



On Hospital Design – Identifying Building Attributes of Hospital Design

Holst, Malene Kirstine; Kirkegaard, Poul Henning; Christoffersen, Lars D.

Publication date:
2012

Document Version
Accepted author manuscript, peer reviewed version

[Link to publication from Aalborg University](#)

Citation for published version (APA):

Holst, M. K., Kirkegaard, P. H., & Christoffersen, L. D. (2012). On Hospital Design – Identifying Building Attributes of Hospital Design. Paper presented at Congress of the International Federation of Hospital Engineering, Tromsø-Bergen, Norway.

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal -

Take down policy

If you believe that this document breaches copyright please contact us at vbn@aub.aau.dk providing details, and we will remove access to the work immediately and investigate your claim.

On Hospital Design – Identifying Building Attributes of Hospital Design

Mrs. Holst, Malene Kirstine
Ph.D. Student
ALECTIA A/S, Denmark
Department of Civil Engineering, Aalborg University, Denmark
Mrs. Holst (born 1984) completed her M.Sc. in Engineering Architectural Design in 2009 from Aalborg University. Following Holst was employed as research assistant at Aalborg University until commencement of Industrial Ph.D. Studies at ALECTIA A/S 2011.

Teknikerbyen 34
DK-2830 Virum
+45 23 39 50 26,
mkho@alectia.com
mkoh@civil.aau.dk

Prof. Kirkegaard, Poul Henning
Professor
Department of Civil Engineering Aalborg University, Denmark

Prof. Kirkegaard (born 1962) completed his M.Sc. in Civil Engineering in 1988 from Aalborg University and Ph.D. in 1991 from Aalborg University. Kirkegaard has published 275 scientific papers and supervised 15 Ph.D. students. In 2010 Kirkegaard got a full professorship at Aalborg University.

Sohngårdsholmsvej 57,
C-101, DK-9000 Aalborg
phk@civil.aau.dk

Mr. Christoffersen, Lars D.
Research Manager
ALECTIA A/S, Denmark

Mr. Christoffersen (born 1961) completed his Civil Engineering degree in 1991 from DTU and Industrial Ph.D. in 2005 at ALECTIA A/S in collaboration with DTU. Christoffersen became research manager at ALECTIA A/S in 2008, and has supervised 7 Ph.D. students. In 2010 Christoffersen became Adjunct Professor at DTU.
Teknikerbyen 34
DK-2830 Virum
ldc@alectia.com

Proposed topic

Hospital design, architecture and construction – models/logistics

Keywords

Hospital Design, Layout Design, Quantification of Aesthetics, Organization and logistics

Abstract

The present paper surveys the input parameters in hospital design and describes them formally as building attributes in preparation for facilitating planning and designing of hospitals with the aim of a more optimal design process. The overview of the hospital functionalities, bonds, logistics and needs is based on an approach of understanding the complexity of the hospital functionalities based on capacities, qualities and times beforehand specific department or units are described. This approach attempts to create an overview of the hospital functionalities respecting capacities, qualities and times and defining the building attributed on this basis as detailed specifications.

Introduction

Hospital design encompasses an extensive complexity in the several aspects to fulfill, respect and approach. Generally hospital design is based on practice, standards and benchmarks implemented by experienced hospital planners, architects and hospital responsible. The design process is commonly initiated as a democratic process with a broad user participation of physicians, nurses, hospital responsible, expert groups, architects, engineers, politicians etc. The user group identifies, generates and prioritizes essential information defining the design problem and anticipating solutions for certain areas. The user group is a central element especially in the early design phase including development of tender documents where experience and the professional competencies are implemented and define the point of departure for the following design process [1,2]. The several aspects inherent in hospital design are not surveyed in a traditional scientific manner, but the identification, clarification and evaluation relies on an experiential and personal understanding. Current hospital design lacks of a scientific approach characterized as evidence-based and research-based. Evidence-based design is emerging to imply hospital design hereunder 'healing architecture' as a research field analyzing hospitals for better surroundings and healing atmospheres for patients [3,4]. Other hospital research is primarily based on analyses of different aspects within hospitals [3-13], where research in overall hospital is more limited [5,6], and research in generative design within hospitals is further reduced [7,14].

