise the profile of moves towards performance based codes and standards. However, it is a relatively slow transition from prescriptive codes and standards to performance based ones and there is a significant amount of resistance to the move as manufacturers and enforcers find that performance based quantitative objective criteria are both difficult to set and measure.

Comparison of Planned activities and actual work accomplished

Planned Activities during the entire project	Actual work Accomplished
1st Workshop – Early 2003	Held 23 June 2003
2nd Workshop – Late 2004/ Early 2005	Not held due to change in emphasis and direction regarding EU Construction Products Directive (CPD)

State of the Art:

The User Platforms are different from the other Domains in that they were not required to produce a state of the art document since their main objective was to act as a focal point for the collection of the views and ideas of stakeholders.

Results & Conclusions:

Initially the main Pre Standardisation and Standardisation bodies were regarded as including CIB, ISO, CEN, CENELEC, ANSI, ASTM etc. However, collective communication with the main Standardisation bodies was not practical or beneficial to the project as the development of standards takes place within the Technical Committees and Sub-Committees. Some Technical Committees and Sub-Committees were identified – in particular within ISO and CEN and although the brief for the Standards bodies is to produce performance based standards where ever possible, it became apparent that many of the standards under development were equipment/product standards and a large conceptual leap and a considerable period of gestation/development would be required to establish any meaningful understanding of the PeBBU concept within the product standard community.

The main result/benefit of this Platform has been the general publicity and communication with the Standardisation bodies, Regulators and Enforcers which has continued the general awakening of individuals regarding the concept and meaning of Performance based Codes and Standards.

ANNEX XVII: STATE OF ART SUMMARY REPORT FOR GT1: GENERIC TASK 1 – SUPPORT ON CPD

Task Leader:

Eric Winnepenninckx, Piet Vitse, Luk Vandaele (BBRI)

Task Website:

http://www.pebbu.nl/maincomponents/newtasks/cpd/

Scope and Objectives:

During the period 1998-2000, CIB, the International Council for Research and Innovation in Building and Construction - initiated and commissioned various international programmes and R&D projects related to Performance Based Building. Based on the achievements of those projects CIB proposed in 2000 the establishment of the Thematic Network PeBBu Performance Based Building. This Network is to elaborate on the activities carried out by CIB, its commissions and its members since it adopted Performance Based Building as a Priority Theme in the CIB Pro-Active Approach in 1998.
The European Commission decided to fund the PeBBu Network through a Network subsidy within the Growth Programme that is part of the 5th Framework Research Programme, with a start date of 1 October, 2001 and run for 4-years until 30 September 2005.

The objectives of the PeBBu Network are stimulation and pro-active facilitation of international dissemination and implementation of Performance Based Building in building and construction practice. It has been acknowledged that the Construction Products Directive (89/106/EEC – CPD) should be a basic element in PeBBu work and therefore, the introduction of the CPD was considered to be a horizontal task in PeBBu.

The Steering Committee of the PeBBu Thematic Network decided on 4th August 2003 to develop a new cross-cutting activity on the integration of the knowledge of the Construction Products Directive into the work of the various domains and tasks of PeBBu.

Two main objectives were formulated:

- To inform PeBBu domains about the CPD.
- To examine the relationship between product conformity attestation (the CPD) and works having been installed using a performance based approach.

Both objectives were met and documented in the CPD supporting document.

Objective I

The first objective of this activity was to provide basic info on the CPD to the PeBBu domains and tasks and to receive and incorporate feedback in a final report that aims at linking PeBBU with the CPD. More broadly, part A of this document can be used to widely inform people about the CPD.

The Construction Products Directive (CPD - 89/106/CEE) defines six essential requirements for construction works, which are detailed in interpretative documents. Starting from those essential requirements for works, the European Commission, after consultation of the Member States of the

European Economic Area (EEA), specifies the regulated characteristics for construction products and kits in mandates to the European Standardisation Committee (CEN) and the European Organisation for Technical Approval (EOTA) to develop harmonised technical product specifications, i.e. harmonised European standards or European Technical Approvals, for the performance assessment of the building products.

The EC New Approach directives in general and the CPD specifically introduce a mandatory system of conformity attestation throughout the construction products sector. For some parts of the industry, CE Marking is not really new, due to other existing EU Directives, but the CPD has important particularities.

Thanks to the CPD, the way technical product specifications are being written has changed. It is expected that the CPD technical specifications should be a driving tool towards performance based works specifications and regulations in a very large part of geographical Europe.

Objective I: To inform PeBBu domains about the CPD.

This objective has been achieved through Part A of the "CPD supporting document".

Objective II

Although the CPD starts from the 6 essential requirements for works, it leads to product conformity attestation only. It does not provide the link between the performance based approach used in product specifications and a performance based approach for works.

Therefore, in Objective II, this project examined how such a link is being or could be established.

Attention has been given to the European voluntary product assessment systems, which exist for many years in most European countries, and are expected to remain in place, although their scope might be very different, as far as they are not in conflict with the CPD and if there is a market driven demand.

At the moment, the CPD is at the end of its first phase, with the first generation of harmonised technical specifications becoming available and being used in the construction sector. The activity explored domains that the CPD does not cover for the time being and where supporting standardisation activities are on-going (e.g. dangerous substances, durability, life cycle analysis, environmental declarations, …).

Objective II: To examine the relationship between product conformity attestation (the CPD) and works having been installed using a performance based approach.

Accomplished Workplan:

	Deliverable	Milestone	Type	Actual work accomplished
1.	Draft report on CPD for discussion	1 Jan 2004	Report	Accomplished
2.	First revised report on CPD	1 March 2004	Report	Accomplished
3.	Circulation enquiry questionnaire	1 March 2004	Question-naire	Accomplished
4.	CPD Document	1 Dec 2004	Report	Accomplished
5.	Final Report	1 Jun 2005	Report	Accomplished (1 Sep 2005)

State of the Art:

Up until August 2005, developments within the framework of the CPD have been considered in the final report, the CPD supporting document. Whenever Domain leaders or members requested further or other information than that provided, the report has been adapted accordingly.

The CPD supporting document contains hyperlinks to websites, ensuring readers can retrieve actual information.

Inter-relations with other Domains/Tasks:

The inter-relation with other PeBBU domains has been considered in detail in Part B of the CPD supporting document.

Dissemination and Implementation:

The Construction Products Directive is a complex directive. In many cases, background information, which is presented in the "CPD supporting document" is required for complete implementation. Especially small and medium sized enterprises may find the document interesting since it brings together information which is available, but from many different sources.

The European level is described above. The document already generated interest from AusPeBBu members attending PeBBu workshops. It is possible that it will create interest in other parts of the world as well.

Deliverable	Intended Use	Target Audience	Dissemination
CPD supporting document	Information on the Construction Products Directive	PeBBu members	PeBBu network
		All other	PeBBu network

Conclusions:

The PeBBu task was completed successfully.

Annex XVIII: State of Art Summary Report for GT2: Generic Task 2 – Decision Support Tools for PBB

Task Leader:

Pekka Huovila, VTT

Task Members:

Janne Porkka, VTT; Salam al-Bizri & Colin Gray, Reading University

Task Website:

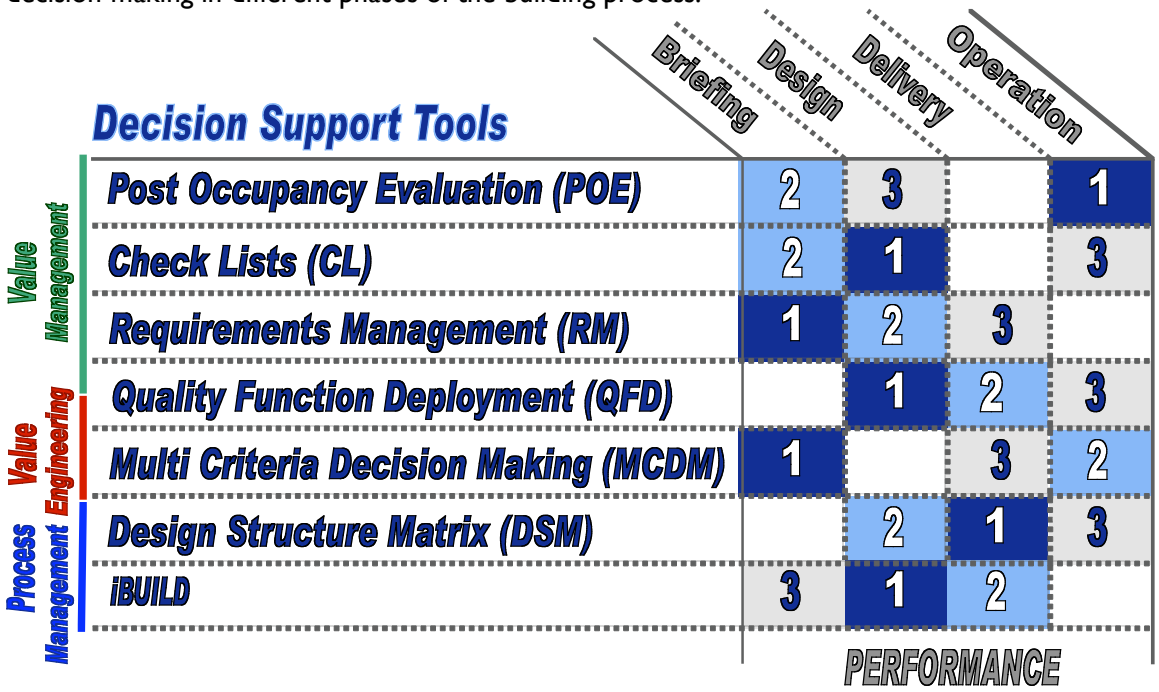
http://www.pebbu.nl/maincomponents/newtasks/toolkitpbb/index.php

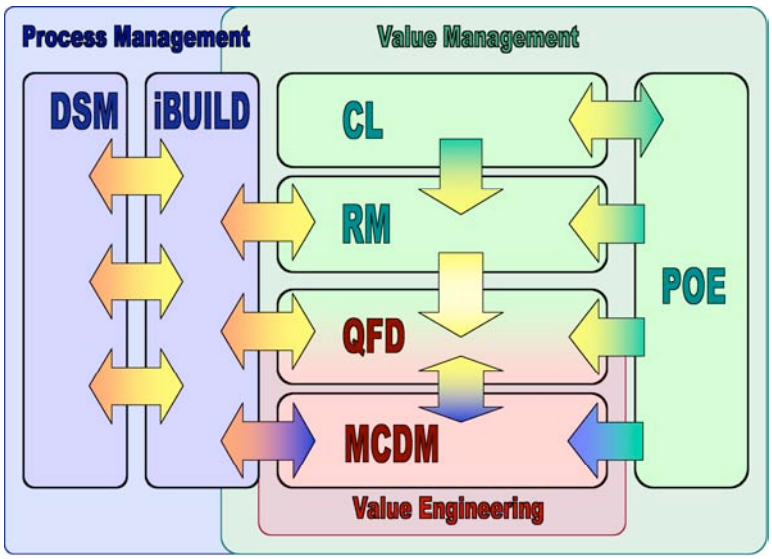
Scope and Objectives:

To collect a set of decision support tools and test their applicability in different PBB domains.

Conceptual Framework:

Promising value management, value engineering and process management tools were selected to support decision making in different phases of the building process.





The long-term objective is to achieve an integrated platform where different tools can be chosen to be used for different purposes depending the user needs.

Accomplished Workplan:

Seven promising tools (Check Lists, Requirement Management, Quality Function Deployment, Multi Criteria Decision Making, Design Structure Matrix, iBuild and Post Occupancy Evaluation) were selected and tests carried out in two occasions.

The first test was run 18-19 October 2004 at TNO Delft together with researchers and practitioners using a Finnish simple family house project as a real case.

The second presentation and validation was run 17-19 November 2004 in Porto within the PeBBu community using a Dutch IFD building as a case.

Findings were documented and relevant tools made available for parties interested in.

State of the Art:

The following observations were done during the work

- Traditionally the emphasis has been very much on design and construction
- The emphasis is shifting from construction of facilities to operations
- ICT tool development needs input from operation to setting the requirements
- Tools for performance verification are needed.

Inter-relations with other Domains/Tasks:

Tool demonstrations and tests were run in different PeBBu Domains

- Domain 1 Life Performance of Construction Materials and Components
- Domain 2 Indoor Environment
- Domain 3 Design of Buildings
- Domain 6 Legal and Procurement Practices

- Domain 7 Regulations
- Domain 8 Innovation.

