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# Performance Based Design and Management of Healthcare Facilities

## A research program in progress

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**ABSTRACT**

**Subject/Research problem**

Healthcare is in need of methods and sound research data to provide a better fit between supply and demand with regard to functionality, serviceability, architectural and perceptual qualities, technical aspects, economical issues and sustainability. This paper presents a research programme in progress of the Faculty of Architecture of the Delft University of Technology. This program aims at the improvement of healthcare real estate in terms of organizational performance and user satisfaction. The environmental aspects range from the urban setting of everyday life to the way buildings such as hospitals, nursing homes and assisted living facilities promote or frustrate the medical procedures and people's wellbeing as evaluated by the end users (employees, patients, visitors). In addition to the functional performance of buildings in terms of health outcomes, other aspects such as the impact of indoor and outdoor environment and corporate real estate strategies helping organizations to strengthen their portfolio's are studied as well.

**Research Questions**

What is the impact of different design concepts, design interventions, technological innovations and real estate management strategies on peoples' health and wellbeing? And how can healthcare buildings being built and managed in a way to improve its present and future performance taking into account the different views and interests of various stakeholders?

**Approach**

The multi-method approach includes a review of literature; interviews and workshops with experts and end users; analyzing policy documents, long term accommodation plans and so on; field studies including analyses of best-practices and Post-Occupancy Evaluation; research by design i.e. designing new tools, design concepts, design solutions and real estate strategies; criteria selection, data gathering and knowledge modelling technology for performance based design; development of an ontology that specifies the relations among numerous aspects, and evaluation/validation through computational simulation and by field experts.

**Results**

Exploration and testing of present or new theories and development of concepts and tools in the field of design and management of healthcare facilities.

**Applications**

The research data and products will be applied in design and decision making processes in the field of care and cure.

## 1. INCREASING SYNERGY BETWEEN RESEARCH PROJECTS

In the Faculty of Architecture's research portfolio 2003-2008 healthcare facilities and healthy environments were part of different departmental programmes. The Department of Architecture was strongly involved in the organization of an international conference in Groningen, April 2005. This project has resulted in the book "The Architecture of Hospitals" (Wagenaar, 2006). It has also been the catalyst for a follow-up project "Architecture in Health", organized by the 'Bouwcollege' (a governmental organization until recently responsible for the planning and cost and quality control of all Dutch healthcare facilities). Other issues that have been studied earlier are the concept of Healing Environments, Evidence Based Design, and healthcare facilities on different levels of scale (Hansen, 2008; Durmisevic, 2005; Durmisevic, 2007). The Department of Urbanism was involved in studies into healthy environments, in particular the impact of urban design concepts on people's health and wellbeing (Esch and Hordijk, 2006; Van Esch et al, 2007). The Department of Building Technology developed a so-called flex-tool in order to assess flexibility and adaptability of healthcare buildings (Durmisevic and Durmisevic, 2006; Durmisevic and Durmisevic, 2007b). Furthermore this department was a co-organizer of a Symposium on Architecture in Health 'Thinking Differently, Designing Differently: Architecture in Health - Between Science and Practice' (Architecture in Health, 2008). Staff from Building technology have also conducted research on climate design and technical services in order to improve indoor air quality and as such peoples' health. The Department of Real Estate and Housing started a project on the impact of neighbourhood design on the time children spent in outdoor activities (Van Oel, 2005). Furthermore this department applied its theoretical framework of corporate real estate management and its evaluation methodologies in the field of healthcare real estate, both on building level and portfolio level (Van Hasselt, 2005; Huisman, 2008; Van der Voordt, 2008). All this work resulted in a number of publications with theoretical reflections, case studies, typological studies, design guidelines and recommendations for real estate strategies.