In defining a scientific approach, a top down overview of the primary hospital functionalities and secondary supportive functionalities is performed. The complexity of the building typology necessities focus on functionalities and bonds to achieve highly functional hospitals, focusing on the primary functionalities. 'Care-focused' hospitals where the hospital design is driven by 'patient flow logistics' [15] attempts optimizing the hospital design in terms of users, staff and most importantly the patients by being patient-centered focusing on the 'patient flow logistics'. The modern hospital as an institution of knowledge implies growing complexity in linking different types of specialized knowledge and coordinated them with proliferating diagnostic techniques and methods of treatment as well as key services and amenities needed for their operation [16]. Short supplies, long queues and delays, bottlenecks, waste of resources, long lengths of stays, low level of productivity, inappropriateness of clinical settings and workload variability, are wastes that should be avoided in hospital design [15].

A top down perspective on hospital design is utilized, as the complexity is a critical point, even to the experienced hospital planner, architect and engineer, caused by the high variety of functionalities, bonds and needs. Traditionally in hospital design, the complexity is simplified into operational sizes with different focal areas. Though, this approach causes problems and faults in both the design process and the construction phase, as the overview of the entire hospital is either not existing or at a poor level, as the input parameters are many and not clearly identified. The lack of clearly identified parameters for hospital design habitually implies massive economic costs both during engineering projection but mostly during the hospital lifecycle as reconstructions and reorganizations often is a necessity.

The present paper surveys the input parameters in hospital design in Denmark and describes them formally as building attributes in preparation for facilitating planning and designing of hospitals with the aim of a more optimal design process. An overview of the hospital functionalities, bonds, logistics and needs is based on an approach of understanding the complexity of the hospital functionalities based on capacities, qualities and times beforehand specific department or units are described. This approach attempts to create

an overview of the hospital functionalities respecting capacities, qualities and times and defining the building attributed on this basis as detailed specifications.

Hospital Functionalities

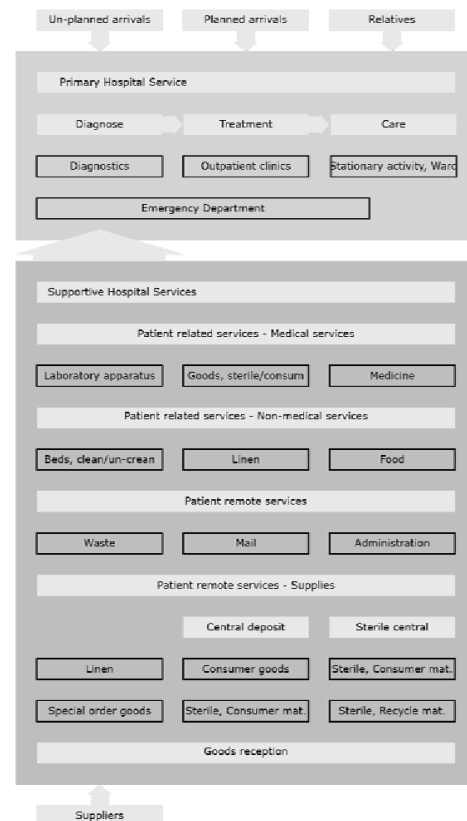


Figure 1. Hospital functionalities divided into primary functionalities and secondary functionalities, where the latter is divided into patient related and remote.

Surveying hospital functionalities from a top down perspective facilitates categorization of the different functionalities and elaboration of the interconnections. The primary functionalities are defined by and immediate understanding of a hospital, namely the functions directly related to the health of the patient. The secondary supportive functionalities are divided into 'patient related' and 'patient remote', of which an implication to the primary functionalities exists. In defining the functionalities and bonds of the hospital from a top down perspective, the understanding of a hospital and its design is decomposed into principal drivers and derivatives. This approach illustrated by Figure 2, promotes an understanding of a hospital of functionalities regarding needs and requirements in terms of capacity, qualities and time horizons, with principal drivers defined by the external factors of geography and demography, which define and derive the needs for treatment and following their derivatives in first degree, second degree etc.