Incentives for PBB Implementation:

When the market requests for high performance the best tools should be used in order to be competitive.

Barriers to PBB Implementation:

Adopting systematic procedures may mean changes to traditional practices, thus raising resistance. Investing on issues early in the process may result in additional work at that stage, even though that would lead to overall gains.

Proposed Research Agenda:

The following recommendations were drawn

1 Internationally accepted performance based building classification: a "PBB Master list 2006"
2 A "PeBBu II" should be activated focusing on "ePeBBu Platform" and "PeBBu compatible
3 A cross-disciplinary study a "PBB Roadmap" objectively assessing various future scenarios could provide a discussion basis bridging various professions and disciplines.
4 Self sustaining profitable business models are needed to breed customer oriented networked life cycle services
5 The development needs to be encouraged and assured at all levels.

Dissemination and Implementation:

PeBBu Domains, PeBBu website, PeBBU members, PeBBU publications and real projects.

Conclusions:

The proposed tools add value to current PBB practices. Further work is needed towards an integrated platform.

ANNEX XIX: STATE OF ART SUMMARY REPORT FOR GT3: GENERIC TASK 3 – CRISP INDICATIOR ANALYSIS

Task Leader:

Pekka Huovila VTT

Task Members:

Jean-Luc Chevalier, Jacques Chevalier CSTB, Ilkka Heinonen VTT

Task Website:

http://www.pebbu.nl/maincomponents/newtasks/crispindicators/

Scope and Objectives:

To study the applicability of the existing CRISP (crisp.cstb.fr) sustainability indicators and their applicability as PBB indicators, and to develop a PeBBu indicator browser.

Conceptual Framework:

CRISP provides a sustainability framework and PeBBU a PBB framework. These frameworks have performance indicators as their common nominators.

Accomplished Workplan:

The CRISP database was studied and its applicability for PBB analysed.

State of the Art:

CRISP provides a sustainability indicator database. The PeBBU follow up could be related with populating a PBB indicator database, which does not exist at the moment.

Inter-relations with other Domains/Tasks:

The task is not PeBBu Domain or Task specific.

Incentives for PBB Implementation:

Indicators are very useful when a reliable estimate is needed of a complicated system, or when a trend is wanted to be measured. Especially if they are easily interpretable and reliable.

Barriers to PBB Implementation:

Without a systematic framework enabling a structured database, the use of performance indicators remains case specific.

Proposed Research Agenda:

A systematic framework is required. That could logically be followed by collection and validation relevant PBB indicators. Finally, simple tools are needed to support their use.

Dissemination and Implementation:

The PeBBu browser may be used for populating the indicator database and for searching relevant indicators.

Conclusions:

At present the CRISP database does not provide sufficient added value for PeBBU as such. A considerable additional effort is still required to support PBB through performance indicators.

ANNEX XX: STATE OF ART SUMMARY REPORT FOR AT1: ALIGNED TASK 1 – COMPENDIUM OF PBB MODELS

Task Leader:

Dr. Foliente, G., CSIRO

Task Members:

Peter Boxhall, CSIRO; Dr Phillip Paevere, CSIRO; Dr Seongwon Seo, CSIRO; Dr Selwyn Tucker, CSIRO

Task Website:

http://www.pebbu.nl/alignedcomponents/compendia/compendium1/

Overview:

The Compendium of Building Performance Models is an on-line library of software tools (descriptions and links), currently presented on the Aus-PeBBu web-site and specifically compiled to facilitate the implementation of Performance Based Building. The setting up of the Compendium commenced as a CIB task in 2000, under the leadership of Dr Greg Foliente of CSIRO, Australia. In 2003, the further development of the Compendium was taken over as one of the activities of Aus-PeBBu, and the Compendium was installed in the "Performance Models" section of the Aus-PeBBu web-site, www.auspebbu.org.

Since 2003, the Compendium has been expanded and updated to include a total of 37 performance models entries. In addition a separate Guide to Environmental Design and Assessment Tools (incorporating 27 Australian and international environmental rating tools) has been incorporated.

Building Performance Models:

The term "building performance models" refers to computational procedures and/or computer programs that can be used in:

- developing quantified performance criteria for building codes and standards;
- designing a building or part of a building to a target performance; or
- evaluating the whole building or any of its part as built at commissioning or at any time during building occupancy, e.g., as part of a performance review or audit.

The availability of such models is at the heart of the implementation of performance based building.

The Compendium is intended as a "one-stop shop" for the building, construction and property industry worldwide, so that building professionals, product manufacturers, building officials and researchers can find in one place all of the building performance tools that are needed to support, implement and further develop performance based building.

Since the performance models are intended to be used in supporting, implementing and developing performance based standards, emphasis is given to models based on "first principles" and which target "in-service performance".

Structure of the Compendium:

The following outline is being used as the basic framework for the Compendium. Based on VTT-Prop, developed in VTT Finland, it is structured to include most models that can be used to apply the performance approach in both building procurement/production and building regulation.

A Building Performance

A 1 Safety
- A 1.1 Structural Safety
- A 1.2 Fire Safety
- A 1.3 Safety in Use

A 2 Comfort
- A 2.1 Acoustical Comfort
- A 2.2 Visual Comfort
- A 2.3 Hygrothermal Comfort
- A 2.4 Structural Serviceability

A 3 Health & Hygiene
- A 3.1 Air Quality
- A 3.2 Water Supply and Other Services
- A 3.3 Waste Disposal

A 4 Service Life
- A 4.1 Structure
- A 4.2 External Enclosure
- A 4.3 Internal Enclosure
- A 4.4 Built-in Furnishings and Equipment
- A 4.5 Services

B Cost and Environmental Performance

B 1 Life Cycle Costs
- B 1.1 Investment Costs
- B 1.2 Service Costs
- B 1.3 Maintenance Costs
- B 1.4 Disposal and Value

B 2 Environmental Impact from Land Use

B 3 Environmental Impact from Building
- B 3.1 Embodied Environmental Impact
- B 3.2 Recycling
- B 3.3 Environmental Impact from Use of Building
- B 3.4 Environmental Impact because of users

C Construction Process

C 1 Design

C 2 Site Operations

D Operation

D 1 Useability

D 2 Maintainability

The long-term expectation is that some sections of the Compendium will be populated with many models, while others may be empty. Sections without any entry will not be excluded; they are an important part of the Compendium in that they identify gaps in knowledge or tools. Where there are many known models under a given heading/sub-heading or section/sub-section, further sub-divisions will be introduced.

Compendium Entries:

There are two types of Compendium entries. One type provides all of the information requested in the on-line submission form. The other type is a model summary, combined with a web-site link for additional model information. Contributions are reviewed and edited, so that entries provide factual and objective technical information, and not just marketing material.

Each entry in the Compendium includes:

- Name of model, relevant Compendium section(s) and keywords
- A brief description of what the model does and the nature of the input and output data.

The following additional information is available by means of a link to either further details provided as part of the model contributor's submission or to an appropriate web-site:

- Classification/Status (i.e. one of the classifications described below)
- The scope of applications (what the model is intended for and what it is not for), scientific basis (i.e. a short overview or outline of physical/mathematical concepts, with publication references, limitations/assumptions) and extent of experimental validation.
- Developer/Publisher/Supplier (with contact information)
- Availability (i.e. if software: commercial, shareware, freeware with or without source code)
- System requirements (hardware and software)
- An example of a project where the model has been used before.

Classification of Models:

The models are classified as follows:

- *Model based on 'first principles'* – one that is used to improve our fundamental understanding of building performance, either as a research tool or a diagnostic tool. Based on "first principles", this is, if too complicated for practical application, the ideal model from which a simplified model for performance-based codes and standards can be derived.
- *Model implementing a standard* – one that wholly implements a computational procedure for evaluating performance that is recognised in regional/national or international performance-based codes or standards.
- *Model with part(s) implementing a standard* – one that implements, in at least one part or aspect of the model (typically a computer program), a computational procedure for evaluating performance that is recognised in regional/national or international performance-based codes and standards. In this case, the portion of the program's function that implements a recognised standard should be identified in the model description, together with a reference to that standard.
- *Widely used in practice* – one that does not have the status of a formal standard but is used widely in the industry or in an industry sector and is generally accepted by professionals in this area (like a "de facto" standard).
- *Under development* – one that is currently under development. This may be upgraded to any of the above classifications in the future.
- *Other* – if the model cannot be classified into any of the above; a proposed classification should be supplied.

Contributing to the Compendium:

Software developers, building professionals and researchers are encouraged to submit performance models relevant to the aims of the Compendium. Their contributions will benefit the worldwide building industry, and are also expected to bring benefits to individual contributors as follows:

- Software developers would have worldwide exposure for their software products and the opportunity to provide factual and objective technical information about the capabilities of their software.
- Building professionals, in sharing the building performance analysis tools that they use, would give others a chance to know about these tools. The Compendium, in turn, would give building professionals an idea about the range of tools available to enable them to work more effectively and efficiently. The use of generally accepted tools/models in building projects has the potential to hasten the acceptance of selected design by building officials. The use of appropriate models in design has the potential to improve the quality of construction, and thus reduce the occurrence of expensive and time-consuming litigation.
- Researchers could gain worldwide exposure for new performance prediction or evaluation tools that they have developed. This can give others a chance to try a particular model and provide feedback to the researcher, and/or provide an opportunity for the researcher to commercialise his/her work (in part or in whole).

Guide to Environmental Design and Assessment Tools:

The Guide to Environmental Design and Assessment Tools is a supplement to the main Compendium, and is provided to give building design professionals and other industry stakeholders a consistent framework and basis for comparing the applicability and basic technical contents of common environmental performance rating tools. Australian tools are covered more extensively, but the guide also includes ones developed in other countries.

The guide has been produced by CSIRO members of Aus-PeBBu Domains 4 and 6, Drs Greg Foliente, Seongwon Seo and Selwyn Tucker. An early version of the guide has been published in the BDP Environment Design Guide of the Australian Council of Building Design Professions (Feb 2004).

The guide comprises the following parts:

- Outline of the Guide, including the objectives, scope and limitations of the information provided.
- Table 1, which presents a summary list of the environmental rating, design and assessment tools considered in the guide, along with related website or contact information.
- Table 2, which shows applicability of the tools based on building types and the primary object of assessment, which may be product level, part of a building (e.g. whole façade), whole building, or a portfolio of buildings or a whole development.
- Table 3, which identifies applicability of the tools according to the stage/phase in the life cycle of the building. For simplicity, only four stages are considered: planning, design, operation and maintenance, and end of life.
- Table 4, which identifies the primary attributes considered by each tool in assessing the environmental performance of buildings and their constituent parts or components.

Annex XXI: State of Art Summary Report for AT2: Aligned Task 2 – Conceptual Framework & Compendium of PBB Statements of Requirements

Task Leader:

Françoise Szigeti, International Centre for Facilities (ICF)

Task Members:

Kathryn Bourke, MPhil, Faithful & Gould, formerly with Building Research Establishment (BRE); Joséphine Prior, PhD, Building Research Establishment (BRE)

Task Website:

http://www.pebbu.nl/alignedcomponents/compendia/compendium2/

Scope and Objectives:

The Compendium 2 project was set up to confirm what is understood by a Performance Based approach as it applies to Building (PBB). The Compendium 2 team was mandated to prepare a "consensus based conceptual framework" for the PeBBu project overall and to develop documents that would provide examples of how the Performance Based Building (PBB) approach is used during actual building projects. This consensus has been significantly accomplished by presentations, papers and other verbal and written communications with members of the PeBBu project. (CIB 2003, PeBBu 2002, Prior J J and Szigeti F. 2003a, Prior J J and Szigeti F. 2003b, Prior, J. J., Szigeti, F. & Oostinga, D. 2004, Szigeti and Davis 2005).

The primary objective for this Compendium 2 was to provide support to the PeBBu Domains and Tasks so that they would prepare their own conceptual framework within an overall understanding of the PBB approach.

In order to accomplish this objective, the Compendium 2 project includes the following deliverables:
1. Conceptual Framework (articles, papers, presentations, and other documents);
2. Compendium of PBB Statements of Requirements (SoR), including Case Studies;
3. Related Terminology, Bibliography, List of key words to be used for research mapping, and Glossary of related Abbreviations, Acronyms and Initialisms.