At the end of 2008 a faculty wide program has been set up on "Performance Based Design and Management of Healthcare Facilities", in order to stimulate debate and co-operation between researchers working on different projects and the publication of a website (www.hedi.tudelft.nl). The programme deals with the development of theory, design concepts, real estate strategies, technological innovations and design and decision support tools in order to contribute to sustainable solutions which promote public health, add value to organisational goals and objectives and increase overall Quality of Life. The aim of this programme is to 1) study trends and developments in the field of health (care and cure); 2) investigate and develop performance requirements; 3) analyse and evaluate buildings and outdoor environments ex post and ex ante (both best practices and worst cases); and 4) develop new tools, design concepts, technological innovations and real estate strategies in order to improve people's health and wellbeing and to support the design, construction and management of healthcare facilities. With this the participants aim to contribute to a healthier built environment that fits with people's preferences and needs, organisational goals and values and other performance criteria such as cultural value, economical feasibility and sustainability. Scientifically the program aims to improve our understanding of the impact of architectural, urban and technical design and real estate strategies on people's health and wellbeing, organisational performance and the needs of society as a whole.

## 2. HYPOTHESES AND RESEARCH QUESTIONS

The main hypothesis is that integrated and performance based design and management of the built environment can significantly improve design and construction practice and contribute to people's health and wellbeing in a positive way. This is done by considering functionality, perceptual qualities, economic feasibility and sustainability in an integral way. All projects have their own research questions. Together the projects aim to contribute to an answer on four main questions:

1) What is the impact of different design concepts, design interventions, technological innovations and real estate management strategies on peoples' health and wellbeing?
2) How can we build and manage healthcare buildings in a way to improve its present and future performance taking into account the different views and interests of all stakeholders?
3) Which "evidence based" theories, tools and guidelines do exist or should be developed in order to support design and management of healthy environments and healthcare facilities?
4) Which technology is required by users, what is the effectiveness of existing technology and what is the impact of technology such as domotics, robotics, telemedicine and e-health on future real estate development in healthcare sector?

## 3. INTEGRAL APPROACH

Characteristic for the Faculty's program is its *integral* approach, which is seen as a precondition for *performance based* healthcare design (figure 1). There are many disciplines involved in planning, design and construction of a building wherein each discipline considers only one segment of a building. Yet a building system only functions satisfactory when all parts combined contribute to it. It is often on the borderline where different disciplines meet that new insights and innovation appears from such integrated solutions. Currently, there is a lack of systematic integration of multidisciplinary expert knowledge throughout the design process. Modern information processing technologies should play an important role in dealing with this complexity and fragmentation. Furthermore, from a passive prescription of how a building is to be constructed, we need to move towards performance driven design, construction and management of the built environment and performance based regulations and product development as well. Initial research indicates that financial savings from a fully integrated performance based system could be as high as 25% (Szigeti and Davis, 2005). There are many definition of what Performance Based Design. For this research program the definition of Krawinkler (1999) is found to be most fitting to our activities: "*Performance based design is a shift away from the dependence on empirical and experience-based conventions, towards a design and assessment process more firmly rooted in the realistic prediction of system behaviour. This implies a shift towards a more scientifically oriented approach with an emphasis on accurate characterization and prediction*" (Krawinkler, 1999). In that respect, performance based design focuses on the achievements and satisfying the demanded requirements.

The Health program will focus on four main themes (figure 2):

1. *Utility value* (functionality & experience). A building should fit to its purpose (functional), enabling efficient processes, supporting the overall well-being of all users (mainly staff and patients, but also visitors) and in general have a positive influence on health; This theme deals with the relationship between built

environment, medical processes and patient/staff/visitor satisfaction, and considers in a broader sense the relationship between built environment and health.