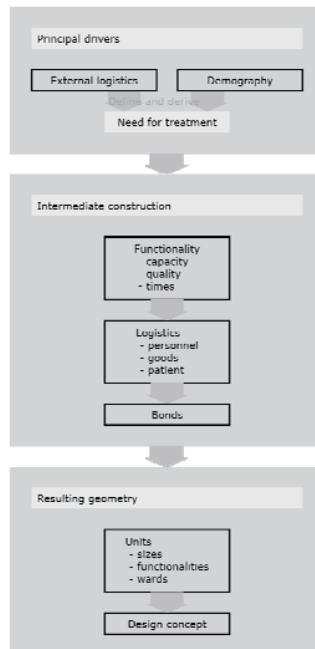


Figure 2. Top down perspective on hospital design. Principal drivers derive the intermediate construction in terms of functionalities, logistics and bonds that are defined quantitatively with respective perspectives.

Principal drivers

The external factors defined as external logistical and demographic conditions define the need for treatment. The external logistics includes the *external infrastructure* in terms of:

- Public transportation for patients and personnel
- Private transportation for patients and personnel
- Connectivity to other hospitals for shared functionalities

Demography defines the geographic conditions in terms of:

- Population size
- Age distribution
- Health of the population

Combining the conditions of the external factors derives and defines the need for treatment for the hospital in terms of population, shared functionalities and connectivity. Firstly an analysis of the current demography is needed including an extrapolation of a defined future, eg. 10 years as Figure 3 below in dimensioning of the needs. Dimensioning is based on health records for corresponding geographies and demography or existing conditions if local records exist. Figure 3 outlines how the 'need for treatment' derives from the demography and external logistics. The first step in the figure is an analysis of the current situation of demography including an extrapolation thereof. The external logistics define which functionalities the actual hospital must fulfill, and which can be shared with other hospitals.

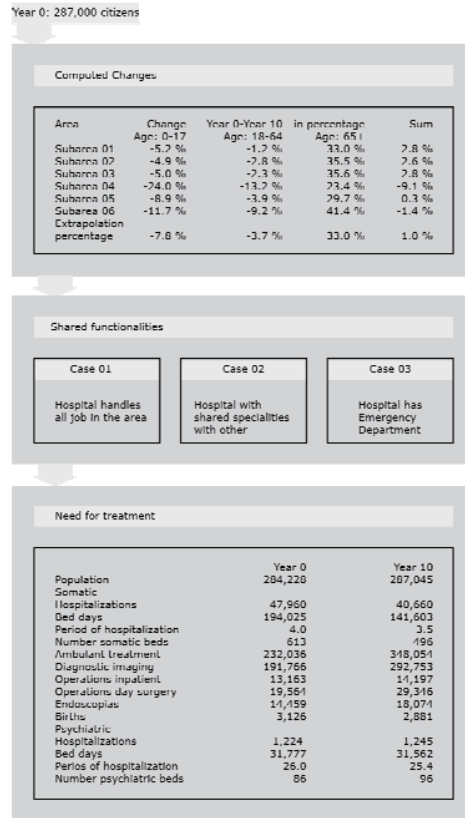


Figure 3. Definition of the need for treatment on basis of demography and shared functionalities. The illustration contains data from Danish hospital competition tender documents [1,2].

Intermediate construction

Derived by the principal drivers is the intermediate construction that is a quantitative analysis and description of the functionalities of the hospital and logistics. The need for treatment defines and dimensions the functionalities of the hospital, based on the amount and distribution of treatment. The intermediate construction is a description of the hospital building attributes described as quantities in the attempt on defining the input parameters on hospital design and describe them formally for more scientific design approach. The functionalities of the hospital are described formally in terms of *capacity*, *quality* and *time* in Figure 4. The formal description of the building attributes provides information for the design approach, where *quality* includes perspectives of placement and relation, as qualities of connectivity. Light, hygiene are further qualitative design parameters, where stay relates both *times* and *qualities* of the functions. The *times* are defined as minutes, hours, days and/or weeks including data for the hospital design to combine with the *capacities*, in terms of period of hospitalization, typical times for surgeries in dimensioning the capacity. Definition of the latter is strongly influenced by the demographic conditions and health records. This three-valued approach of *qualities*, *capacities* and *times* gives a formal description of the building attributes in terms of quantitative data.