The PBB Conceptual Framework synthesizes the overall concept of Performance Based Building approach. The Compendium 2 reports on studies of PBB projects, on the Statements of Requirements that were prepared for those projects, and summarises lessons learned. This Compendium 2 is concerned primarily with communicating requirements in the form of Statements of Requirements (SoR) for projects and Functional Statements that appear in performance-based codes and other such documentation. Both the regulatory and the non-regulatory documents should include methods for assessing whether a facility performs as stated.

Conceptual Framework:

The overall consensus based PBB Conceptual Framework has been summarised and reported in a CIB News Article posted at the CIB Website (Szigeti and Davis 2005).

The Compendium 2 -- PBB Statements of Requirements (SoR) -- was developed in the context of a Conceptual Framework for the Whole Life Cycle of Facilities. The essence of the Conceptual Framework for this Compendium 2 is that, for a project to be a PBB project, it has to include a PBB Statement of Requirements, together with the means of verifying that the results meet the stated requirements, preferably within the context of a Life Cycle Management approach. The Conceptual Framework shows how links and matches can be made between user requirements (demand side) and the performance of assets (supply side). At this time in the implementation of PBB, it is too early to expect that all building project phases will be conducted using a PBB approach. On the other hand, any part or phase of a building project can be performance based. (Szigeti and Davis 2001)

Figure 1 illustrates the Life Cycle Management of Facilities, and other constructed assets. It shows the Life Cycle from the perspective of those who manage, operate, maintain and use them, whether as owner-occupier or landlord. It also shows the key role of SoRs as the documents of reference throughout. User and stakeholder requirements define the objectives for the constructed assets to be provided for a specific purpose, but independent of what solution might be chosen. They can be expressed in qualitative or quantitative terms. Performance requirements translate user requirements in more precise quantitative and technical terms, usually for a specific purpose. (Gibson 1982)

In the near future, the core of such a Life Cycle Management process will be a shared and interoperable information data base that can be accessed by all stakeholders in real time. SoRs will be added to during the different phases of the life of a facility. They will be updated and managed using computerized tools and carry all requirements throughout the life of the facility as part of the portfolio and asset management data. They will also exchange into the Enterprise Resources and financial data for the organization. In this manner, it will be possible to directly link the mission of the organisation to the constructed assets that support the organization. This is illustrated in Figure 2.

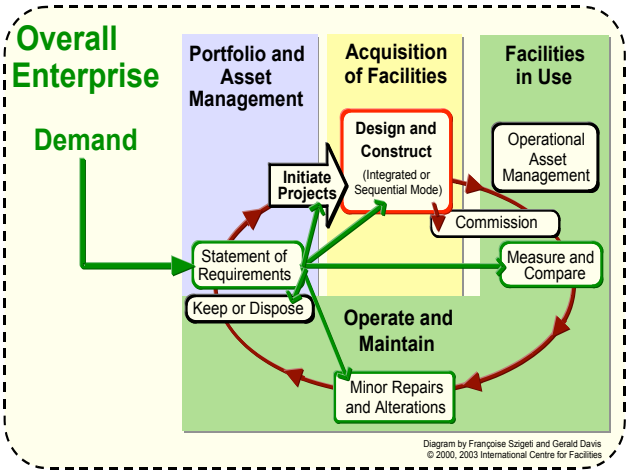


Figure 1: SoR and Whole Life Cycle Management

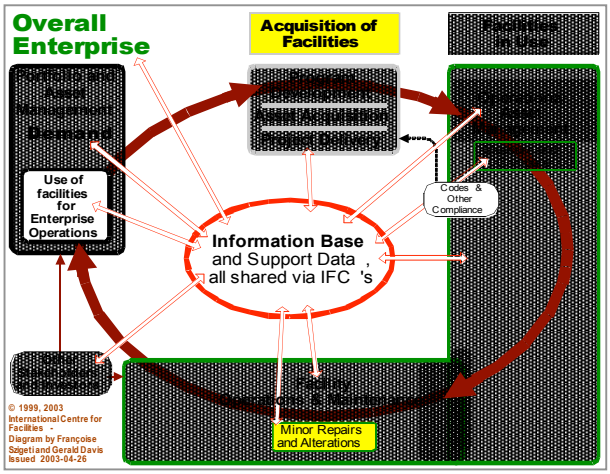


Figure 2: Information and Whole Life Cycle Management

Methodology and Process:

The Compendium 2 is an aligned task that was commissioned by CIB (The International Council for Research and Innovation in Building and Construction) and completed during 2005. It was co-funded by the Rijksgebouwendienst (RGD, Government Building Agency, The Netherlands), with in-kind contributions by the International Centre for Facilities (ICF, Canada) and the Building Research

Establishment (BRE, U.K.). The Dutch Government Building Agency and the United Kingdom Ministry of Defence contributed projects serving as case studies.

This task was designed as a study of the PBB approach as used in practice. The Compendium 2 includes an Interview guide for studying the Performance Based Building (PBB) approach to the procurement and the Whole Life Cycle Management of Buildings, Facilities and other constructed assets and a template for capturing and reporting the information collected. It reports on the studies of the selected completed projects using the template to present the information gathered.

Key to the PBB approach is that requirements for a project define what a constructed asset, facility, building or building product is required to do and not with prescribing how it is to be constructed or manufactured. (Gibson 1982) Successful application of the PBB approach therefore depends on closely matching user requirements (demand) with the performance of assets (supply). To illustrate how PBB has worked in practice to-date, real life applications of the PBB approach in projects developed by Dutch Government Building Agency and the United Kingdom Ministry of Defence were studied. The case studies focus on projects that are part of major programs for which performance based procurement was put in place rather than the more traditional prescriptive approach. These studies test how PBB was understood and used in practice by the project teams involved. They were analyzed and compared to each other so that lessons learned could be summarised. The Compendium 2 shows how to gather such data in a consistent way using the prepared template, so that more case studies can be collected in the future. This Compendium will be accessible at the CIB PeBBu Website. (Prior, J. J., Szigeti, F. & Oostinga, D. 2004)

State of the ART:

This Compendium project is the first of its kind in that it presents studies of completed building projects that were procured using a PBB approach. It is therefore in and of itself a "State of the Art" report. This Compendium and the other documents prepared for this task provide access to references, terminology and definitions, and related key word that give researchers an up to date view of the consensus about PBB reached in the course of the PeBBu project.

It should also be noted that Statements of Requirements are a key element in the ISO 9000 series of standards. To be able to measure quality, provide quality assurance and quality management systems, it is essential to explicitly state the requirements of the customer, and to include a process that ensure that the quality of the end product, expressed by a level of performance for a given cost, be measurable and verifiable. Thus this task makes explicit how PBB links to ISO 9000.

Inter-relations with other Domains/Tasks:

This team participated in the break-out sessions of all Domains during PeBBu meetings and presented at all PeBBu general meetings in order to help provide congruence between the work of the Domains and the overall PBB conceptual framework and to create a consensus about the use of terms and concepts.

This project was coordinated more specifically with Domains #2 – Indoor Environment, Domain #3 – PBB Design of Buildings, Domain #5 – Organisation and Management (closed), Domain #7 – Regulations, Domain #8 – Innovation, and Domain #9 – Information (closed).

1. The Domain #2 conceptual framework is congruent with the overall PBB conceptual framework. Both teams worked on the Domain #2 conceptual framework and terminology.
2. The team members of this task and Domain #3 collaborated on the application to the overall PBB conceptual framework of The Hamburger Model (Szigeti and Davis 2005).
3. A team member of this task provided written contributions to the Domain #5 report, in particular about the state of PBB in Canada.
4. A team member of this task provided written comments to the Domain #7 reports

5. The team members of this Task and Domain #8 collaborated on a Delphi Study of PBB Definitions.
6. A team member of this task collaborated with the Domain #9 leader to create a framework for the structure of PBB information, and a set of related key words for use in the research mapping task aligned with the PeBBu project.

Research Agenda:

This project did not specifically address a Research Agenda. On the other hand, the very nature of the Compendium 2 project was to study PBB projects and PBB Statements of Requirements (SoR), and to develop a methodology for further studies. It is very important for the implementation of a PBB approach to help stakeholders start projects with a better understanding of what works and what does not. PB Statements of Requirements are the cornerstone of projects and it is essential to the implementation of PBB that more examples of SoRs be generally available, including the lessons learned from such actual PBB projects. It is therefore recommended that such case studies of PBB projects be included as part of the Research Agenda for PBB.

Incentives for PBB Implementation:

Governments and businesses are "performance oriented" and "customer focused". In trade, as well as in business, there is a strong trend towards using a Performance Based approach, with the World Trade Organisation leading the charge. (Prior and Szigeti 2003b) Clause 2.8 of the Agreement on Technical Barriers to Trade of the World Trade Organisation (WTO 1997) states:

> *"Wherever appropriate, Members shall specify technical regulations based on product requirements in terms of performance rather than design or prescriptive characteristics."*

Although the WTO Agreement does not specifically apply to the Building and Construction sector, it is indicative of a strong trend towards a performance approach. The European Community and several European countries are also following suit as part of the general movement towards reducing barriers to international trade within the EU.

Validation and verification are important. At each hand-over point from Mission / Objective all the way to the last transaction in the supply chain, the basis for the decisions and choices should be as transparent and explicit as practicable. This is particularly true of procurements in the public sector and for publicly traded corporations, regardless of the specific procurement route. There are a number of countries moving significantly towards PBB as the basis of construction procurement, in particular in the public sector, such as in The Netherlands and in the UK. In the USA, the federal government has taken the lead in implementing a performance based approach to procurement in general and to the management of facilities in particular (US Government 1993, US Government 2004). Performance-based contracting is now mandatory. The USA Federal Acquisition Regulations (US Government 2000) state that:

> *"Performance-based contracting means structuring all aspects of an acquisition around the purpose of the work to be performed, with the contract requirements set forth in clear, specific, and objective terms with measurable outcomes as opposed to either the manner by which the work is to be performed or broad and imprecise statements of work."*

Barriers to PBB Implementation:

Starting a building and construction project using a PBB approach means that all stakeholders need to share an understanding of PBB. Expressing requirements in ""user" and "performance" language sufficiently precisely to be linked later to actual results is more difficult than in prescriptive language. There is not yet sufficient knowledge linking user and performance requirements to performance measured in use. This was shown to be a challenge within each of the case studies. Buildings and

constructed assets, as a whole, are subject to many variables while in use. Research about their performance in use is therefore expensive and time consuming, and the results are often difficult to interpret. More projects and PB Statements of Requirements need to be validated by studies such as those conducted by the RGD and included in this Compendium so that lessons can be learned from such experiences.

Dissemination and Implementation:

This project and its deliverables are part of the publications of the CIB PeBBu project and are included in the PeBBu Website. Dissemination within the PeBBu network has occured on a continuing basis throughout the project. It is also intended to publish the Compendium and the Case Studies as a paper based document. The Template and Interview Guide will serve others who want to undertake similar studies of Performance Based projects, as well as to those who want to start Performance based projects and prepare PB Statements of Requirements.

Conclusions:

Comments:
This Compendium 2 project was completed during the spring of 2005. Although the Compendium contains only a few case studies, some comments can be made, based on the findings from these case studies. Statements of Requirements have to be very carefully stated so that it is easy to verify that a proposed solution can explicitly meet those requirements.

High level statements of requirements need to be paired with indicators of capability so that design solutions can be evaluated before they are built in order to avoid misfits. In particular, the need for change has to be taken into account, since constructed assets have a long life, while uses, activities and requirements can change very rapidly. When checking a design solution against the "explicit and implicit" requirements for a project, it is essential to test different ways that the spaces might be used in order to anticipate changes. Otherwise a building, in whole or in part, can become very quickly unfit for the occupants.

Key Lessons from the Case Studies:

1. There is no such thing as a completely fresh start – existing documents that are cast as prescriptive / input requirements will continue to be used and cited in PBB projects, and used alongside output / performance requirements.
2. Typically, the higher level requirements are easier to describe in output terms – the separation of the detailed design response does not seem well developed from the case studies.
3. Some stakeholders involved in PBB projects will gain influence and authority, others will lose. There will therefore be resistance to the change.
4. Incomplete ability to foresee future demand may cause problems which are difficult to manage in a PBB context. For example, flexibility does not seem to have been well developed, judging from the case studies. On the other hand, this is a problem for all building projects, since buildings are "hard", fairly static, difficult to change unless planned that way, and long-lasting, whereas what people "do" is in constant change. Equally, without a measure of the changing match between demand and supply it is difficult to justify paying for increased flexibility to accommodate changing demand.
5. Spatial and environmental requirements tend to be set prescriptively, even though it would appear that, in principle, issues of foreseeability and acceptability of variable performance based on user requirements are equally applicable to these aspects of performance requirements as to any others.
6. The more successful projects include FM expertise from the outset. Integrated teams seem to be closely linked to the adoption of a PBB approach.