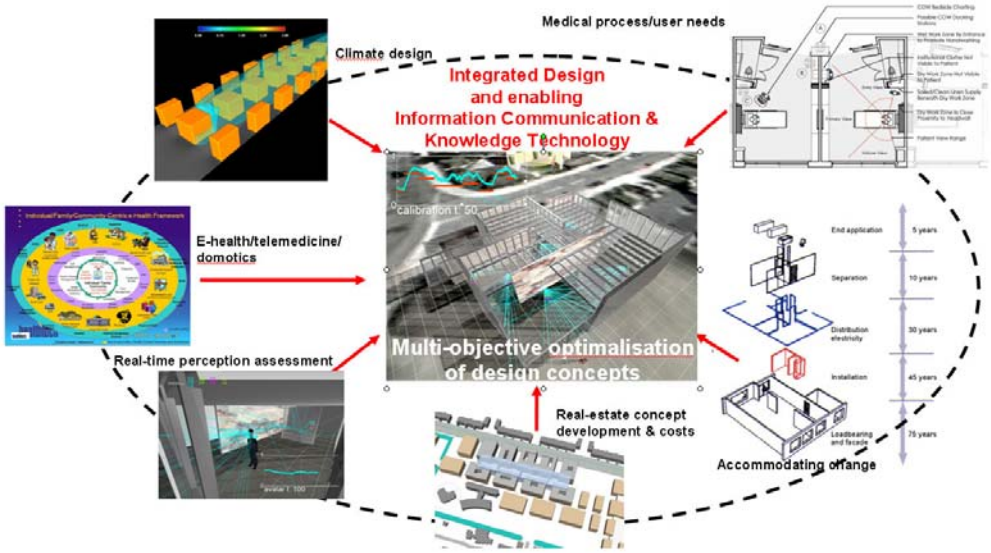


*Figure 1: Integrated/Performance based design and management tools applying advanced Information Communication & Knowledge Technology*

2. *Future value*. Due to technology development in the healthcare, socio-economic factors, demographics and ever changing functional requirements, healthcare buildings are changing layouts and structures frequently. Among all healthcare facilities, the most frequent changes occur within hospitals. It is common in the healthcare sector that the functional life cycle of buildings is therefore by far shorter than the technical life cycle of building components. A building should be innovatively planned and constructed to be able to accommodate change in a future. The ability to accommodate changing needs determines the future value of healthcare facilities. This theme aims at finding adequate solutions as to increase future value of healthcare buildings and ensure a sustainable future development.

3. *Performance based design:* This theme deals with the development of design/management methodology and tools that are based on measured performances rather than subjective and biased personal judgment. Evidence Based Design appeared as a need to introduce more objectivity by supporting design decisions with current best practices. But this theme goes even beyond. Performance Based Design is a theme that will deal with pro-active designing and making efficient use of research results, where the effects of design changes on performance will be evident. This third theme will add to the body of knowledge that uses evidence based design as a starting point to develop performance measurement tools which can be used during design process. Due to a generic character it is thinkable that projects in this theme can deal with issues mentioned in other themes by further developing and implementing existing technology to specific domain within healthcare.

4. *Technology*, both with regard to building systems as well as supportive technology such as robotics, domotics, e-health and the ways it effects real estate development. Technology development has a tremendous impact on healthcare services, healthcare buildings but also our home environment. By now it has

become abundantly clear that the typologies developed during the first post-war decades are rapidly becoming relics of the past. This theme deals with changing typologies due to technology development and emergence of e-health, telemedicine, domotics and robotics as well as the development of special applications for the healthcare sector (knowledge based models). These technologies emerged due to shortage of medical staff, which will become even more problematic in the future. Exporting medical services outside of strictly defined healthcare buildings, empowering citizens with adequate tools to take more responsibility of their own health a significant impact on the building concepts can be expected.