Stationary activities, ward			
Hospitalizations	47,960	Placement	Centrally with easy access
Bed days	194,075	Light	Natural and Artificial
Period of hospitalization	4.0	Stay	Hours, days, weeks
Number somatic beds	613	Hygiene	Medium

Emergency Department			
		Placement	Centrally with easy access
		Light	Artificial
		Stay	Hours
		Hygiene	High

Operations			
Operations inpatient	13,163	Placement	Centrally with easy access
Operations day surgery	19,561	Light	Artificial
Endoscopies	14,459	Stay	Minutes, Hours, days
Births	3,126	Hygiene	High

Outpatient Consultations			
Ambulant treatment	232,036	Placement	Centrally with easy access
		Light	Natural and Artificial
		Stay	minutes, hours, days
		Hygiene	Medium

Diagnostic imaging			
Diagnostic imaging	191,766	Placement	Centrally with easy access
		Light	Artificial
		Stay	Minutes, Hours
		Hygiene	Medium

Service functions			
		Placement	Access to remaining functions
		Light	Natural and Artificial
		Stay	Personnel: Day/night-stays
		Hygiene	Low

Figure 4. The capacities, qualities and times related to the different functions. Dimensioning of the capacities based on the need for treatment on basis of the demography and external logistics. The illustration contains data from Danish hospital competition tender documents [1,2].

A formal description of the intermediate construction also includes a formal description of the logistics of the hospital, derived by the functionalities.

Hospital logistics

The several flows in the hospital can be described as a three layered logistic system including all transportations and flows of materials, products, capacities, finance, information etc. The functional requirements and logistics are closely connected, as logistic qualities are included in the functional qualities, as it relates the functionalities and defines the bonds connecting them in a three layered system of patients, personnel and goods.

Likewise the formal description of functionalities in terms of capacity, quality and times, the logistics can formally be described as the flow from 'source' to 'sink' [17] covering a particular product group, of which the patient, personnel or goods may be considered a product. It is the objective to minimize 'Non Value Adding' processes leaving only 'Value Adding' processes in the logistic supply chain [18], by elimination of waiting time, transportation and motion, three of 'the seven wastes' to be eliminated according to the lean methodology. These perspectives are thus described formally in the logistic network of the hospital as quantities to compute in handling the logistics. The supply chain is partitioned into large number of factors influencing each other.

The logistics are described formally in diagrams below and categorizing into groups of patients, personnel and goods. The survey of the logistics in three layers is an attempt of making a scientific-based design model for hospital

design based on the empirical data from the experience-based design approach, thus the democratic design approach is implemented, and meanwhile the design model is driven by data emphasizing design opportunities in both complexity and innovation.

The logistics of patients includes the patient related logistics with origin in the patient in terms of inpatients, outpatients and relatives i.e. different person flows following the patient and the procedure of the patient in a hospital.

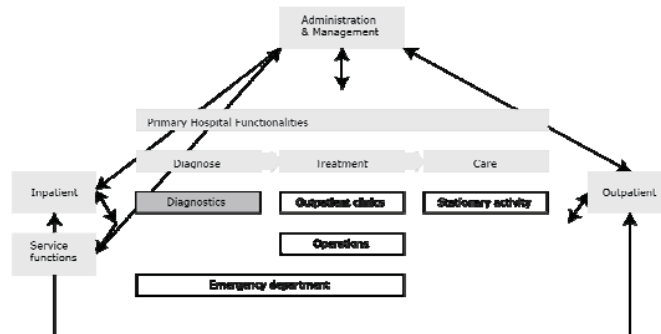


Figure 5. Patient logistics: The bonds between inpatients, outpatients, the primary hospital functionalities and service functions the patient relates to.

Figure 5 illustrates the overall bonds relating patients in terms of inpatients and outpatients to the primary hospital functionalities. Administration and service functions are included as connectors, as it is service functions the patient relates to. The relationships are characterized as both definitive and relative bonds based on the patient.

The personnel logistics include a high level of complexity as it includes three layers: patient related, personnel transportation and goods related. The personnel logistics include the different person flows in a hospital, including: Care personnel; physician, nurse, healthcare worker, etc., technical personnel, building technicians, students, etc.