The projects studied show that PBB principles can be used in a variety of situations, such as: Technically challenging and innovative projects, Refurbishment and heritage projects, Long-term projects, and Commercial projects.

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ANNEX XXII: STATE OF ART SUMMARY REPORT FOR ADDITIONAL TASK: PEBBU PROTOTYPE INTERACTIVE WEBSITE TASK – A GUIDE TO PBB

Task Leader:

Marcel Loomans – TNO; Dik Spekkink – EGM; Mansi Jasuja – CIBdf

Task Website:

http://www.pebbu.nl/

Scope and Objectives

This is the report of an additional task that has been performed within the PeBBu Thematic Network Project. This report presents the framework for the PeBBu Prototype Interactive Website that has been the basis for the included content for the website. The content is provided for by the final reports from the separate Domains and Tasks. As the website is a prototype, it has a relatively simple lay-out and working procedure.

The intention of the (prototype) PeBBu interactive website is to open up (part of) the extensive PeBBu information to the interested parties in the building process. Furthermore, the website should be relatively straightforward and give good guidance to the most interesting information for the visitor. This means that the visitor can find the information that is of interest to him/her within a few steps. It was not the intention that all available information is gathered in this website. Instead, it should present an easy to use starting point that refers, through hyperlinks, to available stakeholder-specific information. This information, to a large extent is obtained from the PeBBu project.

Framework:

The best way to guide a visitor through the website is by identifying the main interest of that visitor in relation to the Performance Based topic. For that a more dimensional matrix normally would be required. To simplify this a 2-D matrix is applied with the stakeholder (e.g. the visitors profession) on one axis and building related (in the form of PeBBu Domain and Task) topics on the other. The latter has been chosen as it can be related directly to the PeBBu project and with that to the content that has become available. Figure 1 gives an impression of a part of the matrix.

	Prof. Client	User	Owner	Design team	…
Materials and components	>>	>>	>>	>>	
Indoor Environment	>>	>>	>>	>>	
Design of Buildings	>>	>>	…	…	
Built Environment	>>	..	…		
…	…				

Figure 1. 2-D Matrix as applied for PeBBu Prototype Interactive Website.

The ultimate idea is to complete for each combination of stakeholder and topic a separate web page with information and links to other sites that support this content. For some combinations there will be no or a very limited amount of information, other combinations may have an overlap in the information (i.e. reference to the same [type of] information). As the Task has a limited budget, only a section of the matrix contains links to separate information pages. Nevertheless, the structure is such that the open spaces can be filled along the way and there is no limitation to the content for a specific combination.

Result:

Below an impression is given of the result of the Task. As indicated above, within the Task it was not the intention to complete all possible combinations that follow from the developed framework. Figure 2 presents the introduction page for the pilot website. This page presents a short introduction to PeBBu and Performance Based Building (PBB) in general. Amongst others a reference is made to the mapping database which already contains a vast amount of information. Also, e.g., a listing of acronyms is given as in the building process acronyms are heavily used but not always (widely) well understood by the stakeholders. A link to a general presentation on PBB should help the visitor to gain a better idea of the main principle of PBB.

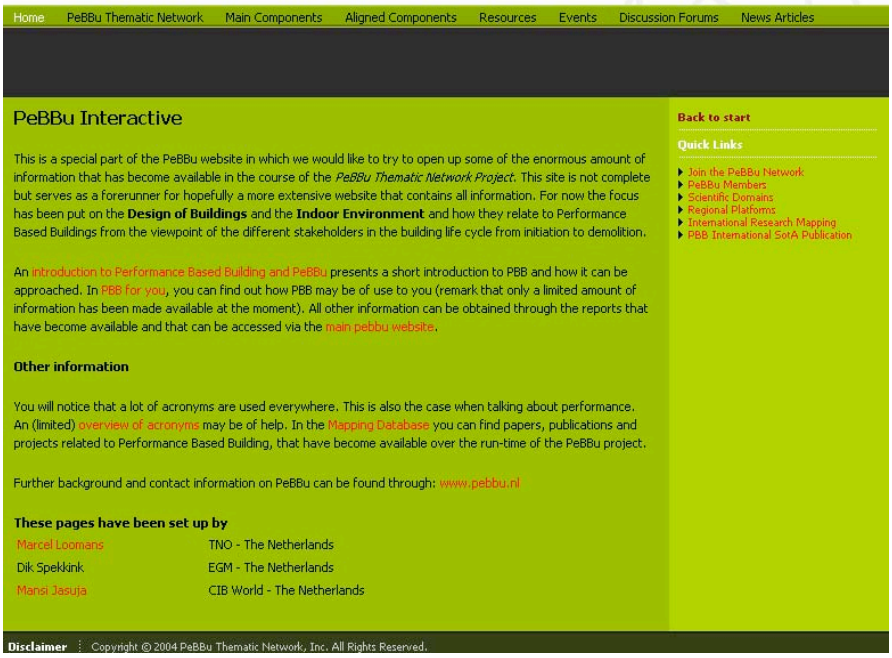


Figure 2. Introduction page – PeBBu Interactive.

After this (relative) general introduction the next step is towards the interested stakeholders. By identifying the stakeholder, the available information can be customised to that specific stakeholder. Figure 3 shows how this step is made. Here a selection should be made with respect to the general type of stakeholder that represents the background or interest of the visitor.

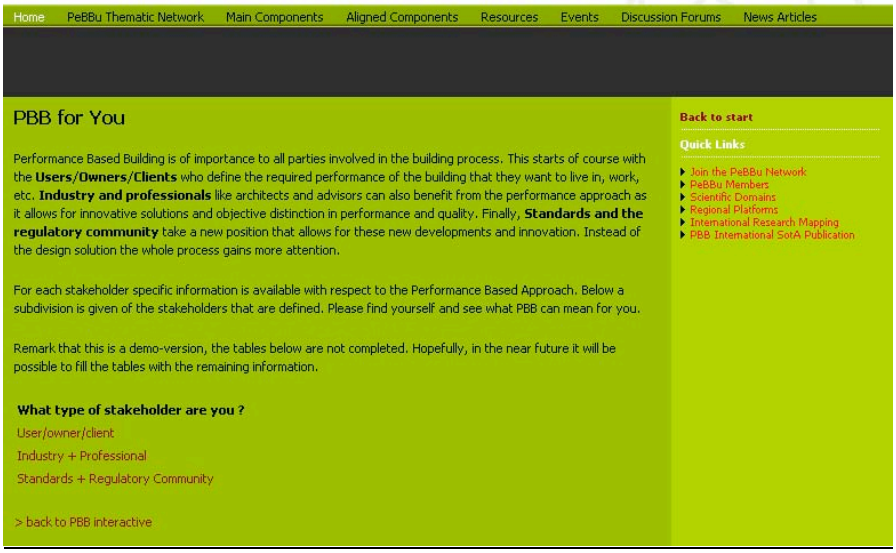
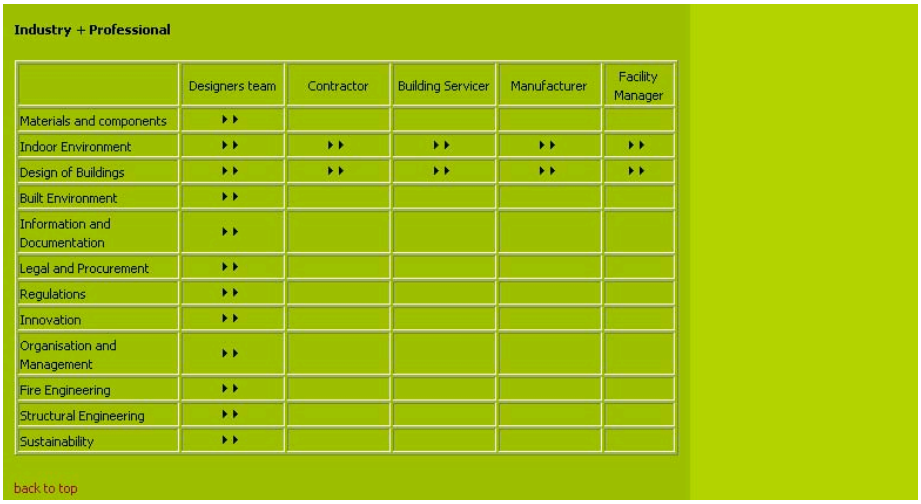


Figure 3. (general) Stakeholder identification.

To optimise the content for the user of the website, a further subdivision is provided for (see Figure 4). First, the general type of stakeholder is subdivided further. Besides, also a subdivision is provided with respect to the building and building process. As indicated, this subdivision is closely related to the subdivision of the PeBBu project (amongst others Domains and Tasks).



	Designers team	Contractor	Building Servicer	Manufacturer	Facility Manager
Materials and components	▸▸				
Indoor Environment	▸▸	▸▸	▸▸	▸▸	▸▸
Design of Buildings	▸▸	▸▸	▸▸	▸▸	▸▸
Built Environment	▸▸				
Information and Documentation	▸▸				
Legal and Procurement	▸▸				
Regulations	▸▸				
Innovation	▸▸				
Organisation and Management	▸▸				
Fire Engineering	▸▸				
Structural Engineering	▸▸				
Sustainability	▸▸				

Figure 4. Specification of stakeholder and building topic.

With the third step (i.e. the third activated link), the visitor opens the web page that provides the information on Performance Based Building that is tuned to the interest of the visitor (see Figure 5). Given the short route, and the overview provided by the tables as shown in Figure 4, it is hoped for that the visitor will also make side-steps to view information from other points-of-departure. The latter is regarded important as the application of the performance approach is supported by a better understanding of the interest and capabilities of the other stakeholders. This more or less is the first step towards an integral approach, which is required to fully take advantage of PBB.

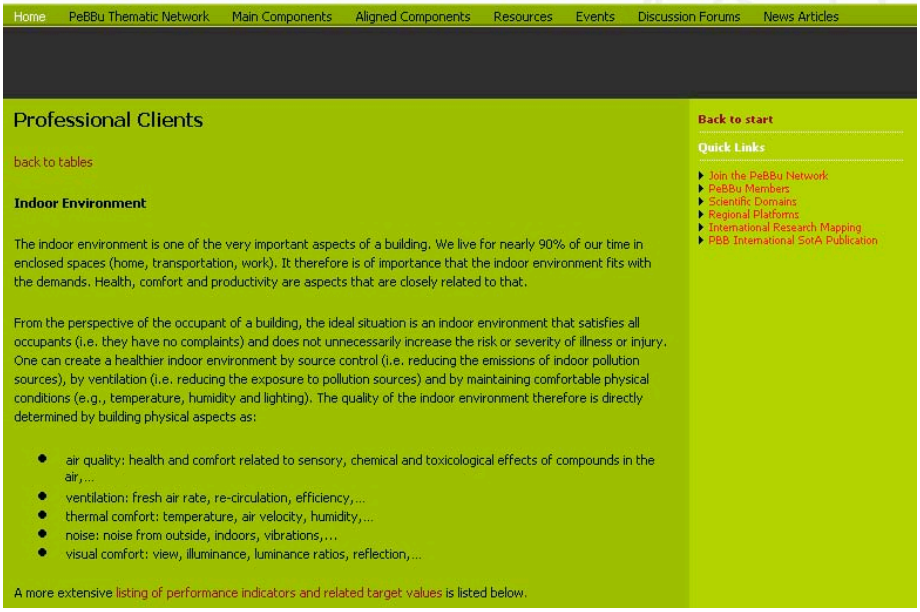


Figure 5a. Stakeholder and building topic specific content.