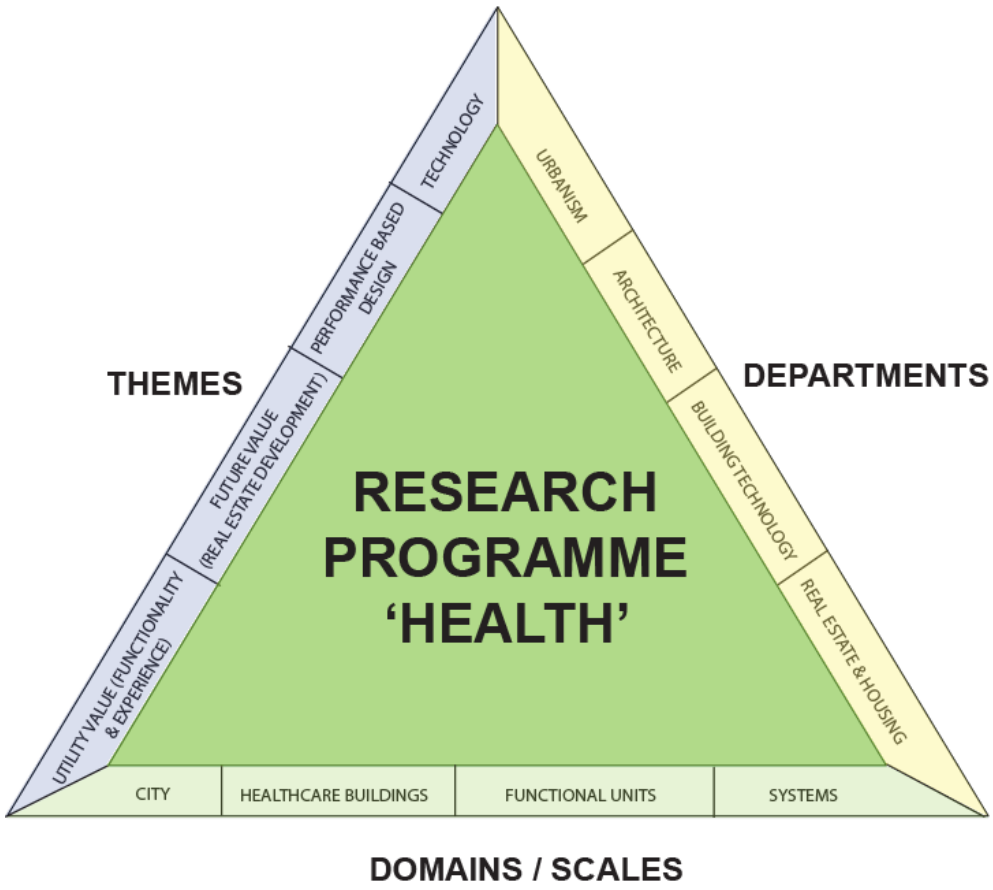


*Figure 2: Research area of research program Health**

*A detailed information regarding domains/scales:*

*a. City: city as a whole, neighbourhoods, public spaces such as parks, sanitary equipment, and the housing stock.*

*b. Healthcare buildings :a) Cure: general and specialized hospitals, psychiatric clinics, rehabilitation facilities; b) Care: specific housing for the elderly, nursing homes, old people's homes, facilities for assisted living, small scale facilities for people suffering from dementia; c) Health facilities: fitness, wellness centres and so on.*

*c. Functional units: specific functional areas within a healthcare institution such a patient room, operation room, waiting room etc.*

*. Systems: installations, façade systems, construction elements and joints, etc.*

*) *Figure 2* does not imply that the Faculty intends to cover the entire field. Research projects will differ with regard to covering one or more topics, levels of scale and input of one or more disciplines.

## 4. A CLOSER LOOK AT TEN RESEARCH PROJECTS

For an overview of current research projects we refer to the new website www.hedi.tudelft.nl (under construction). Here below we present a short summary of ten research projects, as to briefly explain some of the main activities.