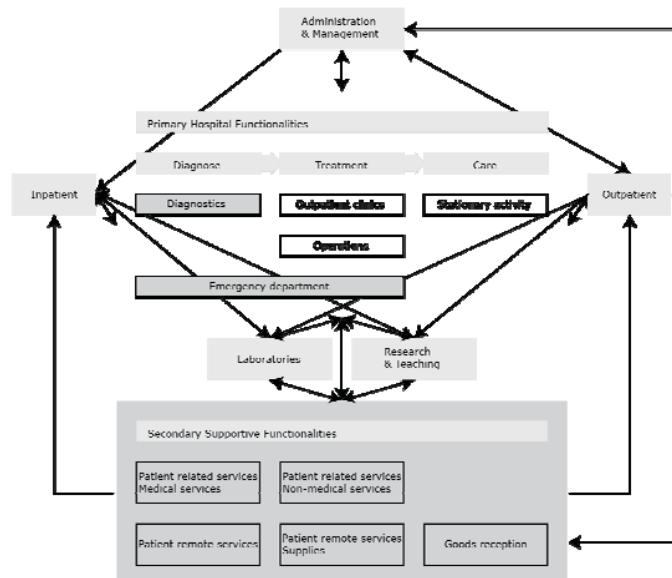


Figure 6. Personnel logistics: Relating all functionalities of the hospital in several respective qualities depending on the character of the logistic.

Goods include all 'cold logistics' in a hospital. The cold logistics can be divided into the three groups of *Patient proximal medical services*, *Patient-related non medical services* and *Patient remote services*. The goods are handled both by personnel and transportation systems that can be either man handled in both ends, one end or fully automatic. When personnel are involved in the goods logistics, convergence with the personnel logistics will occur.

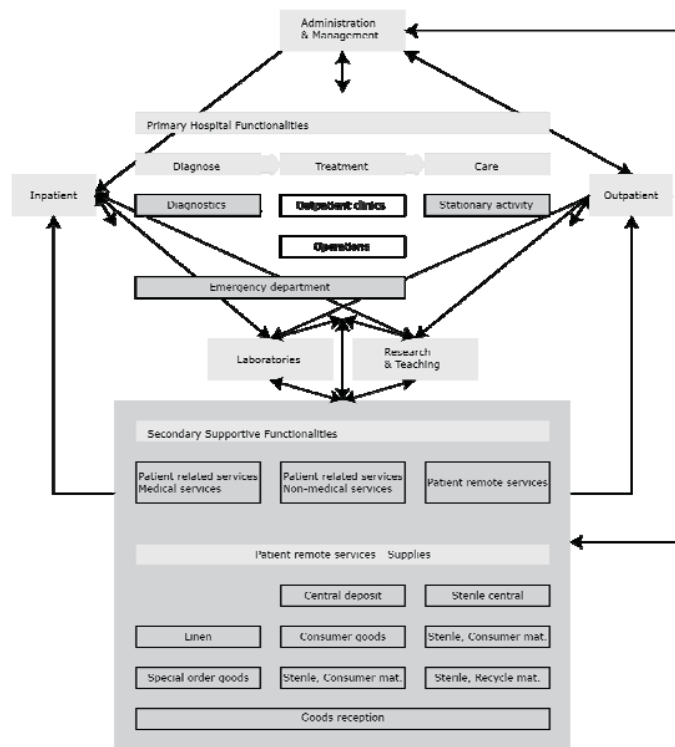


Figure 7. Goods logistics: Relating the primary hospital functionalities are secondary supportive services divided into patient related and patient remote. The patient-related medical services include: Medicine, Laboratory apparatus, Sterile goods and Consumer material. The patient-related non medical services include: Food, Linen, incl. clothing and Beds, clean and unclean. The patient-remote services include: Waste, Mail and Administration.

The figures illustrate the logistics of the hospital and describe them formally. Connecting the functionalities and logistics provides data for the formal description of the intermediate construction for defining the resulting geometry.

Conclusions

Engineering objectives as cost and performance are transformed into quantitative input parameters along with architectural design parameters concerning aesthetic and usability, where the latter are more difficult to describe formally because of the difficulty in describing qualitative parameters formally. Especially these parameters rely heavily on experience, whereas the engineering parameters are more standardized.

This attempt to identify and clarify the principal drivers, the derivative in form of the intermediate construction that defines the building attributes of the hospital. The approach aims organizing the parameters into manageable diagrams for hospital design, to clarify the complexity with the aim of opti-

mizing the design process, construction process and following maintenance and manageability. The aim is to improve the design process and thereby the quality of hospital designs in terms of cost and functionality.