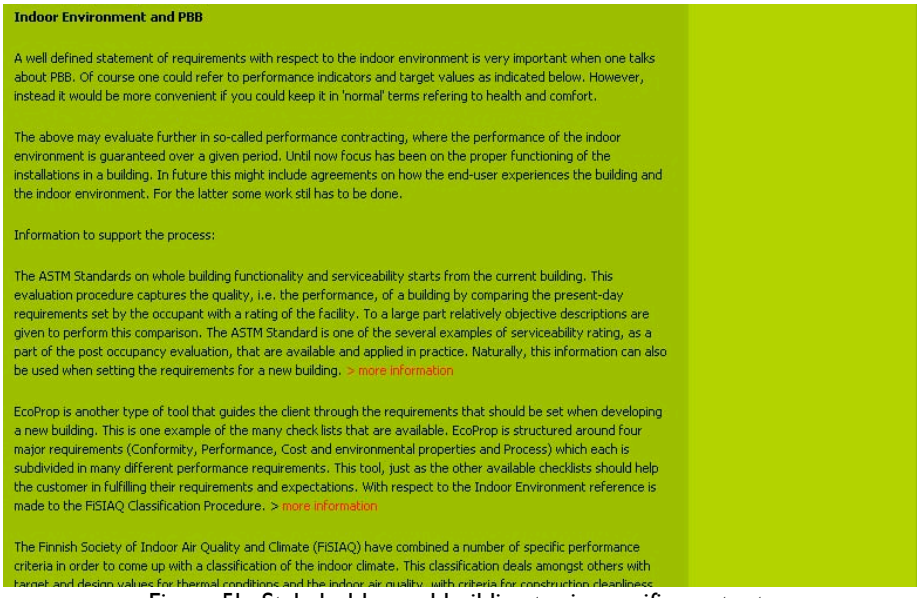


Figure 5b. Stakeholder and building topic specific content.

The content in the web pages, as visualised in the screen dumps shown in Figure 5, has been taken from the text that is available in, for example, the Domain reports. It was not the intention to rerun the project, it was the intention to better open up the information that has become available. Short textual information and links to further information (external websites or PeBBu related websites) therefore has been the procedure for developing this prototype website.

Conclusion:

The Interactive website will be accessible through the main PeBBu website (www.PeBBu.nl). The prototype as developed within this Task will be available at the end of the project. In this prototype the table as shown in Figure 1 will be filled (horizontally) for the building topic "Indoor Environment" and "Design of Buildings". Furthermore, (vertically) this will be done for the "Designers team" (stakeholder). It is hoped for that the website can be completed in due course, as this will increase the value of this website significantly.

ANNEX XXIII: STATE OF ART SUMMARY REPORT FOR NP1: NATIONAL PLATFORM – SWEDEN

Task Leaders:

Åke Skarendahl, Director, BIC - Swedish Construction Sector Innovation Centre, Stockholm; Christer Sjöström, Professor, University of Gävle

Task Website:

http://www.bic.nu

Everybody is supportive – few can make it happen!

The performance concept is crystal clear in its basic idea and it is no problems of getting a strong acceptance for its rationale in vide circles within the construction sector. The performance concept has received positive attention in Sweden since the end of the 1950s. Swedish researchers have been quite active in various national and international projects aimed at developing and promoting performance thinking in building. Authorities and standardisation bodies have taken initiatives, some positive results have been delivered, test applications have shown significant profits and the actors in the sector have been supportive.

So far so good! Application of the performance concept is common practice in most industrial sectors. However, in construction we are still far from routine adoption and good examples of breakthrough applications are still scarce. Why?

The problem is likely to partly depend on the complexity of the process within which the concept is to be realized. Performance is closely connected to end customer values. Obvious difficulties lie in understanding as well as in describing user values and in the determination of conformity of the delivered products with these values. Here the construction sector has similar challenges as other sectors and as is the case in other sectors they should be solvable.

A more difficult and critical obstacle is the very organisation of the construction process. The value chain is extremely fragmented with several deliveries within the chain. The procurement process is still by large relying on detailed technical specifications with the lowest price as the only decisive requirement. In the beginning of chain the performance of the delivered products have little relevance for the end user values. When a product finally meets the user there are limited possibilities for dialogue and influence. There is an obvious need for a change!

Who has the key?

The fragmented and sequential value chain characterising the construction sector is likely to in itself, constitute a severe hindrance for a successful application of the performance concept. What is needed is a holistic view of the entire process in development of a product, or in realisation of a project and in maintaining an asset as is often the case in construction. Who has the key to do this? This is likely to require either a strong client or a strong contractor being in charge of the whole process. However, virtually anyone can volunteer to take the initiative to play this role. It is not a matter of which actors are producing what but who has the full responsibility of what is to be delivered to the end customer.

This can be compared with other sectors, e.g. the car industry. There are a large number of independent companies involved in producing components of a car, normally the majority of the value added. There is however only one having the full responsibility of design, quality, performance etc. of the product to be delivered to the end customer. In such a case the interface between the end user and the product responsibility is clear and natural.

Performance approach instrumental for innovation climate

The construction sector is often, rightfully, accused of having severe problems in low – if any - productivity increase, in lack of ability of avoiding problems like the sick building syndrome, in difficulties in achieving zero-fault in delivered products, in limited success in improving energy efficiency, in a vague response to end user needs and in constantly increasing costs. The innovation climate in the sector is unfavourable, yet creativity and innovation are likely to be some of the most important vehicles for a change.

The conclusion that the introduction of a performance approach in the construction sector is strongly hampered by the fragmented and sequential nature of the sector is equally valid when it comes to innovation. The launching of new products and new services that survive on a competitive market has to be based on a close compliance with user performance requirements. Innovation, in the same way as performance approach, requires a holistic view incorporating the whole process. In addition, a holistic approach also encourages concurrent action in the development making reduced lead-times possible. The relay has to be replaced by integration and concurrent mode of work. Performance concept is essential for innovation!

BIC - Swedish Construction Sector Innovation Centre

In order to improve the innovation climate in the sector as well as to stimulate increased efforts in developing innovations, BIC - the Swedish Construction Sector Innovation Centre (www.bic.nu) has been established. Innovation requires end user focus, activities covering research, development, demonstration implementation etc. as well a sector-wide engagement. To be able to cope with this holistic approach, BIC has members representing authorities, sector actors (asset owners, designers, contractors, suppliers) as well as the research society.

BIC is an innovation broker being a sector partner to the state research funding organisation in support of innovation projects consisting of research as well as implementation tasks. In addition to structuring financial and organisation of innovation projects other brokerage activities cover knowledge, expertise, networks as well as mapping of needs/possibilities.

A Swedish National Platform

The performance approach is closely linked to the development of innovation systems as well as in improving the innovation climate. The obvious interlinking between performance approach and innovation system development leads to the conclusion that a combined approach is relevant. This is done in a national effort in Sweden with BIC as the platform.

The objective of the platform is to encourage development of the Swedish construction sector through increased use of performance based legal frameworks, standards and specifications, development of evaluation tools, indicators and criteria. The strive towards the use of performance based procurement practice is equally important.

The platform is working through creating interaction, normally through meetings between users, clients, code writers, standardisation bodies, designers, contractors, suppliers, and knowledge providers targeting

the use of performance approach in innovation processes. It also supports the use of performance approach in mainstream routine construction activities.

International dimension

Legal frameworks as well as standards are increasingly turning international in character. This sharpens competitiveness and increases trans-national trade of products and services for the benefit of the end users. International cooperation in the work of promoting development within performance as well as in innovation is thus an evident objective.

BIC as well as other partners of the Swedish platform are taking part in the PeBBu network. The Swedish platform for performance based building and innovation is a national activity but a strong international linking, preferably through the PeBBu network, is within the objectives and will be further developed. The forthcoming meeting of the PeBBu North European Platform will be arranged by its Swedish partner.

For more information on the PeBBu Swedish Platform, please contact: Mr. Christer Sjöström, at: christer.sjostrom@hig.se

ANNEX XXIV: STATE OF ART SUMMARY REPORT FOR ARP: ALIGNED REGIONAL PLATFORM – AUSTRALIA, AUS-PEBBU

Task Leader:

Program Director: Dr Greg Foliente, CSIRO; Deputy Program Director: Dr Phillip Paevere, CSIRO; Program Coordinator: Peter Boxhall, CSIRO.

Task Members:

Brian Ashe, Australian Building Codes Board; Dr Steve Brown, CSIRO; John Carson, Australian Building Codes Board; Dr Ivan Cole, CSIRO; Dr Peter Newton, CSIRO; Dr Lam Pham, Australian Building Codes Board; Peter Scuderi, CRC for Construction Innovation; Dr Selwyn Tucker, CSIRO.

Task Website:

http://www.auspebbu.org/

Scope and Objectives:

The Australian Performance Based Building Network (Aus-PeBBu) is a group of researchers and building industry representatives who are participating in the activities of the European Union PeBBu program. Aus-PeBBu is also running activities (working groups, industry seminar/workshops and a web-site) aimed at promoting performance based building in Australia. CSIRO's Division of Manufacturing and Infrastructure Technology has received industry and CSIRO support and a three-year funding grant (from July 2003) from the Australian Government's *International Science Linkages* programme to operate Aus-PeBBu.

Network Structure and Technical Domains:

The structure of the Aus-PeBBu network is shown in Figure 1. The Secretariat, based at CSIRO Manufacturing & Infrastructure Technology, Highett, Victoria, comprises:

- Program Director - Dr Greg Foliente
- Deputy Program Director - Dr Phillip Paevere
- Coordinator - Peter Boxhall

The network incorporates seven technical domains, each of which has a coordinator and a working group of three to five members. This framework is similar (but not identical) to that of the European PeBBu network. The coordinators of the domains are:

- Domain 1: Building Materials and Components – Dr Ivan Cole, CSIRO
- Domain 2: Indoor Environment – Drs Steve Brown and Philip Paevere, CSIRO
- Domain 3: Building Design and Engineering – Dr Lam Pham, Australian Building Codes Board
- Domain 4: Environmentally Sustainable Built Environment – Drs Greg Foliente and Peter Newton, CSIRO
- Domain 5: Innovation - Peter Scuderi, CRC for Construction Innovation
- Domain 6: Legal and Procurement Matters – Dr Selwyn Tucker, CSIRO

- Domain 7: Building Regulations and Standards – Brian Ashe and John Carson, Australian Building Codes Board

Aus-PeBBu's domains are predominantly concerned with advancement in the following three key areas:
- the description of appropriate building performance requirements
- methods for delivering the required performance (reliable methods and tools for design and analysis)
- methods for verifying that the required performance has been achieved.

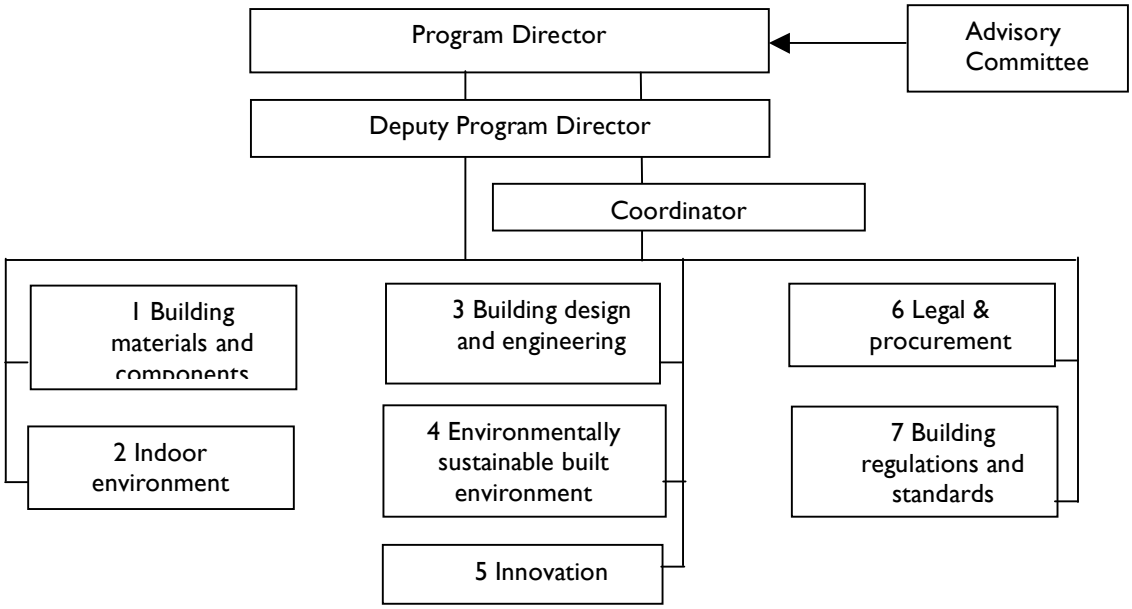


Figure 1 Aus-PeBBu Network Structure

Industry Participation

Key Participants

Participation in any technical domain is open to any company, association or individuals in the building and construction industry. Key participating organisations include:
- CSIRO
- Australian Building Codes Board
- Cooperative Research Centre (CRC) for Construction Innovation
- Australian Procurement and Construction Council
- International Alliance for Interoperability - Australasian Chapter

Project Advisory Committee

Aus-PeBBu's program director is provided with ongoing independent advice by a four person external Advisory Committee, which consists of prominent representatives of key stakeholder groups in Australia's building and construction industry – see Table 1.