### 4.1 Healthcare Architecture in a Changing World

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The project's main focus is the analysis of interactive processes in various fields – medicine, social security systems, healthcare systems, technology development, politics, architecture, on the evolution of healthcare buildings i.e. their typology, the 'distribution' system these imply, their urban setting, etc.. Inspired by a historical methodology, the studies have a strong bearing on recent trends and future developments. These are seen as motivated by an ever changing context, continuous shifts in power relations and modifications in healthcare systems. This project results in a Dutch book on housing for the elderly, a Hospital Design Manual, and a Compendium (in English) summarizing the results of earlier research projects and new research

### 4.2 The Added value of Architecture

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Architecture has a thorough impact on how hospitals function. Consequently, architecture effects hospital business. It can either make hospitals more profitable or improve public opinion about them, or do the exact opposite. This research project investigates the way medical processes are accommodated, the organization of staff/patient interaction, and the way patients and staff evaluate hospital design. By exploring theories and empirical data on hospital strategies, corporate real estate, and architecture (theory, history and case studies), this project aims to pinpoint the ways in which architecture contribute to hospitals that are more functional, have a better public profile and improve their business performance.

### 4.3 Hospital Architecture in Hungary

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During the twentieth century, Hungary has witnessed major social and political changes. These have had a deep impact on the country's healthcare system, and consequently on hospital architecture. Starting at the beginning of the twentieth century, this project tries to explain the sequence of hospital typologies by analyzing the shifting context that produced them. Naturally, the socialist era (1948-1989) plays a dominant role, as do the subsequent transformation processes. By describing continuities and discontinuities and comparing what happened in Hungary with international trends, the project aims to contribute to the long overdue overhaul of hospital architecture in this part of the world.

### 4.4 Computational intelligence for advanced design of health-care facilities

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The goal of this project is to develop and apply computational methods to determine the basic spatial structure of a care facility in such a way that the facility performs optimally with respect to the pertinent criteria. One challenge is to deal with the large amount of relations among functional units and the multiplicity of criteria relevant for spatial organization. A second challenge is to deal with conflicts among criteria proficiently, so that solutions are found that optimally match the criteria. The work concerns computational generation of multiple alternatives for the spatial structure of

hospitals based on the performance related criteria. In accordance with the general specifications and objectives, the design takes place by means of computation.

### 4.5 Ontology-based intelligent healthcare and implications in healthcare Architecture

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This project aims to develop ontology-based intelligent healthcare agent for the respiratory waveform recognition to assist the medical staff in judging the meaning of the graph reading from ventilators. The medical experts confirm the classified result instead of reading the respiratory waveform from the scratch. By doing so, the workload of the medical staff is greatly alleviated. The approach is a pilot application to respiratory healthcare. However similar approaches can be devised for other medical healthcare domains.

### 4.6 Life cycle design of healthcare facilities

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Earlier research has developed a systematic approach to design of transformable buildings and access flexibility and adaptability of buildings by disassembly potential of their components. The present research projects explores whether this methodology be adopted for the design of healthcare facilities. The hypothesis is that one of the key factors that will determent a life cycle performance of the building in the future will be its ability to transform on three levels of building physical composition: building, structural and material level. Some of the aimed results are a design support tool (DSM) for life cycle design of healthcare facilities and hospital design, and guidelines for customization of construction of hospital facilities and system development.

### 4.7 Knowledge modelling for performance based healthcare design

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This project aims to improve building performance in terms of design, construction and management by developing generic tools in healthcare domain which employ latest state-of-the art knowledge. There is a lot of accumulated knowledge, on topics such as Evidence Based Design or flexibility of healthcare facilities, but what is missing are integrated knowledge models that combine both existing norms as well as qualitative aspects. Such tools would support planners and designers of healthcare facilities during decision making process, since already from the beginning they would have a better insight in building's performance due to integrated approach. This research will deal with the issues of context modelling and development of generic tools. in the field of design and management of healthcare facilities Knowledge modelling techniques (such as neural-trees, neuro-fuzzy systems, etc.) will be applied to create meta knowledge by integrating various sub-components.