The state of hospital architecture [in Denmark] is strongly defined by the design process, developed through project competitions, where consortiums of architects, engineers and hospital planners cooperate around the project with point of departure in tender documents defining the starting point with pre-defined limitations, foci, conjunctions etc. As Figure 2 illustrates hospital design can be divided into functionalities instead of defined departments in terms of better organizing the functionalities regarding qualities, capacities, times and interconnecting bonds.

State-of-the-art in hospital design is fundamentally characterized by the division of labor in design consortiums divided into responsibilities of the different professionals and the focus in evaluating the design proposals. Examples of poor functionality and engineering solutions over interesting architectural form occur as project winners. This illustrates a major problem in hospital design, namely a focus in creating iconic architectural pieces rather than highly functional buildings respecting both functionality and architectural expression.

This discussion can be addressed to most architecture, as a discussion of architecture as functional integrated solutions or conceptual artistic form. The present paper advocates functional integrated solutions, as it is the conviction that inspiring architectural form arises of functional requirements where a corresponding arrangement of all parts of the building is present simultaneously [19]. While understanding logistics in a broad sense as the functionality of the hospital; defining design with respect to logistics emphasizes a circular form finding process that draws from an idea to a drawing, from a drawing to an experiment, from an experiment to a construction, and from a construction back to the idea again, meanwhile the work of the mind is not separated from the work of the hand. The design model is developed through a procedure, where aesthetic, functional and technical requirements are developed together through iterations of sketching, evaluation and modification.

Reference List

- [1] Region, Det nye hospital i vest - DVN Gødstrup Programgrundlag, (2010).
- [2] Region Syddanmark OUH, Bind 2 - konkurrenceprogram for nyt OUH, (2010).
- [3] R.S. Ulrich, C. Zimring, X. Zhu, J. DuBose, H.B. Seo, Y.S. Choi, A review of the research literature on evidence-based healthcare design, HERD. 1 (2008).
- [4] A.K. Frandsen, C. Ryhl, M.B. Folmer, L.B. Fich, T.B. Øien, N.L. Sørensen, M. Mullins, Helende Arkitektur, (2009) 281.
- [5] R.F. Carr, Hospital, Whole Building Design Guide a program of the National Institute of Building Sciences. (04-21-2011) 11-18-2011.
- [6] R.W. Hall, Patient Flow: Reducing Delay in Healthcare Delivery, International Series in Operations Research & Management Science. 91 (Randolph W. Hall).
- [7] P.M. Hahn, J. Krarup, A hospital facility layout problem finally solved, Journal of Intelligent Manufacturing. 12 (2001) 487-496.

- [8] S.H. Jacobson, S.N. Hall, J. Swisher, Chapter 8: Discrete-Event Simulation of Health Care Systems, in: Anonymous Patient Flow: Reducing Delay in Healthcare Delivery, Springer, US, 2006.
- [9] D. Jones, A. Mitchell, Lean Thinking the NHS, Lean Enterprise Academy, UK, 2006.
- [10] D.R. Towill, Viewing Kaiser Permanente via the logistician lens, *Int. J. Health Care Qual. Assur.* 19 (2006) 296-315.
- [11] Feachem, R.G.A., Sekhri, N.K., White, K.L., Getting more for their dollar: A comparison of the NHS with California's Kaiser Permanente, *Br. Med. J.* 324 (2002) 135-141.
- [12] D.J. Medeiros, E. Swenson, C. DeFlitch, Improving patient flow in hospital emergency department, (2008).
- [13] Newell, S., Edelman, L., Scarbrough, H., Swan, J., Bresnen, M., 'Best practice' development and transfer in the NHS: The importance of process as well as product knowledge, *Health Services Management Research.* 16 (2003) 1-12.
- [14] I.W. Gibson, An approach to hospital planning and design using discrete event simulation, (2007).
- [15] S. Villa, M. Barbieri, F. Lega, Restructuring patient flow logistics around patient care needs: Implications and practicalities from three critical cases, *Health Care Manage. Sci.* 12 (2009) 155-165.
- [16] C. Logan, P. Goad, J. Willis, Modern hospitals as historic places, *Journal of architecture.* 15 (2010) 601-619.
- [17] M. Christopher, *Logistics and Supply Chain Management.* (1992).
- [18] Stalk, G., Hout, T.M., *Competing Against Time.* (1990).
- [19] M.K. Holst, M. Mullins, P.H. Kirkegaard, *Performative Tectonics,* (2010) 1004-1011.