Table 1 Project Advisory Committee

Name	Position/Background	State
Judith Carr	Executive Director – Building Management, Department for Administrative and	SA

	Information Services, South Australia	
Andrew Clowes	Associate Director - Information and Strategic Technology, Jones Lang LaSalle, Brisbane	QLD
John Macdonald	Director, Design Inc, Melbourne	VIC
Dr George Walker	Research Director, Aon Re, Sydney	NSW

The Advisory Committee members have been meeting (face-to-face or teleconference) with the Aus-PeBBu Secretariat about twice a year, as well as having occasional e-mail communication and participating in project seminar/workshops.

The main purpose of the Advisory Committee has been to provide the Aus-PeBBu management group with broad advice across all building domains as well as advice relating to effective dissemination of PeBBu outputs to the Australian building and construction industry.

Participation in EU PeBBu Domain Meetings:

Aus-PeBBu has been represented at all of the EU PeBBu domain meetings held since the commencement of Aus-PeBBu in July 2003.

The Manchester meetings (12 to 14 January 2004) were attended by:
- Selwyn Tucker (PeBBu Domains 1 and 6)
- Greg Foliente (PeBBu Domains 2 and 8 meetings and the Technical Committee meeting)
- Lam Pham (PeBBu Domain 3)
- John Carson (PeBBu Domain 7).

The participants at the Porto domain meetings (17-19 November 2004) were:
- Selwyn Tucker (PeBBu Domains 1 and 6)
- Steve Brown & Phillip Paevere (PeBBu Domain 2)
- Lam Pham (PeBBu Domain 3)
- John Carson (PeBBu Domain 7)
- Peter Scuderi (PeBBu Domain 8)
- Greg Foliente (various domain meetings and the Technical Committee meeting).

Brief reports on, as well as the Australian presentations to, these domain meetings are available on the "Program & Domains" page of the Aus-PeBBu web-site (see below).

Five Aus-PeBBu representatives also attended the final EU PeBBu meetings and conference sessions held in conjunction with the CIB Symposium in Helsinki, 13-17 June 2005 – Greg Foliente, Phillip Paevere, Peter Scuderi, Selwyn Tucker and John Macdonald (from Aus-PeBBu's Advisory Committee).

Aus-PeBBu Web-site and Communication with Australian Industry:

An Aus-PeBBu web-site, www.auspebbu.org, is being used, in combination with e-mail, as the main means of communication with building industry stakeholders and as the main vehicle for providing Aus-PeBBu Domain coordinators and Working Groups with access to EU PeBBu reports and network information. The web-site also incorporates a compendium of building performance models, including a new guide to environmental design and assessment tools.

Information on both EU PeBBu developments and Aus-PeBBu activities has also been communicated to Australian building industry stakeholders by means of news articles in selected building industry publications, notably the newsletters of the CRC for Construction Innovation (e-mail distribution to 1700

building industry stakeholders). In addition a major article by Aus-PeBBu's program director was published in the 30 April 05 edition of the Australian Building Codes Board's "Australian Building Regulation Bulletin" (readership 18,000 plus).

Aus-PeBBu Seminars:

The other major means of communication with industry has been seminars, of which there have so far been four, with a final one scheduled for March 2006.

Aus-PeBBu National Launch

Aus-PeBBu was officially launched in Melbourne on 8 October 2003 by Dr Sherif Barakat and Dr Wim Bakens, the President and Secretary General, respectively, of CIB. (The Aus-PeBBu launch was arranged to coincide with a week of CIB Board meetings being held in Melbourne.) The launch took the form of a morning seminar and panel discussion and was attended by 25 Australian building industry stakeholders (from industry, government and research organisations) in addition to 5 international CIB Board members.

Industry Seminar 24 June 2004

Around 40 building industry stakeholders attended Aus-PeBBu's second industry seminar, "Innovation and Trade through Performance-Based Building and Construction", which was held in Melbourne on 24 June 2004. In addition to speakers from Aus-PeBBu covering the latest developments from EU PeBBu, keynote speakers from Japan and Singapore were invited to outline the current state-of-play in their countries, where the introduction of performance based building is well advanced.

Assoc Prof Siew Eang Lee, Director of the Centre for Total Building Performance at the National University of Singapore, presented best practice case studies of performance based buildings in Singapore. Mr Wataru Gojo, Head of the Standards and Accreditation System Division of the Building Department, NILIM in Japan, presented features of Japanese building regulations and the Japanese performance indication system for houses.

Other speakers were Aus-PeBBu network members, Drs Greg Foliente and Lam Pham from CSIRO and Advisory Committee member, Dr George Walker from Aon Re (Insurance) Australia. The seminar concluded with a facilitated session aimed at obtaining industry feedback on how best to advance performance based building practice in Australia. All of the seminar presentations are available on the Resources page of www.auspebbu.org

"Clients Driving Innovation" International Conference, 25 to 27 Oct 2004

The third Aus-PeBBu seminar was held in conjunction with the International Conference "Clients Driving Innovation" on Queensland's Gold Coast, from 25 to 27 Oct 2004, hosted by the CRC for Construction Innovation. This provided the opportunity to disseminate information to a much wider industry audience than would otherwise have been achievable (there were 210 attendees).

A session of presentations by five of the Aus-PeBBu domain coordinators was preceded by a key-note conference presentation by Greg Foliente (Co-author: Prof John Kelly from Glasgow Caledonian University) – "Client-Driven Innovation through the Performance Approach and Value Management".

The topics covered in the Aus-PeBBu session were performance criteria for indoor environments, the European Construction Products Directive, service life performance and planning, environmental labelling of manufactured products and stakeholder engagement in the performance approach. These and the key-note presentation are available on the Resources page of www.auspebbu.org.

Australian Building Codes Board Conference, 11 to 16 September 2005

The most recent Aus-PeBBu seminar was run jointly with the APEC Informal Network on Performance Based Building (see Section 8 below). This was held in conjunction with the Australian Building Codes Board Conference and IRCC Global Policy Summit in Surfers Paradise, Queensland, from 11 to 16 September 2005.

The seminar, entitled "Assessing Building Performance – An Integrated Model", was presented by Danny Shiem-shin Then, Associate Professor in Facility Management and Asset Maintenance at The Hong Kong Polytechnic University. (Danny Then is also the current Joint Coordinator of Working Commission CIB W70 on Facilities Management and Maintenance, and Director of Research of the Hong Kong Institute of Facility Management.)

The presentation considered performance measurement of building assets as operating facilities, with a prime focus on the relationship between building assets and their contributions to business outcomes.

CRC for Construction Innovation, 2nd International Conference, March 2006

Aus-PeBBu is to be a Gold Sponsor for the CRC for Construction Innovation's 2nd International Conference, "Clients Driving Innovation: Moving Ideas into Practice", to be held in Queensland from 12 to 14 March 2006.

This arrangement will give Aus-PeBBu a keynote (international speaker) session, linked to presentations by Aus-PeBBu network members in other sessions of the conference. This forum will be used to communicate to industry the final outcomes from the European and Australian PeBBu networks.

Asia Pacific Network:

Aus-PeBBu has recently extended its informal network to East Asia, with counterparts in China, Hong Kong, Indonesia, Japan, Thailand, The Philippines, Singapore and Vietnam.

The first seminar-meeting of the APEC Informal Network on Performance Based Building (APEC-PeBBu) was held in conjunction with the Australian Building Codes Board Conference and IRCC Global Policy Summit in Surfers Paradise, Queensland, from 11 to 16 September 2005. The main focus of the first meeting was familiarization with the current building regulatory systems in each of the participating countries, based on submissions and brief presentations by each of the delegates.

Key Reports and Publications:

Other notable outputs from Aus-PeBBu include the following key reports and publications:

- Pham, L. 2005. "The EU Construction Products Directive – An Introduction", CMIT Doc, Highett, Victoria, Australia, January 2005. (Note: This is an introduction to the EU Construction Products Directive, written for Australian Industry stakeholders.)
- Bakens, W., Foliente, G.C. and Jasuja, M. 2005. "Engaging the stakeholders in performance based building: Lessons from the PeBBu network", Building Research & Information 33(2):149-158..
- Foliente, G.C., Bakens, W. and Jasuja, M. 2005. "Stakeholder engagement in the performance approach – The Australian and European Performance Based Building Networks" Chapter in K Hampson et al. (eds.), *Clients Driving Construction Innovation: Mapping the Terrain,* Pearson Publishers, Australia, in press.
- Foliente, G.C., Tucker, S. and Huovila, P. 2005. "Performance-based framework and applications for nD Models in building and construction", in P Huovila (ed.) Performance Based Building, RIL,Helsinki, Finland.
- Foliente, G.C., Boxhall, P. and Pham, L. 2005. "Facilitating Innovation & Enhancing Trade – The Performance-Based Building Networks in Australia & Asia", in P Huovila (ed.) Performance Based Building, RIL,Helsinki, Finland.

- Foliente, G., Seo, S., and Tucker, S. 2004. "A guide to environmental design and assessment tools". BDP Environmental Design Guide. (GEN 57, 8 pp.) , Building Design Professionals of Australia, Melbourne.
- Huovila, P., Leinonen, J., Paevere, P., Porkka, J. and Foliente, G. 2004. "Systematic performance requirements management of built facilities." Procs. International Conference on Clients Driving Innovation, CRC Construction Innovation, Gold Coast, Australia.

ANNEX XXV: SUMMARY REPORT FOR NN1: NATIONAL THEMATIC NETWORK – ISRAEL, ISR-PEBBU

Task Leaders:

Becker, R. (Task), Paciuk, M. (Website)

Task Members:

Becker, R. (Technion), Paciuk, M. (NBRI), Pilzer, D. (Ministry of Interiors), Baum, H. (NBRI), Shohet, I. (Ben-Gurion Univ.), Wasserman, R. (NBRI), Binun, E. (Inst. Of Stand.), Bar-Asher, N. (Ministry of Interiors), Rosenfeld, Y. (Technion)

Task Website:

www.technion.ac.il/~isrpebbu

Scope and Objectives:

One of the leading objectives of the PeBBu Network aims at facilitating and stimulating implementation and dissemination of the principles of PBB at national level. To achieve such an objective, it is essential that existing knowledge, documentation and deliberations related to PBB, which has evolved throughout the years, becomes available to all stakeholders involved in local building and construction practices.

Although a wealth of documentation has already been made available at the EU PeBBu website, Israeli practitioners and builders do not generally master the English language to the extent that allows for an easy and fluent understanding of the available texts. It was therefore considered of utmost priority to develop a Hebrew-based website with two initial purposes: 1) coalesce in one site existing resources in Hebrew, which have direct relevance to the PBB concepts, thus making them easily available to the Israeli building sector at large, and 2) establish a PBB-related communication and discussion platform for the target stakeholders at national level (designers, builders, manufacturers, suppliers, entrepreneurs, code writers, standardization body, innovators).

Deliverables:

The website is structured to be bilingual (English and Hebrew), though at this stage – given the above considerations – efforts are geared toward elaborating its Hebrew contents. The site is comprised of the following domains:

- Home – Statement of the PeBBu Thematic Network's objectives and links to EU-PeBBu and to the National Building Research Institute at the Technion, coordinator of ISR-PeBBu.
- Contents – Documents providing an overview of the performance concept in building and its applications at national level.

  The presently available documents illustrate the state of the art in various areas, such as implementation of PBB in the local building activity, the discipline of Building Performance from an academic point of view, the development of a national research agenda in Physical Performance of

Buildings, the application of the performance approach in standards, and its implementation in the rewriting of building regulations.

In a future stage, PBB-related documents in English and main conclusions of the PeBBu Thematic Network will be translated into Hebrew and added.

- Resources – Lists of available PBB-related bibliographical resources, both in Hebrew and in English.

  Listed resources in Hebrew include general PBB references, Israeli Standards featuring performance based requirements and performance-related reports and handbooks written and published by the National Building Research Institute and which may be ordered through the site.