### 4.8 Spatial Context Modelling and Design Guidelines for a Hospital Waiting Room

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The purpose of this joint PhD-project of the Faculties of Architecture and Industrial Design Engineering is to identify and reduce key problems causing stress and discomfort in the use of hospital waiting rooms from a design perspective. It is assumed that if perceived attractiveness is increased then customers' (patient, visitors) satisfaction during waiting and their overall satisfaction will increase. With regard to data analysis, computing techniques will be explored instead of using statistical analysis methods. The research aims to develop specific knowledge regarding design variables of a waiting room, and to develop design guidelines for waiting rooms;

### 4.9 Successful Healthcare Real Estate Strategies

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Briefing, design and management of buildings are strongly affected by changing views, the economic context, demographics, technological innovations, time spirit, site characteristics, juridical prerequisites and policies of the national government and private organisations. This research project investigates how healthcare organizations cope with these impact factors on their real estate and which information and key performance indicators they use or should be developed in order to support complex decision making processes. The focus of this project is to explore theories, tools, key performance indicators and best practices of strategic real estate management in the domain of care and cure.

### 4.10 Impact of growing competitiveness in healthcare on real estate management

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As a consequence of a growing competitiveness, healthcare organizations become more and more self responsible for the opportunities and risks of their real estate. Therefore healthcare organizations have to rethink the impact of their corporate strategy on their real estate strategy and vice versa. This PhD-research investigates the impact of changing corporate strategies on real estate strategies, choices with regard to urban setting of healthcare institutions and the architectural typology of hospital buildings. Case studies of Dutch common hospitals will be used to develop a decision support tool that will be made transferable to other sectors in healthcare.

## 5. CONCLUDING REMARKS

The research program on Performance Based Management and Design of Healthcare Facilities is still under construction. Apart from these projects on Improving Healthcare Real Estate (HCRE) a number of research projects is being conducted into Supporting Healthy Environments (HE). These projects focus on the impact of design concepts, design interventions and real estate strategies on people's health and wellbeing. For example the studies into "Environmental quality of densely urbanized areas", "Child-friendly and Healthy Neighbourhoods: supporting Independent Mobility and Playability", "Restorative immediate green environments in urban residential neighbourhoods" and "Design Guidelines for Healthy Neighbourhoods". On program level the Health programme is linked to the Delft research Initiative (DRI) Health, a joint project of the Delft University of Technology Faculties of Architecture, Industrial Design Engineering, Applied Sciences, Electrical Engineering, Mathematics and Computer Science, and Mechanical, Maritime and Materials Engineering. There is already a start document for collaboration of three Dutch Technical Universities (3TU) where three universities are reaching an agreement on future collaboration regarding the topic of Healthcare Architecture. Furthermore, the Health program looks for co-operation with Medical Delta, a joint program of the Universities of Delft, Leiden and Rotterdam and the TNO Institute of Technical research. Finally participants also co-operate with other national and international organizations and research institutes such as the Top Institute Healthy Elderly (Top Instituut Gezond Ouder), Dutch Centre for Health Assets / TNO, Clemson University (USA), Loughborough University (UK), European Health Property Network (EuHPN), Global University Program for Healthcare Architecture (GUPHA) and many others. Being the initiators of the Health program, it is our hope that the 3TU Research Day will be an important step to further co-operation between researchers from different fields in order to contribute to better healthcare facilities, now and in the future.

In the Faculty of Architecture's research portfolio 2003-2008 healthcare facilities and healthy environments were part of different departmental programmes. We are currently elaborating on possibilities to create an overall taxonomy that designers could easily access and incorporate into their designs. A possible direction is to make use of knowledge modelling trees for taxonomy which in a later stage can be incorporated into CAD environment. In this way, by making use of knowledge from different departments we can realize a better synergy which will at the same time result in more realistic tree model since numerous aspects are dealt with simultaneously, taking into account possible mutual influences. This initiative is a part of collaboration with TNO Health Assets in the scope of Architecture and Health.

Future steps:
1) Positioning of all 3TU health related research in a diagram in order to identify similarities and differences;
2) Using a diagram as a basis for a literature review of the state-of-the-art knowledge in this field in order to explore future challenges for a common research agenda.

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