  Listed resources in English include CIB originated reports and proceedings in PBB areas, as well as performance-related papers published by Israeli researchers in international journals and proceedings.

  Whenever possible, electronic versions of the above listed resources are made available.

  In following development stages, the most relevant published PeBBu Network updates and reports (in English) will be translated into Hebrew and made available at the site.

- News and Events - List of ongoing and future PeBBu related activities at national and international level.

  Present national news and events include an update on the ongoing effort - led by the Ministry of Interiors - to prepare an entirely new set of performance-based regulations, the recent launch on CD of Thermo-Kar - a computerized system that enables checking compliance of building envelope elements with thermal insulation and energy conservation requirements stipulated in the Israeli Standard SI 1045, and the up-coming national conference on building and infrastructures – organized by the Israeli Engineering Organization – where a number of presentations on building performance related subjects will be given.

- Links – List of PeBBu related websites and additional sites in the general area of Performance Based Building.

  The provided links feature academic institutions, research centers and professional organizations, both at national and international locations.

- About the network – Basic information about the structure of the international PeBBu Network and of the national ISR - PeBBu Network.

  The objectives and main components of the international network are overviewed.

  As for the national network, the names and tasks of its Steering Committee members are presented and basic information for membership application and for enquiries is provided. Potential additional members as well as visitors to the site are asked to input pertinent information with the purpose of creating a data base of Israeli stakeholders in the area of Performance Based Building.

In the near future a forum for discussion among network members will be activated.

ANNEX XXVI: EXECUTIVE SUMMARY OF NAS REPORT: NAS – NEWLY ASSOCIATED STATES OF EUROPE

Task Leaders:

Dr. Károly Matolcsy, ÉMI npc, Hungary, kmatolcsy@emi.hu; Gábor Tiderenczl, PhD., ÉMI npc, gtideren@emi.hu; Dr. Peter Matiasovsky, Slovak Academy of Sciences, Slovakia, usarmat@savba.sk

Task Members:

Mrs. Evelina Stoykova, Sofia Energy Centre, Bulgaria; Ing. Milos Kalousek MSc., Brno University of Technology - Faculty of Civil Engineering, The Czech Rep.; Mr. Piotr Bartkiewicz Warsaw University of Technology - Institute of Heating and Ventilation, Poland

Task Website:

http://www.pebbu.nl/maincomponents/nasexpansion/

Scope and Objectives:

Connected to the overall objectives for the PeBBu Network, the specific objectives of the NAS extension:

- to stimulate and facilitate a maximal alignment between the international PeBBu activities and national research and dissemination activities concerning the development and implementation of PBB in the countries,
- to initiate and facilitate the establishment of National or Transnational PeBBu Platforms in the NAS countries,
- to attract new PeBBu members / observers from the NAS countries

The main work objectives:

- to organise special NAS workshops
- to develop the NAS State of the Art Report in 3 phases
- to attract new members or observers

Conceptual Framework:

In the course of 2001, when it became obvious that the EU would be expanded to include the EU-NAS – Newly Associate States, the response of the PeBBu Network was to manage a **PeBBu NAS expansion** that formalised through a PeBBu contract amendment in the beginning of 2003**.** This ensures a **complete European perspective for the stimulation and establishment of Performance Based Building practices**.

One of the main tasks under the PeBBu **NAS programme** was to produce a **State of the Art Report** on PBB in the NAS countries. The **PeBBu NAS State of the Art Report** addresses the background, the present situation and the vision and strategies of future implementation of PBB – Performance Based Building in the respective NAS (newly associated states of Europe) countries. Task

members are 13 organizations from **Bulgaria, Czech Republic, Hungary, Lithuania, Slovakia, Slovenia and Poland.**

The **NAS SotA Report aims** to enlighten, why the NAS countries show plenty of **common features** even if they are belonging to different regions, different language families, they have different historical background, different size and economical situation. A main feature of this report is to investigate the situation, the barriers and the opportunities of PBB related to the **historical background** of the NAS countries that strongly determined the possibilities of PBB and still influence the development of the construction sector. First of all this is due to the artificial socio-economical system that developed in these countries after the 2nd World War during the time of socialism.

The NAS members discussed also the status of PBB in general in the NAS countries considering the **PeBBu scientific domains & other domain areas**. **Vision to the future and overall strategies** of PBB implementation in the NAS countries were also determined by the partners. A **table of barriers, strategies & actions** related to historical periods were worked out and several **best-practice examples of PBB** in the participating countries were presented. The NAS Status Report also reflects these achievements.

Accomplished Workplan:

The PeBBu NAS Status Report was prepared on the bases of the lessons learned from:

- PeBBu workshops
- Special PeBBu NAS workshops
- PeBBu documents
- Contribution of the PeBBu NAS members
- Relevant literature
- Scientific background of the task leaders

For assisting the preparation of the report **two special NAS workshops** were organised by the task leader, both in Budapest, Hungary and there was also an informal NAS workshop held on the Manchester meeting. The first meeting was joined to the first series of PeBBu workshops on the 27th of March 2003. After this workshop a **first version of the NAS report** was prepared. A **first draft for commenting** was prepared by the task leader and sent to all NAS members. After further work conducted by the task leaders, Dr Angela Lee and Professor Peter Barrett (University of Salford, UK) assisted the preparation of this first version. For developing the NAS Status Report, a second workshop was organised in Budapest, Non-profit Company for Quality Control and Innovation in Building (ÉMI npc) in the 9th of July 2004. The minutes of the meeting was prepared by Dr. Gábor Tiderenczl (ÉMI npc) and sent out for commenting among all NAS members. On the bases of the lessons and documents connected to this workshop and the advanced PeBBu work during this period, the first version of the NAS Report was changed in many aspects and developed further by the task leaders. This **2nd version of the NAS Report** was also sent out to the NAS member and to Mansi Jasuja, the Programme Manager of PeBBu. The report was finalised on the bases of the comments from the members and from the PeBBu Secretariat.

The **final version of the NAS Report** was developed in the last year of the PeBBu work. The NAS members had **two workshops** during this time. The first workshop was organised in the 11th of April 2005 in Bratislava. On this workshop the PeBBu NAS State of the Art Report was presented. Presentations and discussions were made on barriers and opportunities of PBB in the NAS countries, best practice options, visions, strategies and actions of implementing PBB in the NAS countries. Also the next tasks were discussed and approved on this workshop. The last workshop was organised in the 21st of July 2005 in Sofia. On this workshop further best-practice examples were presented, the differences in content and approach of the NAS Report and the EEP Report were discussed, final PeBBu tasks and necessary contributions were discussed and approved. After preparing the "final draft" of the NAS Status

Report, it was sent for **commenting** to all partners and also to the PeBBu Domain leaders. After integrating all received comments, the NAS Status Report was finalized during August 2005.

State of the Art:

The State of Art of NAS is reviewed on the special PeBBU NAS State of the Art Report. The **scope** of the PeBBu NAS Report is to give an analysis of all aspects of potential relevance to the envisaged future implementation and actual application of PBB – Performance Based Building in the respective NAS (newly associated states of Europe) countries. Task members are representatives from Bulgaria, Czech Republic, Hungary, Lithuania, Slovakia, Slovenia and Poland.

The **objective** of the Report is to present the background and the Status of PBB in the NAS countries with special focus on the ongoing PeBBu scientific domains and other PeBBu domain areas. Further **aim** is to provide a future vision and strategies for the implementation of PBB in the NAS countries in general and in the PeBBu domain areas.

The **1st chapter** describes the **historical background** of the NAS countries, summarizing the main common characteristics of history that determined the possibilities of PBB and still influence the development of the construction sector. After the WW II all of the NAS countries were occupied by the Soviet army, and within some years became **soviet satellite states** with a very similar structure. An artificial socio-economical system was developed that determined the development of he construction sector and the possibilities of implementing the concept of PBB. There were special barriers of PBB due to this artificial system. In 1989/1990, the soviet systems collapsed, and new, democratic states were established. A **transition period** started from a planned economy to a market oriented economy in 1990s with consequences and changes in every sphere of life. New barriers raised and the PBB thinking became even weaker than it was before the changes. In 1995 the NAS countries applied for EU membership and in the 1st of May 2004 ten of these European nations became **member states of the EU**. This situation gives new challenges and also new opportunities for these countries. These challenges and opportunities determine the development of the construction sector and the possibilities and strategies of further implementation of the PBB concept

The **2nd chapter** of the report analyses how the **construction sector** has been developed in the NAS countries, that determines also the barriers and opportunities of PBB. The former socialist system determined the development of the sector with the dominant role of the state and the practice of industrialization and mass production, that resulted a significant construction boom but with low quality buildings. Opportunities of getting proper building materials were very low, the lack was the most general feature and generally the performance criteria was adjusted to the only available solution. The changes in the sector during the transition period occurred as a consequence of the former building practice. The strong role of the public sector stopped and there was a high decline in the production. The market type building demand became dominant and the investor began to be a dominant partner that often resulted in the lack of acceptable architectural quality. International companies have had a continuously increasing role. The transition period had also its difficulties as low skilled workers, low workmanship, low onsite safety, lack of quality inspection, instable financial background, high corruption rate and extremely high black market. Also the problem of housing affordability emerged. On the other hand all up-to date products are available and there are several prominent investments in the NAS. The special situation of the construction sector results also a special status of PBB in the NAS countries.

The **3rd chapter** describes the **status of PBB** in the NAS countries. Building activities in the NAS countries are the least performance-based among the PeBBu regions. Although CPD is entirely implemented in the NAS countries, the standardisation process is still rather weak and perspective in character. As a result of the NAS countries' accession to the EU, it is expected that also the introduction of the performance concept will accelerate. There is a general agreement among professionals of its wider introduction.

The **4th chapter** aims to point out the general **barriers and opportunities of PBB** according to different historic periods in the NAS countries, namely before the political changes, in the transition period and after the EU extension. In the time of socialism, special barriers obstructed the implementation of PBB in the artificially isolated NAS countries, as the mass production, the COCOM list, the PLAN driven economy, etc. Most of these features are already over but some of them are still living or have influence. As regards the implementation of PBB, after the political changes new barriers and opportunities raised. There are still remnants of socialist mentality and short term thinking. Lack of holistic approach, lack of cooperation, lack of finance, the weak credit systems and the low level of responsibility are all strong barriers. On the other side the transition period resulted also new opportunities, as the CPD implementation, the availability of new products and high quality buildings. The EU extension gives again new barriers and opportunities for PBB implementation in the NAS countries. Opportunities are partly related to obligations. New barriers can be some deformations of the market, influence of some interest groups, cartel agreements, tax policies or governmental decisions. On the other hand the free market environment and the support for several sectors provide new opportunities for PBB in general and in the various domain areas.

The **5th chapter** addresses the **status of PBB in the 6 ongoing PeBBu domains**: Life performance of construction materials and components; Indoor environment; Design of buildings; Legal and procurement practices; Regulations; Innovation. On the bases of the current situation some strategies are listed that can serve the future implementation of PBB in the discussed scientific area.

In **Domain 1 "Life time of building materials and components"** we can see a development of quality and plenty of new up-to-date products, a product evaluation system and developing standards on one hand, however still plenty of low quality items on the market on the other hand. There are several researches related to durability issues, however few reference service life data are available and the factor method is not used in the NAS countries. Well defined performance criteria, indicators, measurement and simulation tools are needed for further development.

Regarding **Domain 2 "Indoor climate"**, there are legal regulations containing requirements on the maximum concentration of certain pollutants. There are many problems of moulds. In practical design generally only aspects of comfort are considered, a more holistic approach to indoor climate and healthy building is seldom realised and this would be needed. Strategies should also address simulation, modelling and testing tools in order to predict complex indoor environment performances and also training special designers for indoor climate.

As regards **Domain 3 "Design of Buildings"**, the former large state building design companies operated in the NAS countries divided into small design offices and the new situation caused new problems as well. In practice the successful PBD usually depends explicitly on the responsibility and possibilities of all decisive partners and their quality, but mainly on architect - client cooperation. Unfortunately, architects generally have a narrow orientation. Often "Ideal catalogue construction solutions" are applied and no explicit criteria and methodologies of the whole building performance monitoring and testing is used. A main barrier of PBD is that particular design participants do not consider the construction and its results as one complex system. Explicit performance criteria, less empirical approaches, more complex tools & databases, whole life education & training are needed as a strategy.

Concerning **Domain 6 "Legal and Procurement practices",** building affairs belong to the public administrational proceedings in the NAS countries. As former former Ministries responsible for construction were ceased, responsibility for sector was distributed among 3-8 ministries. Inefficient operation was the consequence and especially housing policy became critical. The development of the institutional background, a construction policy and strategies are strongly needed. Regarding the procurement process, the building manager is responsible for it. The level of the application of performance criteria depends in particular cases on the building manager - his cooperation with architect, designer, contractor and his communication with the client. In strategies it is important to develop

construction process coordination and optimisation, facility management and the tendering process. Also more information and databases are needed.

According to the main points in **Domain 7 "Building Regulations"**, the regulatory framework in NAS is composed of the Act on Construction and the Act on Construction products; National Technical Standards, European Standards (EN) and International Standards (ISO). The competent governmental institutions develop laws and decrees, while the Standards Institutions develop standards. Regulations are partly performance based. Although performance based concept has been integrated in the NAS Building Regulation in many areas, the national Standardisation process is still rather weak. Thus, main strategies are to develop the institutional background of regulating the construction process and to develop performance based regulations and national standards on the bases of complex performance criteria and whole life cycle approach.

As regards **Domain 9 "Innovation",** after 1989 as large construction companies and central programs, also large research institutes were ceased and financial funds radically decreased. Mainly the Academic Research Workshops, Higher Educational Institutions, Innovation Parks, and Institutions for quality control exercise research activities today. Although there were several research programs related to PBB during decades, the application of innovation has several barriers as the common attitude of builders, the lack of R&D capacities of construction companies and the strong financial barriers. Great part of the innovative products comes out of the international research but there are excellent results also in the NAS countries. Several strategies could be defined, but first of all it is necessary to identify long-term values and make a balance between values and interests. Governments should promote innovation, education and training.

The **6th chapter** gives a summary of the **situation and the potential strategies** in the following **other PeBBu domain areas**: Built Environment; Organisation & Management; Information and documentation; Fire safety & engineering; Accessibility; Facilities management; Energy & water management; Environmental sustainability; Education & training; Intelligent buildings; Structural design & engineering; Construction products directive (CPD).

The **7th** chapter of the report discusses the vision to the future and some overall strategies to realize that vision. In general it can be said that only a **stable political, legislative, economical and social environment** in NAS will provide the **optimum conditions** enabling the creation of the infrastructure necessary for a wider PBB implementation. The **main vision to the future** concerning the implementation of PBB is that **after 10 years the differences between the NAS countries and the former EU countries will be decreased to a minimum level and most of the barriers will be ceased**. Regional cooperation will be increased. Several strategies are needed to realize this vision.

Inter-relations with other Domains/Tasks:

A strongly related task was to prepare the Status Report for the East European Regional Platform. **Comparing with the East European Regional Platform's (EEP) Status Report** of PeBBu, the NAS Status Report focuses on status and the common features as a consequence of the common historical background and analyses the situation related to the following historical periods: the time of socialism; the transition period and the present time after the EU accession. In contrast, the EEP Status Report focuses on regional aspects, describing status in each country and is based more on national reports and status in the countries. Thus, the two reports complement each other and a complete overview of the status and future of PBB of the EEP/NAS countries is provided by the EEP Status Report and the NAS Status Report together. The task is inter-related with all PeBBu Domains and with the new PeBBu tasks, the issues of which is analysed in both the PeBBu EEP and the NAS Report with slightly different approach.

Incentives for PBB Implementation:

The NAS Report concluded that the realisation of the basic conditions of a wider PBB implementation in future will depend on the **involvement of the potential PBB holders -** relevant construction process partners: clients, architects, contractors, producers, facility managers into the performance based concept in practice. The specified conditions for optimum realisation of PBB for each of construction process partners must be accompanied with the adequate complete information necessary for their fulfilment. In the Status Report there is a description of the basic conditions for PBB implementation needed by the various construction process partners.

Barriers to PBB Implementation:

The 4th section of the NAS Status Report aims to point out the general **barriers and opportunities of PBB according to different historic periods in the NAS countries**, namely before the political changes, in the transition period and after the EU extension. **In the time of socialism**, special barriers obstructed the implementation of PBB in the artificially isolated NAS countries, as the mass production, the COCOM list, the PLAN driven economy, etc. Most of these features are already over but some of them are still living or have influence. As regards the implementation of PBB, after the political changes new barriers and opportunities raised in the **transition period**. There are still remnants of socialist mentality and short term thinking. Lack of holistic approach, lack of cooperation, lack of finance, the weak credit systems and the low level of responsibility are all strong barriers. On the other side the transition period resulted also new opportunities, as the CPD implementation, the availability of new products and high quality buildings. The **EU extension** gives again new barriers and opportunities for PBB implementation in the NAS countries. Opportunities are partly related to obligations. New barriers can be some deformations of the market, influence of some interest groups, cartel agreements, tax policies or governmental decisions. On the other hand the free market environment and the support for several sectors provide new opportunities for PBB in general and in the various domain areas.

Proposed Research Agenda:

The detailed research agenda produced by the group is included in the Status Report of the East European Regional Platform. (See on the State of At Summary Report of Task15!)

Dissemination and Implementation:

For using the result of PeBBu the following action points can be highlighted in the NAS countries:

- Effort on regulation, legislation & control should be increased
- More national support of regulation and legislation
- Environmental performance and healthy building should be a priority topic
- There is a high demand to take benefit from the dynamic building industry
- More incentives for change should be encouraged
- Client driven solutions should be developed, it is important to make the client interested and better informed
- Building classes and building certification should have larger emphases.

Targeted audience/recipients for disseminated/transferred information:

- All members of national platforms and other related persons and corporations

- Organs of the public administration: chief authorities, ministries, etc.
- Associations of construction industry
- Civil associations
- Local government officers
- University teachers, designers
- House builders, international big industrial and commercial clients,
- Local authorities' technical staff
- General contractors and subcontractors
- Young researchers
- Chief executives of relating organisations

Exploitation and dissemination strategy for each individual partner:

- Regional and national conferences for all interested parties
- Web display – national and regional databases – for general information about international and home achievements and events
- Publications at all kind of media
- Training courses specialised according to the different professions and branches of construction industry and stakeholders of the society

Conclusions:

The realisation of the basic conditions necessary for the application of performance based building principles in future will depend on the **involvement of the potential PBB holders** - relevant construction process partners: clients, architects, contractors, producers, facility managers into the performance based concept in practice. Taking into consideration the present status, the barriers and opportunities of realizing the basic conditions, it could be expected that in the coming 20 years the PeBBu approach will be widely implemented in the **NAS legislation**. The **producers** will offer higher quality building materials according to PB requirements. The implementation of **PB design** depends on the legislative framework, the educational system and the attitude of the architects and engineers. In the coming 20 years PB design should be implemented at the design of big public and office buildings, as well as at the design of some more luxurious single-family houses. In the coming 20 years the **building companies** would prefer to execute construction works with **traditional technologies and materials**, even if requirements are given in performance terms. New materials and technologies would be applied only if the client or the designers require it. Following a large **awareness raising campaign** among the whole society, in the coming 20 years PeBBu could be implemented in NAS in big public, office and dwelling buildings, as well as in some single-family houses owned by people that are concerned with the problems of the environment, the energy saving and that require higher quality and longer life span for their dwelling.

The complex solution how to support the PBB in NAS must issue form the promotion and propagation of **cooperative approach** of all partners to the construction based on complex building performance knowledge. The possibility of equal opportunities and the minimum threshold degree of **economical freedom and stability** are the fundamental conditions for this. The accession to the European Union provides new opportunities, partly as obligations for implementing PBB in the NAS countries. If the key strategies will be conducted, **the vision to the future related to PBB in eliminating the differences between the NAS countries and the former EU countries has real and good chances.**

ANNEX XXVII: CIB COMMISSIONS WORKING IN PBB-RELATED AREAS

Several CIB (Task Groups and Working) Commissions have been established to facilitate international exchange and co-operation in areas that cover aspects of PBB on a voluntary basis. As an average, each such commission incorporates 50 appointed representatives of organisations worldwide who meet on a regular basis and aim for joint, voluntary, international Research & Development (R&D) projects in their area. In addition, there exist some international projects of special relevance to PBB which have been initiated by the commission with a more general scope, and who have decided to focus part of their work on aspects of PBB.

Below is a list of the CIB Task Groups and Working Commissions, which are working in areas related to PBB, and an inventory of their current projects:

Task Group TG25 - Façade Systems and Technologies

- Project: Performance Definition for Façade Systems

Task Group TG36 - Quality Assurance

- Project: Development of Quality Management Systems in Construction based on the Performance Approach

Task Group TG37 - Performance Based Building Regulatory Systems

- Project: Analysis of Case Studies on Quantitative versus Qualitative Aspects of Performance Based Regulation
- Project: Analysis of Case Studies on Multiple Levels of Performance in Buildings and Structures
- Project: Analysis of Case Studies on Acceptable Solutions
- Project: Analysis of Case Studies on Standards used in Performance Based Regulatory Systems
- Project: Review and Compendium of the Quantitative and Qualitative Aspects of Performance Based Regulations

Task Group TG42 - Performance Criteria of Buildings for Health and Comfort (Joint CIB - ISIAQ Task Group)

- Project: Establishment of Performance Criteria for health and comfort in buildings plus guidelines for design and for quality control in the construction process

Task Group TG44 - Performance Evaluation of Buildings with Response Control Devices

Task Group TG45 - Performance Indicators for Urban Development

Working Commission W014 - Fire

- Project: Guidance on Rational Fire Safety Engineering Approach to Fire Resistance in Buildings
- Project: Building and Occupant Characterisation in Fire Safety Engineering Guides
- Project: Compendium of Statements of Objectives and Functional Requirements Related to Fire Safety
- Project: Compilation of Frequency, Probability and Reliability Data to support Risk informed Performance Based Fire Safety Engineering

- Project: Compendium of Reference Cases for Validating the Performance of Zone and Field Models for Fire Safety Engineering
- Project: Compendium of Reference Cases for the Evaluation of Methods for Calculating Temperature in Fire Exposed Structures
- Project: Guidance on Rational Fire Safety Engineering Approach to Fire Safety in Historic Buildings

Working Commission W040 - Heat and Moisture Transfer

- Project: Material Characterisation and Hygrothermal Benchmarking

Working Commission W060 - Performance Concept in Building

- Project: International State of the Art Report on the development and application of Performance Based Building
- Project: Compendium of Validated Models for Evaluating and Grading Performances (see also the description of commissioned projects under Programme Implementation and Coordination)
- Project: Analyses of Economic Benefits from applying the Performance Concept in Building and Construction with Benchmarking and Evaluation Methods that allow for Quantifying Benefits (see also the description of commissioned projects under Programme Implementation and Coordination)
- Project: Collation of Statements and Functional Requirements in Terms of the Performance Concept (see also the description of commissioned projects under Programme Implementation and Coordination)
- Project: Investigation of the Value of Real Estate for Building Owners, in terms of business and economic value, rentability and serviceability
- Project: Performance Based Procurement (to be executed as a joint W060-W092 Project)

Working Commission W077 - Indoor Climate

- Project: Collection of Recent Research on Indoor Air and Performance Based Building

Working Commission W080 - Prediction of Service Life of Building Materials and Components

- Project: Development of Performance Based Methods of Service Life Design based on models of degradation and environmental action

Working Commission W082 - Future Studies in Construction

- Project: Development of Performance Indicators for a Sustainable Built Environment

Working Commission W086 - Building Pathology

- Project: Analysis of how Building Pathology can contribute to Performance Based Building

Working Commission W087 - Post-Construction Liability and Insurance

- Project: Collation of Experiences concerning the Relations between Performance Based Building and Post-Construction Liability and Insurance

Working Commission W092 - Procurement Systems

- Project: Performance Based Procurement (to be executed as a joint W060-W092 Project)
- Collection of Performance Based Building Models related to Procurement issues

Working Commission W099 - Safety and Health on Construction Sites

- Project: Study on Comparability of Safety Performance Related Data

Working Commission W102 - Information and Knowledge Management in Building

- Project: Development of Information Models for Performance Based Procurement and Design

Working Commission W103 - Construction Conflict: Avoidance and Resolution

Working Commission W104 - Open Building Implementation

- Project: Open Building and Performance Based Construction

Working Commission W105 - Life Time Engineering in Construction

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